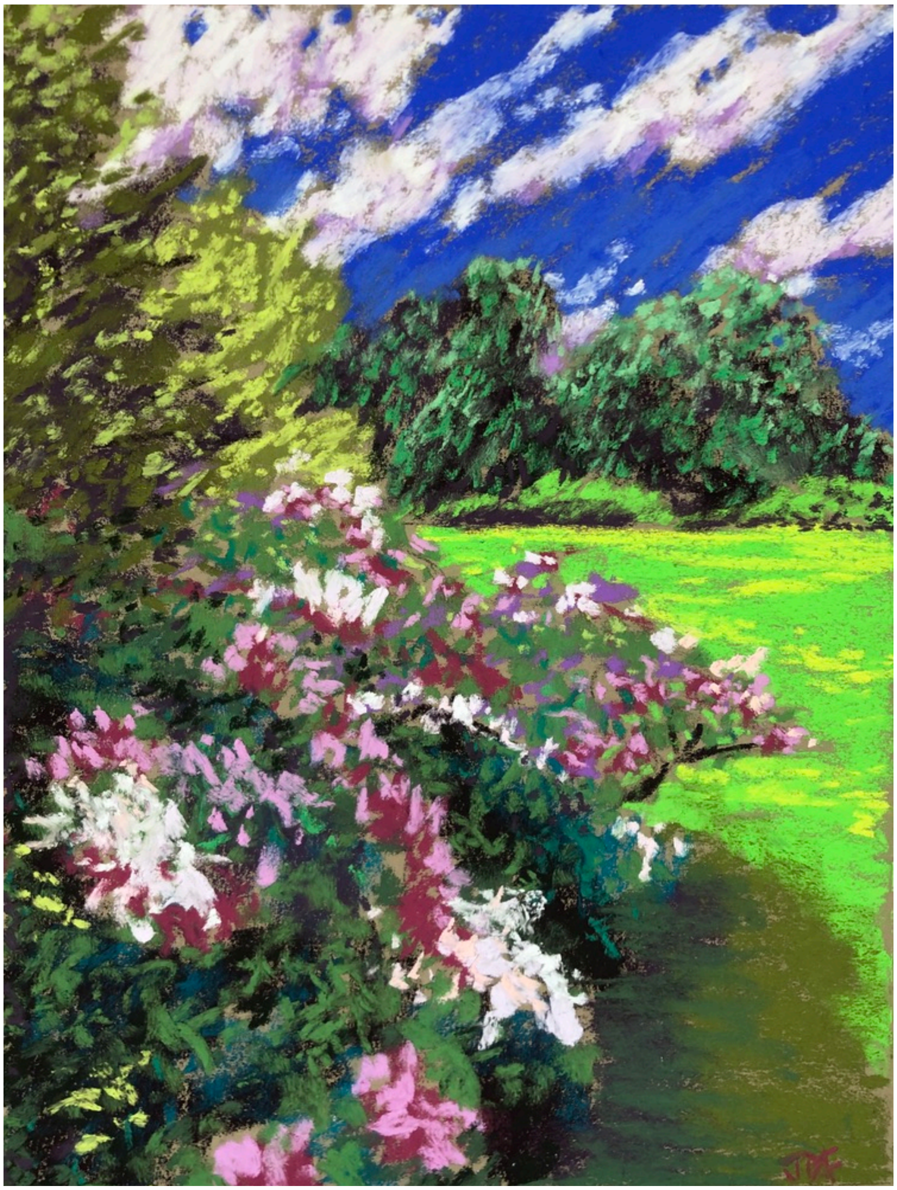
Understanding Aesthetics, Creativity and the Arts: An Interdisciplinary Approach



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Introduction – Beauty, Art and Creativity

In this book we examine three concepts. These are beauty, art and creativity. As we shall see, even the experts cannot fully agree on what these terms mean. We enjoy the experience of art and often say it is "aesthetic", but why do we like art and what goes on in our heads when we have an aesthetic experience? This term, which may have originally referred to beauty, has taken on a much wider connotation now. What is art? The arts and what we mean by the arts have also changed over time. As an example, given that the history of art goes back for millennia, novels and photography, each of which came about less than two centuries ago, are very recent innovations. Artists create, but why? What motivates them to create and how do they go about doing it? These are all questions we will explore, but there are no guarantees of definitive answers.

Aesthetics, art and creativity are all intertwined and it becomes difficult to talk about one without introducing the other. It would be a vast simplification to say that we like art because it is beautiful or that we create art because of a desire to create beauty. One reason is that there are many beautiful things that are not art, including human faces and bodies, not to mention aspects of the natural world. We can and do spend much of our time enjoying the beauty of these things, yet we still have a desire to experience and create art.

The approach taken in this book is interdisciplinary. That is because beauty, art, and creativity are too complex to be understood in just one way. When approached with difficult problems, it helps to study them from different perspectives (Friedenberg, 2016). Often a question that seems unanswerable from one approach can be addressed more readily in another. For instance, the question of why we create art is best understood from an evolutionary perspective, while the question of what goes on in our heads while we do art is best understood from a cognitive neuroscience perspective. However, each approach carries with it strengths and weaknesses. Philosophy is good for defining terms and framing questions but can't provide satisfying causal explanations. Math is good at measuring and describing art creations but not for providing rich theoretical accounts. They each have their own methods also, which we describe when needed.

The perspectives we adopt in order are philosophy, mathematics, physics, evolution, neuroscience, and psychology. Each chapter corresponds to about one perspective. There are two chapters on psychology because of the wide variety of research questions pursued in this area. We combine mathematics and physics together into one chapter because they are both quantitative approaches. We also in this book attempt to survey *all* of the arts, not just the visual ones as has been done most frequently in the past. These arts in the order we approach them are painting, music, dance, literature, architecture and film. There is so much to cover that we must by default leave some things out. There has been far less research attention devoted to song and to theater, so for reasons of economy they are mostly omitted.

This book is aimed at two audiences. Some of it is written from technical and scientific sources and so will be interpretable to this community. Other sections are more introductory and can be understood with little background knowledge. Terms are defined before used. In the case of music there is a separate glossary that can be consulted. Much can be gleaned also by looking at the figures and illustrations. These are mostly self-explanatory. In some instances tables are included. These are meant to summarize a large amount of information and for those who wish to dig further into those areas, primary references are provided. Some sections in this book are summaries of content from seminal works like Etcoff's *Survival of the Prettiest*, Levitin's *This is Your Brain on Music*, and Shlain's *Art & Physics*. I am indebted to them for their extensive treatment of the topics and hope to have acknowledged their contributions sufficiently. Source information is taken also from books in the *Foundations and Frontiers in Aesthetics* series from Baywood Publishing.

In this introductory chapter, we will begin with a brief tour of art to get a better understanding of its history and to see how the arts have been organized over time. We then provide a detailed preview of what is to come in each of the chapters. This book can be read chronologically in the order presented. Alternatively, the reader can just go to the chapters or content that interests them most. The chapters have been written in a self-contained way, but in some instance it may be helpful to refer back to earlier content using the subject index. There is a lot of material here and we encourage instructors to pick and chose content that best suits their purposes.

A Brief Tour of Art History

Defining art is difficult. To begin with there are many different types of art that correspond to different human sensory modalities. The visual arts are the most popular and these would include paintings, movies and graphic novels. Music is an example of an auditory art as is singing. The literary arts include literature like novels and poetry. Then there are the performing arts like theater and dance. Most arts are multi-modal and meant to be experienced through more then one sense. For example films are both seen and heard, but can also be categorized as a narrative art like literature and as a performance art like acting or music. Some arts have a motoric component, meaning they need to be experienced by moving around or through them. These would include sculpture and architecture. Then to complicate things further there are subdivisions within many of these art forms. Music can be broken down into the categories of classical, jazz, rock, and pop, among others. In this book we try to address all of these types of art. Unfortunately, some have been more thoroughly studied than others. Most research has focused on the visual arts and music, with much less work done on the others.

Art has a long history. We've been creating it for a long time. We chronicle the prehistory of art in the section on evolution. Here we describe the diversity of major art movements throughout known history. These are shown in Table 1.1. As can be seen art is constantly undergoing change. Ancient art survives mostly in the form of cave paintings that primarily depicted animals. Egyptian art was mostly in the form of monuments and temples and in artifacts to prepare the Pharos for the afterlife. In the medieval period art was almost entirely tied to the service of the Catholic Church that dominated society. As can be seen, art for many historical periods was about or for the ruling powers.

Table 1.1 Major art movements throughout recorded history.

Time Period	**Movement**	**Key Words**	**Key Works**
Prehistory – 15,000 B.C.E.	**ANCIENT ART**	Cave paintings, ocher, pigment, animals	Unknown artist(s) – *Galloping Horse, Lascaux cave paintings*
3,000 B.C.E. – 300 B.C.E.	**EGYPTIAN ART**	Flatness, hieroglyphs, pyramids, gold, afterlife	Unknown artist(s) – *Death Mask of Tutankhamen*
400 B.C.E. – 350 A.D.	**CLASSICAL ART**	Greek, Roman, Etruscan, temples, statues, sculpture, amphorae, friezes, frescos	Unknown artist - *The Supplicant Barberini*
400 A.D. - 1453 A.D.	**BYZANTINE/MEDIEVAL**	Catholic church, religiosity, mosaics, iconography, idealism, spirituality, symmetry, ornamentation	Mosaics from Ravena - *Christ Separates Sheep from the Goats*
400 A.D. - 1453 A.D.	**RENAISSANCE**	Order, symmetry, perspective, classical, space, movement	Andrea Mantegna – *Madonna and Child*
Renaissance Period	**CLASSICISM**	Ratio, symmetry, proportion, synthesis, myth, scholarship	Raphael – The School of Athens
Mid-Late 1400s	**PERSPECTIVISM**	3-dimensional, depth, linear, aerial, unified, receding, continuous	Episodes of the Battle of San Romano – *Episodes of the Battle of San Romano*
1600s	**BAROQUE**	Drama, transformation, conflict, manipulation, rhetoric, allegory, meditation, absolute power, new genres	Diego Velazquez – *The Triumph of Bacchus*
1700s	**ROCOCO**	Decorative, voyeuristic, playfulness, titillation, ornate, contemplative, aristocratic, Madame de Pompadour, Louis XV	Jean-Honore Fragonard - *Bathers*
1800s	**ROMANTICISM**	Rebellion, freedom, symbol, intuition, emotion, the individual, truth	Casper David Friedrich – *Tree with Crows*
1860-1900	**IMPRESSIONISM**	Physical sensation, effects of light, movement, *en plein air*, bright color	Claude Monet – *Rouen Cathedral* series

Late 1800s	**NEO-IMPRESSIONISM**	Color theory, pointillism, divisionism, dots, strokes, monumental stillness	Georges Seurat – *Bathers at Asnieres*
Late 1800s-Early 1900s	**POST-IMPRESSIONISM**	Communicate emotion, structure, design, symbolic meaning, significant form, early modernism, social vision, Les Nabi	Vincent Van Gogh – *Mountains at Saint-Remy*
1900-1950s	**MODERNISM**	Experimental, radical, ready made, primitive, the unconscious, spiritual order, expressive truth, art and industry, internationalism	Pablo Picasso – *Carafe, Jug, and Fruit Bowl*
1898-1908	**FAUVISM**	Patterns of color, simplified scenes, flatness, intensity non-naturalistic	Andre Derain – *Bridge over the Riou*
High point 1905-1920	**EXPRESSIONISM**	Strong color, distortion, abstraction, community, alienation, social critique, masquerade, purification	Ernst Ludwig Kirchner - *Artillerymen*
Started 1911	**CUBISM**	Flattened volume, confused perspective, collage, multiple viewpoint, still life, analytic, synthetic	Georges Braque – *Clarinet and Bottle of Rum on a Mantelpiece*
Started 1909	**FUTURISM**	Speed, energy, aggression, force lines, crowds, urban, new technology, progress, weapon	Giacomo Balla – *Speeding Automobile*
1919-1933	**BAUHAUS**	German, rational, functional, geometry	Paul Klee – *Ad Parnassum*
Founded 1924	**SURREALISM**	The unconscious, irrational, dreams, automatism, juxtaposition, destruction, eroticism	Salvador Dali – *The Persistence of Memory*
Decades following WWII	**ABSTRACT EXPRESSIONISM**	Universal order, physical gesture, dance, psychic energy, unconscious symbols, contemplation, iconic, stillness	Jackson Pollock – *Alchemy*
Emerged in the 1950s	**POP ART**	Common imagery, cartoons, commercialism, mass culture, advertising,	Roy Lichtenstein – *In the Car*

		kitschy, found objects	
Started in the 1960s	**MINIMALISM**	Simplicity, austerity, repetition, specific object, non-traditional material, sterile, impersonal	Carl Andre – *Steel Zinc Plain*
First named in 1964	**OPTICAL ART (OP ART)**	Optical illusions, stripes, dazzle, trompe-l'oeil	Bridget Riley – *Movement in Squares*
Started in the 1970s	**POST-MODERNISM**	Eclecticism, anti-corporate, critique of institutions, deconstruction, relativism, mass media	Andy Warhol – *Marilyn Diptych*
Emerged in the 1960s	**CONCEPTUALISM (CONCEPT ART)**	Idea, concept, intention, critique, language	Sol Lewitt – *Two Open Modular Cubes/Half Off*

Continuing our quick march through art history we see that the form of the visual arts is constantly in flux. During the ancient Greek and Roman periods statues, frescoes and friezes were popular. Oil paintings as we know them began in the Byzantine period and continued as a dominant visual art form going forward. Styles change dramatically too. Some art styles, like those of the Renaissance, chose to depict the world in a realistic manner and focused on classical themes from mythology and history. Other art styles, like impressonism and expressionism, emphasized the artist's subjective perception and emotions. Later during the modern and post-modern periods, any semblance of reality was abandoned and artworks become abstract and non-representational. To give you a sense of how quickly movements change Table 1.2 shows the minor art movements only. So the history of art doesn't seem to help us with a definition, as the materials, subject matter, styles and other aspects of art are always on the move.

Table 1.2 Minor movements in art history.

Time Period		**Key Words**	**Key Works**
1375-1425	International Gothic	Courtly, idealized, ceremonial, divine	Fra Angelico – *Christ Glorified in the Court of Heaven*
	Secularism	Reason, paganism, political power, the individual	Sandro Botticelli – *Birth of Venus*
	Monumentalism	Political ambition, grandeur, intellectual synthesis, Olympian	Michelangelo Buonarroti – *The Last Judgement*
	Humanism	Reason, philosophical enquiry, private scholarship, human emotion friendship, optimism	Leonardo Da Vinci – *Portrait of Mona Lisa*
	Idealism	Permanence, eternal order, idea over observation, simplicity, clarity	Raphael – *Madonna and Child*

	Illusionism	Deception, imitation, trompe l'oeil, quadrature, foreshortening	Correggio – The cupola of *S. Giovanni Evangelista*
	Naturalism	Light, textures, tones, subtlety, oils, Northern Europe, Venetian School	Giovanni Bellini *Madonna of the Meadow*
Latter half of the 1500s	Mannerism	Contortion, ambiguity	Agnolo Bronzino – *An Allegory of Cupid with Venus*
	Allegoricism	Propaganda, hidden truths, still-life, allusive complexity	Nicolas Poussin – *The Earthly Paradise*
	Baroque Classicism	Nostalgia, golden age, andscape, stoicism, academic, philosophical	Claude Lorrain – *Landscape with Paris and Oenone*
	Pietism	Devotional, austere, orthodoxy, public ritual, Counter Reformation	Francisco Ribalta – *Christ Embracing Saint Bernard*
	Sectarianism	Religious conflict, devotion vs. idolatry, private conscience	Rembrandt Harmensz Van Rijn – *St. Matthew and the Angel*
	Gesturalism	Facial expression, sensibilities, ppostures, complex narrative	Giovanni Franesco Barbieri – *The Raising of Lazarus*
	Emotionalism	Transformation, submission, exclusion, elevation, ecstasy, piety, devotion	Jusepe De Ribera – *The Martyrdom of Saint Philip*
Peak was 1620s-1630s	Caravaggism	Dramatic, chiaroscuro, close-up, erotic, physicality, reality, revelation	Micheangelo Merisi Da Caravaggio – *The Supper at Emmaus*
	Absolutism	Political power, virtue, propaganda, refinement, victory, royal patronage	Peter Paul Rubens – *The Majority of Louis XIII*
	Academicism	Standards, rules, hierarchical, genre, life drawing, history, nobility, official art	George Stubbs - *Whistlejacket*
1700s-Early 1800s	Neo-Classicism	Reason, order, enlightenment, virtue, scholarly, Classical values, new society	Jacques-Louis David – *The Oath of the Horatii*
19th Century (1800s)	19th Century	Reaction, structure, non-academic, impressions, objectivity, subjective emotion, instincts, class politics, social vision, aesthete, empire, symbols, design	Paul Gaugin – *The White Horse*
	Orientalism	Empire, fantasy, cruelty, opulence, eroticism, West depicts East, prejudice	Jean-August-Dominique Ingres – *The Turkish Bath*
	Medievalism	Purity, craftsmanship, tradition, national character, chivalry, faith, industrialization	Edward Burne-Jones – *King Cophetua and the Beggar*
Early 1850s	Pre-Raphaelistism	Bright color, medieval themes, national culture, naturalistic detail, purity,	John Everett Millais - *Ophelia*

		storytelling	
Mid to Late 1800s	Realism	Anti-bourgeois defiance, laborer, the real, social critique, contemporary nude, outrage	Edouard Manet - *Olympia*
	Materialism	The body, historical context, environment, socialism, social conscience, forces, processes, vision	Gustave Courbet – *The Burial at Ornans*
Late 1800s	Secessionism	Decorative style, flatness, ritual sophistication, suggestiveness	Gustav Klimt – *The Kiss*
	Aestheticism	'Art for art's sake', harmonies, suggestion, detached emotion	James Abbott McNeill Whistler – *Nocturne: Black and Gold – The Fire Wheel*
Emerged in 1880s	Symbolism	Disturbance, emotion, the uncanny, anarchy, spiritualism, esoteric, perversity	Edvard Munch – *The Scream*
	Primitivism	Ethnographic, expressive force, intuitive emotion, Vigor, insanity, reproductive nature, wholeness, truth	Alberto Giacometti – *Spoon Woman*
WWI-Mid 1920s	Dadaism	Destruction, liberation, the unconscious, chance, nonsense, ready-mades, anti-bourgeois, nihilistic, witty	Kurt Schwitters – *Merz 163, with Woman Sweating*
	Suprematism	Geometric abstraction, monochrome, assault, spiritual purity, spatial movement	Kasimir Malevich – *Suprematist Composition: White on White*
	Constructivism	Geometric abstraction, kinetics, technology, social utility, social progress, non-spiritual	Naum Gabo – *Kinetic Construction (Standing Wave)*
	Neo-Plasticism	Grids, primary color, black and white, spiritual order, decentralized, peripheric, elementarism	Piet Mondrian – *Tableau 2*
	Spatialism	Art as environment, slashed, process, roughness	Lucio Fontana – *Spatial Concept 'Waiting'*
	Social Realism	Social Critique, social justice, political struggle, ugliness, uncomfortable truths	Nan Goldin – *Nan One Month after being Battered*
Started in 1970s	Neo-Conceptualism	Deconstruction, critique of power, ethnicity, sexual identity, subversive	Peter Halley – Two Cells with Conduit
Emerged in the 1970s	Neo-Expressionism	Crudeness, anti-abstract, primitive, rough, figurative, emotional	Anselm Kiefer – *Parsifal I*
Started in the late 1980's	Sensationalism	Contemporary experience, dark humor, diverse media, insincerity, irony, obscurity, shock tactics, Saatichi	Damien Hirst – *Forms Without Life*

Historical Organization of the Arts

Our understanding of what constitutes the arts has undergone constant change throughout history (Kristeller, 2008). It wasn't until the eighteenth century that the term "aesthetics" was even used. It was then that for the first time the arts were compared based on common principles. It was at that time also that the term "Art" and "Fine Art" were used for the first time in their modern sense. The arts are now considered to compromise five main areas. These are painting, sculpture, architecture, music, and poetry. Other disciplines that are sometimes considered as belonging to the arts are gardening, engraving and the decorative arts, dance, opera, theater, eloquence and prose literature.

The ancient Greeks considered a multitude of human activities as being art, including the crafts and sciences. Plato, Aristotle and the Stoics saw the arts as an intellectual and cognitive endeavor, governed by rational rules. They also applied the term arts not just to material products but also to the virtues. According to them a sculpture and a "soul" could both be beautiful. Likewise, a man's body could be beautiful but so could his character if he demonstrated self-control and ethical conduct. Beauty thus referred to physical and moral goodness. It wasn't until much later that it became associated with what we now call aesthetics.

Poetry in ancient Greece was considered one of the most important of all the arts. Poetry can be considered as verse but also as a narrative art. Aristotle's discussion of the poetic forms deals with narrative and includes elements such as plot and character, but also poem as genre to differentiate tragedy and theater vs. epics. Poets could be inspired by the Muses and in some cases considered to have a form of "divine madness." This poetic madness, also associated with the lover and religious prophet, can be traced back to the time of Homer and Hesiod. Aristotle wrote a complete work on poetry. There were connections between the study of logic, rhetoric and poetics. Music in ancient Greece was also highly admired and approached from a mathematical perspective. Pythagoras during this period wrote a treatise on musical ratios. Music and dance were not considered separate arts but as aspects of dramatic and lyrical poetry. The prestige afforded to the visual arts, painting, sculpture and architecture however was quite low. Seneca refused to allow painting to be considered as a liberal art and there are few writings about visual arts by any philosophers at the time. The visual arts as professions were considered to be "blue collar" manual arts, in line with craft workers or in today's terms like plumbers and mechanics.

Cicero spoke of the liberal arts and their relations but did not provide a list. Martianus Capella defined the seven liberal arts as grammar, dialectic, rhetoric, geometry, arithmetic, music and astronomy. Notice that none of the visual arts are listed here but many disciplines we now consider to be under the heading of mathematics and the sciences are. There were Muses (inspirational spirits) for poetry and music but not for painting or sculpture. Classical antiquity associated poetry with grammar and rhetoric, music with math and astronomy and mostly omitted the visual arts, as they were associated with manual labor. There was no attempt to form a systematic philosophy of the arts or to understand beauty as a quality separate from its intellectual and moral context.

During the Middle Ages there was a subdivision of the seven arts into the Quadrivium (number, geometry, music, and cosmology) and the Trivium (grammar, rhetoric, and dialect). There were seven mechanical arts, these being fabric manufacture, armament, commerce, hunting, agriculture, medicine and theater. Architecture, painting, sculpture and other crafts were categorized as sub-disciplines under armament. Poetry and music were taught in universities at the time, while the visual arts were relegated to artisan's guilds. Painters were associated with the druggists who helped make their paints, sculptors were associated with goldsmiths and architects were associated with masons and carpenters (Kristeller, 2008). For Thomas Aquinas, juggling, shoemaking and cooking are considered as "fine arts" to the same extent that painting and sculpture are today. Aquinas treated beauty as an attribute of God rather than of art.

Despite the rise of reason and philosophy in the Renaissance there was still no system of fine arts or theory of beauty. Poetry was studied mostly as Latin poetry. It wasn't until the sixteenth century in Italy that the visual arts were separated from the crafts and the term "Beaux Arts" was used. In Florence, Italy in 1563 there was the formation of the Academy of Art (Accademia del Disegno), consisting of painters, sculptors and architects. These individuals left the manufacturing guilds and now allied themselves with the fine arts. These academies were to take root later in other European nations.

France was the center of artistic culture during the seventeenth century, melding ideas from the Italian renaissance, French classicism and the enlightenment. It was now that painting and the other visual arts began to flourish. The natural sciences also began to emerge as distinct disciplines at this time with the formation of the Academie des Sciences in France and the Royal Society in England. Science in this era became popular among the general public. Academics and citizens alike would now begin to see the arts and the sciences as distinct areas. Abbe Batteux in his 1746 writing, *Les beaux arts reduits a un meme princie* was the first scholar to lay out a treatise devoted solely to the fine arts and their organization. He considered the fine arts to be different from the mechanical arts because they have pleasure as their end. He grouped the fine arts as poetry, music, dance, painting and sculpture. Eloquence and architecture form a third category because they combine pleasure with usefulness. Batteux considered theater as a combination of all the other arts, since it involves aspects of each of them.

We now turn to the English. Writers such as the Earl of Shaftesbury and Francis Hutcheson rose in prominence during the eighteenth century with their writings on aesthetics. Shaftesbury may be considered the "founder" of modern aesthetics, as he was the first major European philosopher to treat the subject in a serious way. Hutcheson separated moral beauty from sensory beauty. This separation of aesthetics from ethics was made now for the first time since the ancient Greek philosophers.

The German philosopher Gottlieb Baumgarten and his student Georg Friedrich Meier made significant contributions to the study of the arts. Baumgarten is judged with having coined the term aesthetic. He differentiated between "sensuous" knowledge as a counterpart to "intellectual" knowledge. He also is the first to create a general theory of the arts as a domain for philosophical study and to situate it within larger philosophical thought. The theory of art as imitation was popular at the time. Mendelssohn argued that the fine arts (painting, sculpture, dance, music, and architecture) and the belles lettres (poetry and eloquence) should be considered together under a unifying principle other than imitation. He is additionally known for his doctrine of the three faculties of the soul that match up with ethics (goodness), epistemology (truth) and aesthetics (beauty). Thanks to Mendelssohn and other thinkers like Sulzer, people were now thinking of the fine arts as all being related to one another.

Aesthetics during the later part of the eighteenth century grew in popularity throughout Germany. University courses were being taught in this subject, articles and textbooks were also being written. Kant emerged onto the philosophical stage. He included aesthetics as part of his overall philosophical system, placed an emphasis upon the study of beauty and discussed the linkages that exist among the arts. He had his own classification scheme, which was the speaking arts (poetry and eloquence), the plastic arts (painting, sculpture, architecture and gardening), and the arts of the beautiful play of sentiments (music and color). On a less academic side, the eighteenth century saw the rise of art and literary critics and a desire of the general populace to attend art exhibitions, concerts, opera and theater.

This rapid survey shows that our current conception of the arts is a fairly recent phenomenon. Many arts have passed in and out of favor throughout recorded history. There were times where the novel, instrumental music and canvas painting didn't exist (Kristeller, 2008). In contrast, other activities that we don't consider as art now flourished at different periods. Some examples include fresco painting, the illuminated book, tapestry and vase painting. There are many new modern arts. What about gardening? Fashion? Graphic design? Shouldn't they too be allocated a place at the table of fine arts? What we consider to be art will likely undergo further change in the future. The film is perhaps now the most popular art form. Video gaming too, seems poised to become an art as will the design of avatars and virtual worlds for virtual reality systems.

Book Overview

As each chapter in this book shows, there are many different ways to look at the topics of beauty, art, and creativity, each with their own strengths. Philosophers have traditionally been best at thinking abstractly and theoretically. They can help us to understand definitions and concepts. Mathematicians and physicists help us understand stimuli by expressing them in terms of ratios and series and to looking at how forces and objects in the natural world act. Evolutionary theory is best for understanding how art emerged and at giving us explanations for why we create. Neuroscience tells us what the brain is doing while we perceive or produce art. Experimental and cognitive psychology also bring the scientific method to bear and have produced useful information-processing models of art perception and production.

A few notes on chapter order. We present philosophy first because it provides a general framework for understanding the three topics. In the philosophy section we address fundamental questions about the definition of these ideas among other questions. After this the chapter sequence in the book is bottom-up. We get down to basics with understanding simple geometric figures and their construction and then examine beauty in the natural world and a history of art from a physics perspective. The chapter that follows on evolution is about how brains get created, so this is presented prior to neuroscience. We next build upon brain-based explanations with psychological models and studies. The last chapter covers creativity and attempts to bridge the gap between artistic practice and scientific research.

Bringing it All Together – Introduction Chapter Summary

We will end each chapter in this book with a "Bringing it Together" section in an attempt to summarize, integrate, and find common themes. The focus of this book is on three main topics. These are aesthetics, the arts, and creativity. The main thrust of this book will be on aesthetics as the study of beauty. We acknowledge that aesthetics encompasses a wider set of experiences beyond the perception of beauty and do allude to this in several sections.

Our approach is interdisciplinary. In order to best understand these complex topics we need to go beyond the arts and take in other perspectives and methodologies. Each chapter describes a different disciplinary perspective. In order these are philosophy, math and physics, evolution, neuroscience, and psychology. We conclude with a chapter devoted specifically to creativity. We also attempt to cover not just the visual arts, but also all arts including painting, music, dance, theater, literature, architecture, and film among others.

Our definition of art has changed throughout history. Each artistic genre can be subdivided into different types. Painting for instance can be subdivided into different media like oils, pastels, etc. The way in which the arts are categorized has also undergone flux, with different organizing schemes in place at different times in history.

Art serves many purposes. It is a way of creating beauty, exposing political ideas, demonstrating religious beliefs, and of binding social groups together. The result of artistic production can take many forms ranging from cave paintings, to architectural monuments to frescoes and friezes. Historically, artistic styles rise to dominance and then fade after some amount of time, being replaced by others.

Chapter 2

Philosophy – It's the Thought that Counts

In this chapter we survey what many philosophers through the ages have thought about these three ideas of aesthetics, the arts and creativity. We will ask definitional questions like What is beauty? What is art? What is creativity? Why and how do artists create? In addition we will address questions specific to individual arts, such as how music expresses emotion, what constitutes an architectural object, and how is it we care for fictional characters in poems, books, films, and theater.

What is Beauty? Five Ideas

Sartwell (2012) outlines five philosophical conceptions of beauty. Some of these will be expanded upon in the pages to come. We will also exposit others not summarized here but these five are a good place to start. The first conception dating from the ancient Greeks is that beauty is an arrangement of parts into a whole following certain rules like symmetry, proportion, and harmony. Aristotle in the *Poetics* states that every living creature must have a certain order in the arrangement of its parts. Mathematics were believed to be the key to understanding beauty, with certain proportions like the golden ratio considered to be pleasing to the eye. Proportions and part harmony were applied to architecture as well. The Roman architect Vitruvius believed that these ideas could be applied to architecture and to aspects of the human body. We elaborate upon these ideas at greater length in the mathematics chapter.

The second conception of beauty is that of perfect unity. Beauty drives the desire to procreate and so attain immortality, which is unity with God or with the universe. This idea comes from Plato's *The Symposium*. Plotinus also suggests that beauty is equal to "formedness", the source of unity among disparate things. Thinkers during the middle Ages also expressed beauty as the yearning for a mergence with God, which would produce unity. Shaftesbury, the English philosopher also makes this clear as his highest level of beauty The philosopher Schiller writes that beauty, play, and art are the process of integrating or rendering compatible the natural and the spiritual, and the sensuous and the rational.

A third type of beauty is love and longing. Edmund Burke writes that beauty is the quality in bodies by which they cause love or passion. This may seem the most obvious, as humans desire beauty of all types, be they bodies or paintings. This conception is also the closest to the evolutionary approach that we discuss in that chapter. Many thinkers of the eighteenth century explained beauty in a fourth way, that of hedonism or pleasure. Beauty in this notion is what produces a pleasurable response. Hutcheson in his uniformity and variety thesis, states that objects with this property have the capacity to please. This idea becomes relatively commonplace in later writings by Kant, Hume and Santayana.

A final view on beauty is that it is either useful or useless, two opposing views. Some philosophers like Kant have stated that beauty serves no purpose. This is in agreement with the view that art has no end other than unto itself, other than perhaps contemplation. But philosophers like Laertius and Berkeley have taken the opposite view and argued that beauty does serve a purpose. Xenophon suggests that things are beautiful only in relation to the uses for which they are intended and that the type of beauty in each case would differ: a beautiful ox would make an ugly horse. This distinction comes up when we are evaluating the fine arts vs. crafts, with the former sometimes judged useless and the latter useful. The debate also appears in the discussion of "form vs. function" and "form follows function." This debate refers to the relation between an object's appearance and its purpose. In one view a beautiful object is one in which these two ends meld seamlessly. An example would be a sport car that looks fast because it is streamlined and tapered from front to back. In what follows we will outline more specifically what individual philosophers think about beauty.

Classic Theories of Beauty

Plato and Idealism

The ancient Greek philosopher Plato (427-347) in the *Hippia Major* writes of a conversation between Socrates and the Sophist Hippias in an attempt to define beauty. However we must be careful in this interpretation of the text because what was understand to be beauty to be in those days may have been more broad and abstract, perhaps meaning something closer to "fine". That is because they apply these words to describe things like virtue, that we often don't think about as beautiful. Examples are given of a young woman and of art as instances of beauty but these are not generalizable to a broad definition. Plato in the end equates beauty as like the "good". He says beauty behaves as a Platonic Form would. Platonic Forms are abstract concepts that exist outside the physical real world. They are said to be perfect. A Platonic Form of a circle would be perfect because no matter how great the magnification, the circle still retains its curve. A real drawn or inscribed circle, in contrast would show jagged edges and deviations from the curve, i.e., it would have errors.

Plotinus and Beauty as the Good

Plotinus (205 -270) was the founder of Neo-Platonism, a school of thought influenced by Plato. He was born in Egypt but lived in Rome where he founded a school of philosophy. Plotinus says in the *Ennead I, VI* that beauty is found in what is seen (in the perceptual) but it is also found in thought, and in virtues or proper actions. So he is taking a very broad view, calling beauty to be something akin to the "good". He asks the question of whether there is one beauty that applies in all cases or whether there are separate types in each instance. In perceptual beauty we can say that proportion determines beauty. For example the golden ratio of parts in relation to another that make for a beautiful face. We can also say that a color by itself is beautiful even though it lacks proportion because light is formless. Similarly, a fire can be beautiful even though it is lacking constant or specific form.

Plotinus argues that we can only see higher beauty of virtue by practice. Only by becoming good or virtuous ourselves can we know what the beauty of virtue is like. To "see" inner beauty requires a re-working of our soul. We need to look into ourselves and like a sculptor remove superfluous parts, straighten things that are crooked, and brighten those things that are dark. By this analogy, we make ourselves beautiful they same way a sculptor makes a lump of clay or stone beautiful. In either case, beauty is there in the abstract waiting to be revealed. Beauty as the good according to Plotinus requires first an intellectual act. In this way we will know what beauty is and be able to see it. But the idea of beauty itself transcends intellect. In this sense, he is saying it is like a Platonic form.

The Third Earl of Shaftesbury and Disinterestedness

The Third Earl of Shaftesbury (1671-1713) was an English Philosopher. He believed beauty is a harmony or proportion that exists independent of the human mind. It has its origins in nature. Like the earlier philosophers, he too thought that beauty is in both the natural and the moral realms. Shaftesbury proposes a three-part hierarchy. The lowest order of beauty is in physical things like works of art or aspects of nature. The second belongs to human minds and is a type of intellectual understanding. The third and highest form of beauty belongs to God, who created both the natural world and men's minds. Shaftesbury in his writings discusses the beauty of music, painting and literature. He also has an elaborate theory of what makes gardens beautiful, claiming that wild gardens are better than more cultivated ones because they are more similar to what exists in the natural world. He also seems to equate moral goodness with beauty, although subsequent philosophers have debated this.

Shaftesbury also has something to say about the process of experiencing beauty. He claims it is a reaction. In some cases this is immediate and fast, occurring as soon as we open our eyes or listen to sounds. In other cases this reaction is slower and requires reflection or thought. Shaftesbury also implies that beauty is divorced from self-interest. When we see a beautiful face for example the beauty is in the face and not part of our desire for that face. Beauty, as some have interpreted his writings, is a "disinterested" process of responding to the features of an object and not to its value or capacity to increase knowledge. Shaftesbury advocated that we can develop good taste and that this would improve our moral character. An English gentleman in cultivating taste, manner and politeness, could provide a moral foundation for British society that he thought could replace the outdated ideas of the church and court.

Francis Hutcheson and Uniformity in Variety

Francis Hutcheson (1694-1746) is a British philosopher who was a professor at the University of Glasgow. He has a lot to say on various notions of beauty and for that reason we will devote more time to discussing him here. Hutcheson, like other philosophers before him argues for external perceptive qualities of beauty versus internal reasoned ones. One reason for this is that no act of will can make us dislike certain objects that please us nor can an act of will make us like certain objects that displease us. In other words there are certain, perhaps innate pre-programed likes and dislikes that reasoning and training will not be able to change (the smell of strawberries vs. the smell of garbage will both trigger automatic, perhaps innate reactions). These "external" senses come to us at birth, while "internal" senses are derived as a product of experience. He also remarks that it is the arrangement or relation between simple ideas in the form of a more complex idea that produce beauty more than simple ideas themselves. A simple idea here is an indivisible aspect of perception like the color red. We may like the color red but we will in his view never like it as much as when it is presented along with other colors, shapes and lines in the form of a rose.

Hutcheson states that knowledge by itself is not enough to produce taste or the appreciation of beauty. A botanist for example, may be able to distinguish the many different types of trees in a forest based on their leaf structure. But this by itself will not produce an appreciation of beauty. A poet, seeing a forest may without any such knowledge perceive it as beautiful. This superior power of perception can be thought of as taste or an aesthetic sense.

Hutcheson next formulates an interesting theory. He calls this "uniformity among variety". Simply stated, it is that to be beautiful something needs to be not too regular but by the same token not too complex and varied. For example, he states that a square is more beautiful than an equilateral triangle and a pentagon is more beautiful than a square. That is because equal sides and angles of regular polygons are a uniform characteristic but by themselves are made more interesting as we increase the number of sides. But if we continue to increase the number of sides to get polygons that start to look more like circles, these begin to become less beautiful because there is too much uniformity. This type of theorizing is very much in line with modern experimental psychology because hypotheses derived from it can be tested empirically.

This notion of a proper balance between regularity and variety can be applied to a wide variety of disciplines, including that of mathematics. Hutcheson argues that beautiful theorems are those that can explain a great variety of particulars. However, theorems that are too abstract should be less beautiful than those with some amount of variety. For example if we had the statement "The whole is greater than the parts", this accounts for a wide variety of particulars but it is less satisfying than a geometry theorem stating the specific relations between a cylinder, sphere and cone with ratios of 3, 2, and 1. The first is too vague; the latter contains more variety and hence is more beautiful. Other ways in which theorems can differ in their uniformity and variety are in the number of corollaries that can be deduced and the number of instances accountable in physical equations such as Newton's law of gravitation.

Hutcheson next discusses relative or comparative beauty. Comparative beauty refers to that between an original and a copy. A good sculpture, painting or poem of Hercules would be one that retains those marks of strength and courage by which we imagine that hero. If these essential qualities were left out, it would be less beautiful. However, an original subject by itself need not be beautiful to have a beautiful copy. An old man or an ugly rock, if well represented and skillfully reproduced could still be considered beautiful, but perhaps less so than if the original were more beautiful to start with. Another example comes from literature. A "perfect" character with no flaws may be less interesting than one with a mixture of good and bad characteristics because these are the originals with which most of us are more familiar.

David Hume and Taste

People seem to disagree on whether certain objects are aesthetic or not. We run the danger then of saying all of art and beauty is subjective. David Hume (1711-1776) was a Scottish philosopher and intellectual. His solution to this problem was the concept of "taste". He thought beauty involved a value judgment and that this was the consequence of taste rather than of logical analysis. He believed that taste could begin by being an automatic and unconscious reaction but after that it could be developed by knowledge, training and education. Over time people could become sensitive to what is truly beautiful. It would be these individuals, an elite group in effect, that would determine what art is or what constitutes good art.

Immanuel Kant and Intellectual Beauty

Kant (1724-1804) was a German philosopher who thought beauty was an innate and universal concept. To consider beauty was an intellectual, cognitive act and not an emotional reaction to an object. A judgment of beauty in his opinion was intrinsic to the features of the object itself. These features interact with our perception, intellect and imagination. This view is consonant with the scientific view of art that manipulates object features like color, symmetry and balance in a stimulus and then formulates neural and cognitive models of how that information is processed. Kant wrote about "disinterested interest" that is the equivalent of considering the beauty of something independent of desiring it. This interest is an intellectual consideration of beauty apart from emotion.

Kant also distinguished between beauty and the sublime. While beauty is bound by an object, the sublime is boundless. It is best described as a feeling of the wonder and awe of the power and immensity of nature. We feel the sublime when we see the spiral arm of the Milky Way galaxy or the eruption of a volcano. There is a sense of feeling small when we experience the sublime. Whereas beauty is always pleasurable the sublime may involve a sense of pain or fear. Kant states that the sublime is not the same as a religious experience and equates its cause with nature. Art works themselves cannot be sublime but in representing natural events they can cause sublime feelings.

Edmund Burke and the Sublime

Sir Edmund Burke (1729-1797) was an Irish political author and statesman who, like Kant, wrote about the sublime. He writes specifically about the causes of the sublime, its features and how it differs from the beautiful. To Burke, the cause of the sublime is terror, an emotional state associated with pain and danger. In contrast, beauty stems from pleasure. Burke believed that pain was more powerful than pleasure and as a result the sublime was more powerful an experience than beauty. He stated that the power of the arts to induce emotion works primarily through sympathy, our capability to imagine ourselves in someone else's shoes. As a result he thought that all people take some degree of delight from other people's misfortunes. Those things that captivate the emotions most are events like public executions. Because these are real they induce the sublime more than any poem or play about the same subject could.

Burke lists in some detail the different characteristics that make up the sublime and the beautiful. The sublime is characterized first by power. Any object, scene, animal or person with great power can convey more of the sublime. For instance, the ox is a strong animal but fairly mild in temperament. A bull however is powerful, but filled with anger and destruction. The bull ought to thus induce more of the sublime. Scenes that are vast and extensive in size induce the sublime more than the small and contained. According to Burke a tower or mountain one hundred yards tall is more sublime inducing than a field one hundred yards wide. Similarly, a drop in depth of this same amount in the form of a chasm or cliff is even more terrifying in its effects than the tower or mountain. Infinity is a characteristic of the sublime, since this takes physical extent to its extreme limit. Although we cannot physically portray things that are infinite, scenes that convey them like a long horizon line may produce a sense of the sublime.

Another feature of the sublime according to Burke is difficulty. By this he means work that requires great force and effort. Stonehenge, for instance required a great amount of effort to build since the giant stones needed to be worked and moved a great distance. The Egyptian pyramids in Giza, Egypt and the ruins of Angor Wat in Cambodia would fall into this category. Magnificence is likewise a feature of the sublime. The starry heavens at night are example of a natural phenomenon that is magnificent. This quality involves a certain amount of disorder or confusion. Burke next outlines the features of the beautiful, which are the opposites of the sublime. Beautiful things in his scheme are small. Whereas we must submit to the awe and grandeur of nature, beauty is something that submits to us. Instances here might be jewelry like necklaces and rings that contain fine gold and gems. Beautiful things are also smooth. Trees and flowers that have smooth leaves, gardens with smooth slopes, and streams in the landscape are all examples that he gives. Gradual variation is also a hallmark of beauty according to Burke. The outline of a bird's head and they way it blends into its neck and body is cited here.

Beautiful things also tend to be delicate and fragile. The myrtle, the orange, the jasmine and the vine in contrast to the oak inspire a feeling of beauty. The use of curved features in decorative art, such as architectural friezes showing lacy vines fit well in this category. Finally there is color. In Burke's theory colors of beautiful objects cannot be dusky or muddy but must instead be clean and fair. Color should also not be too bright. Milder colors such as light-greens, soft blues, weak whites, pink reds and violets ought to be judged more beautiful than glaring colors. Burke writes that if strong and vivid colors must be used that they be diversified. A single object in his scheme should not have a single strong color. Instead, these colors should be varied and distributed, such as a field of flowers.

Much of Burke's statements are of course theoretical. He is making these assertions based on his observations of art and the natural world. However, their specificity makes them more easily testable by scientific means and later in this book, we will see such tests, looking at whether lines are preferred to curves, whether certain types of colors are preferred to others, etc. These opposing qualities of the sublime and beautiful are exhibited in different schools of art. The sublime is exemplified in the romantic school, perhaps best represented by the German artist Caspar David Friedrich who painted scenes of vast jagged mountains, twisted trees and cemeteries. The beautiful is perhaps best represented by renaissance depictions of subtle female beauty like Botticelli's *The Birth of Venus*.

Modern Theories of Beauty

Mary Mothersill and "Beautiful" Science

Mary Mothersill (1923-2008) was a Canadian philosopher with a degree from Harvard who taught at Columbia University, among other places. She argues in a famous essay that there are no laws of taste. She states that every individual's aesthetic response is different based on factors such as education and background and although we may be aware that we like a particular sonata or poem, we are not necessarily aware of the causes that have led to that liking.

If there is a factor in a work of art that causes us to think that it is beautiful then to be a law of taste that property should generalize to other situations and predict liking in other situations. She doesn't believe that this is the case. First, knowing that one likes songs by Bach or a piece by a composer that is similar to Bach cannot always predict liking for a new piece. It may even be the case that people may like all music by artists of a particular genre such as the Baroque, but she claims she has never met one. Mothersill goes on to state that our taste can change because there are reasons for choice other than knowing what one likes. These could be curiosity about another time or culture and boredom with what one knows.

She then writes that a positive science about taste has to live with phenomenon that 'defy explanation'. Suppose she says that science discovers a new color combination such as red and green that go well together. The knowledge of such a combination is of not much practical use as a feature of beauty that it can reliable predict liking in all situations because there are so many other factors that also predict and that can potentially interact with that factor to never make it useful then say 70% of the time. Knowledge of such a principle will also not always agree with "objective" rules for why we should like a piece. For example a critic may say that a particular piece is excellent for thus and such a reason but then personally dislike it. Conversely someone may like a piece but professionally judge it to not be a good work of art.

Modern research in empirical aesthetics shows that Mothersill's arguments are wrong on a number of counts. In psychological experiments there are two types of variables. The first predict variance (changes in data) across a wide variety of situations and for many individuals. The second are true for a specific situation or a single individual. Research shows that there are stimuli that consistently predict aesthetic choice. Many of these are grounded in an evolutionary explanation and include for instance symmetry, averageness, and sexual dimorphism as factors that predict facial attractiveness. The same is true with art stimuli. Researchers are uncovering structural aspects of paintings, poems, and music that have statistical reliability, meaning they predict choice repeatedly over different occasions. Individual differences can also be studied scientifically and are interesting in their own right. These can be explained based on such variables as art training and personality traits.

As a demonstration of this researchers have developed algorithms that successfully predict pop songs. It is true that tastes can change with the times but these very same researchers have been able to adjust their equations to account for this, showing how different aspects of music like tempo change with stylistic and cultural shifts. Many people now may be familiar with other examples of this. The movie service Netflix makes movie recommendations based on a user's past viewing history. The music service Pandora can also make recommendations about songs based on music you have already listened to and liked. The future will likely see more of this, as there is a lot of money to made by knowing both what particular individuals like and what appeals to a larger audience.

The Tension-Resolution Model of Beauty

In the tension-resolution model of aesthetics all artworks be they paintings, novels or music, achieve their effect by building up tension that then gets resolved (Kreitler & Kreitler, 1972). An artwork when first encountered produces emotional tension. As we further explore the work by looking at different parts of a painting for example, or thinking about a melody that is repeated with variations in a song, we come to understand it and this understanding leads to a satisfying aesthetic experience. If an artwork is too complex then the person experiencing the art would not be able to understand it and so resolution and the subsequent aesthetic satisfaction would not occur. This is what might happen to a naïve observer who does not have sufficient background information to interpret a particular artwork. Differences between naïve and expert artists are one of the themes we will explore later in the book. Also note the relation between this model and the concept of visual dissonance introduced later. The two ideas are very similar.

Howard Gardner and the Three Characteristics of Beauty

Another more contemporary view of beauty comes from Howard Gardner in his 2011 book *Truth, Beauty, and Goodness Reframed*. He argues that there are three crucial characteristics that define beauty. The artwork or object must be interesting, memorable, and invite further encounters. If these three are all present then the observer will have a pleasurable aesthetic experience. An artwork can be interesting, memorable and inviting for a variety of reasons that are sensory, conceptual or emotional. For instance a painting with bright or saturated colors or with a complex texture that encourages the eye to move around is interesting and inviting. A painting that shows some extreme event like a murder however is also memorable and interesting. So this definition is quite broad. It can apply to classical landscape scenes as easily as to postmodern shock art.

Roger Scruton. Where is Beauty?

The English philosopher Roger Scruton specializes in the study of aesthetics. In his book *Beauty: A Very Short Introduction*, he makes a number of interesting points and it is worth summarizing some of them here. His first point concerns where beauty lies. It does not seem to be in the stimulus or thing that causes us to experience beauty, because these things are too many and variable. Almost anything can be called beautiful: concrete objects, abstract ideas, works of nature, and works of art. Beauty can be in things, animals and people, in objects, qualities and actions. We can speak of a beautiful sentence, a beautiful mathematical proof, even a "beautiful" disease. It doesn't seem possible that there can be something that all these things have in common. Instead, beauty may be inside of us. Rather than a property of a thing, it may be a characteristic of the way we have an aesthetic experience. In other words it is in the way we react to things.

It is an old notion in philosophy that beauty is an ultimate value, something that we pursue for its own sake, along with the other two ultimate values: truth and goodness. But beauty can lead us astray. Someone charmed by a false myth may be tempted to believe it and in this case it would be the enemy of the truth. Similarly, a man attracted to a woman may be tempted to condone her vices. In this case, beauty is the enemy of the good. So although arts and beautiful things may be inspiring they probably shouldn't be pursued at the expense of what is true and what is good.

Scruton also points out the difference between artistic products like architecture, carpet weaving and carpentry that serve a function. These are in contrast to other products like a song that serve no practical purpose. On the one hand we can talk about the utilitarian aspects of some creations while on the other we can only discuss their aesthetic values. A practical product like a building can be evaluated in terms of its form and function, but a painting can only be evaluated in terms of its form.

There is a debate in contemporary philosophy on whether beauty is sensory in nature or whether it is more intellectual. On the one hand we can experience the beauty of a hot bath. This seems entirely sensory in nature. On the other hand we can experience the beauty of a mathematical proof. How can both of these encompass beauty? The answer as we shall see later is based on studies in neuroscience showing that beauty can be both of these things and more. It can be perceptual, activating different regions of the visual cortex. It can be intellectual or contemplative, activating parts of the frontal lobes involved in reason. It can also be emotional in the way it is experienced, triggering activity in the amygdala and the brain's emotional centers. In other words, beauty can be perceptual, conceptual and emotional.

Classic Theories of Art

Plato and Art as Imitation

Plato had two primary views about art. The first is about art as imitation, which he wrote about in *The Republic*. The second is the idea that art is dangerous which he describes in *The Ion* and *The Symposium*. We will address these each in turn. Plato was a believer in the ideal world of forms. In this world everything is perfect. There is perfect truth, perfect justice, and perfect beauty. This ideal world is rational, eternal, and changeless. The real physical world is irrational, temporary and changing. Art for Plato was about imitation of some aspect of the real world. So when a sculptor creates a sculpture of a man, he is imitating the real world of forms. The resulting artwork in this case is therefore a copy of a copy, since the real man is himself a copy of his perfect version in the ideal world. We can think of this as the imitative school of art.

Plato's view of art as imitation means that art must attempt to recreate what is seen in nature. A painting in this sense is representational; it attempts to faithfully represent what is in the observable world. A painting should accurately reproduce the colors of a tree or the size of someone's nose. This corresponds to the artistic style of realism in which paintings tend to look more like photographs. In the case of music, Plato thought music was imitation of natural sounds and emotions. Occasionally an artist may be divinely inspired when creating a work and allow us to see into that perfect world of forms. This notion of artist as a prophet or genius has persisted throughout the ages. Even modern day thinkers like Leonard Shlain have thought that artists are capable of predicting revolutions in physics. Perhaps this is the reason why the profession of artist is considered special or different from "ordinary" professions and why some works of art garner so many millions of dollars.

Art can arouse our passions. Think of your favorite movie or song and how it makes you feel. These emotions can affect our character and our behavior. Because of this Plato thought art, especially music, poetry, and drama should be part of education but that they should be censored so as only to portray the good. The young, he thought, were especially vulnerable to this influence and to prevent them from wreaking havoc on society they should be presented with rational art, that which does not stir up the passions.

Leo Tolstoy - Art, Feelings and Religion

Leo Tolstoy (1828-1910) was the Russian novelist who wrote *War and Peace*. He did not think that art was the portrayal of beauty. Tolstoy thought there was no good definition of beauty and that we should think of beauty simply as that which pleases us, which will be different for every individual. Art can therefore only be known by the function or purpose that it serves, which is the transmission of feeling. Art can then be judged in terms of how well it transmits feeling, what he terms infectiousness, and on the value of those feelings, which is its truth or goodness.

Tolstoy thought that an artist has feelings that he/she attempts to communicate by creating something physical like a novel. An observer then interprets that work and experiences, or is "infected" by, those same feelings. The purpose of language differs from art in that it communicates primarily thoughts. Art and language then pass on feelings and thoughts to humankind and play an important role in its development.

It is possible to judge how successful the form of an artwork is by its degree of infectiousness. Tolstoy identifies three factors that determine this. The first is specificity. The more specific an emotion is, the greater its infectiousness. So rather than writing that someone is generally depressed, it would be better to describe the situation that make them depressed, such as the death of their father or what is happening at a funeral. The second factor is clarity. The more clear the emotion being transmitted and the fewer the distractions, the better. The third is sincerity. This is the extent to which the emotion conveyed is genuine or real. Tolstoy thought that this was by far the most important of the three and that artists should avoid artificiality.

Independent of the way in which an emotion is conveyed is the type of emotion itself. This is the content of the art. One can transmit sadness, happiness, surprise, etc. So what feelings should art transmit? According to Tolstoy, art should help to transmit religious feelings and universal feelings. Religious feelings are those about the unity of man with other men and with God. Art that goes against the unification of men, that which divides us from our neighbors and from God, is bad art. Tolstoy also thought that art should communicate feelings that are common to all people, no matter their class, education or culture.

Tolstoy next goes on to critique the art of his time. He believed the purpose of art was to express religion and that since the end of the medieval period and the start of the renaissance it had stopped doing this. He thought the art of his time had lost its religious focus and attempted only to produce pleasure. He also believed art had become exclusive, focusing on specific classes or cultures and catering to their tastes rather than more universal and important messages. In addition, art was now insincere, having become a way to make money or simply reproduce particular artistic styles.

Croce, Collingwood, and Expressionism

Benedetto Croce (1866-1952) was an Italian philosopher and historian who had a lot to say about what art is and is not. In his essay on aesthetics, Croce says that a poem has two main effects. It inspires a complex of images and feelings. The images can be visual representations of what is described in the poem. The feelings are emotions like jealousy or joy. What is true of poetry is true for the other arts like painting, sculpture, architecture and music. Croce then distinguishes art from other fields of human endeavor. He lists seven activities that are distinct from art. These are described in Table 2.1.

Table 2.1. Benedetto Croce’s seven activities that art is not.

	Activity	Description
1.	Art is not philosophy	Philosophy is the logical thinking about categories. Art has its own logic and rationality.
2.	Art is not history	History makes a distinction between reality and unreality. Art does not.
3.	Art is not natural science or math	Natural science is classified and abstract historical fact. Mathematics is operations upon abstractions. Art is neither.
4.	Art is not a play of fancy	Play of fancy seeks to amuse itself with things that give rise to pleasure or emotion and passes quickly from one image to the next. Art is dominated by converting feeling into intuition and by poetic or creative imagination.
5.	Art is not feeling in its immediacy	Art involves contemplated and universal feelings, those that are general to the condition of humankind. Not just quick reactionary feelings.
6.	Art is not instruction or oratory	Art is not limited to any practical purpose. It can be interpreted in a general way independent of a specific philosophy or message.
7.	Art is not any other form of specific instruction.	Art is not any other form of specific instruction not included by instruction or oratory, especially those inspired by a desire for goodness.

Croce thought intuition was a formative part of art. Not every intuition is a work of art but every intuition he believed, has to some degree the qualities needed to create a work of art. To intuit is to express and art is at its heart a work of expression. This idea of what art is eventually came to be known as expressionism. Croce was an idealist, and so even a spectator experiencing art is to some extent “creating” that work of art in their mind. Since he thought that feeling was part of thinking, we are also experiencing feeling to some degree whenever we experience an artwork. The task of the spectator he believed is to realize the artist’s intuition. They may fail at this for all sorts of reasons, including haste, vanity, failure to think carefully, etc. But if they succeed they then share the artist’s intuition and expression.

R. G. Collingwood (1889-1943) was an Englishman and Professor of Philosophy at the University of Oxford and also a historian of Rome. His ideas about art built upon those of Benedetto Croce. According to the technical theory of art, all art is a means to an end. A craft is the making of an artifact to satisfy a predetermined end, so artists are also craft makers. Collingwood rejects this technical definition of art because it would equate art with craftwork such as furniture, bed sheets, and so on. To him, art was the expression of an artist’s emotion. This is the expression theory of art.

Collingwood thought that artists create art to better understand their own emotions. The act of creation makes the emotion conscious, clear, and thus helps the artist to deal with the emotion. It is not the completed artwork that is a means to an end. It is the creative process that is the means. In other words working out the art is equivalent to working out the emotion(s). The endpoint is not what is important here; it is the process. As is the case in most performance art like music and dance, there need not be a physical artifact for something to be an artwork. To Collingwood, artworks are externalized so that an audience can appreciate them, not because that is a necessary part of the artistic process. It is the imaginative experience of the artist that really counts.

Ayn Rand and Objectivism

Ayn Rand (1905-1982) was an American novelist and founder of the philosophy of objectivism. She had a well-developed theory of art rooted in metaphysics. She believed that art, unlike coffeemakers, cars, or carpets, are not an end towards something else. Art is an end unto itself. Its only end is contemplation. Instead of satisfying a material need, she thought art satisfied a fundamental need for people. That need is a view of the universe and of man's role in it. She thought art should affirm that the universe is intelligible to us, that we can act successfully in it and that we can as a result find happiness in it. This is in contrast to a view of life in which man is depraved, incapable of knowing, acting or being happy. She is holding up a heroic and romantic view of humankind, hence the title of her book on art, *The Romantic Manifesto* (1971).

Art according to Rand is a "selective re-creation of reality according to an artist's metaphysical value-judgments." In other words, an artist first selects, then magnifies those aspects of reality that reflect the artist's worldview. The things an artist selects are driven by his or her values. If an artist values free will then she will paint a heroic view, perhaps of a person standing on top of a skyscraper. If an artist values determinism and failure, she may choose to paint an image of a homeless man in the gutter. A viewer who sees one of these paintings would then have one of these different values affirmed, one positive, the other negative, depending upon their own outlook on life.

The important purpose art serves then is to objectify value, which is something a person attempts to gain or keep. A value is abstract. Art concretizes it and make is visible in a single perceptual act. The purpose of art Rand thought, was not to teach but to show what a person's values are. The purpose of art is not education or proselytizing, either about ethics or metaphysics. The teaching of those subjects is in the domain of philosophy. Art instead demonstrates these things in a specific form that is easily apprehended. Rand believed that art is also not a literal reproduction or neutral report on reality. This is the job of science and journalism. These fields report that something *is*. Art in comparison reports that something is *important*.

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The aesthetic response or functional theory of art is probably what makes sense to most people. In this view art is an artifact (something created by a person) that is intended (the artist meant for it to be) to produce an aesthetic (it is beautiful or surprising) response. Nature is beautiful, but is not an artifact, nor was it intended to be beautiful, so it can't be art by the functional account. The aesthetic definition is most closely connected with Monroe Beardsley. Under this definition an artist can intend that a particular response occur but it might not. For example an artist wants a painting to be beautiful but people think it is ugly, in which case it is bad art. The classic counterexample to the aesthetic definition of art is Marcel Duchamp's *Fountain*. This is a photo of a toilet, described in detail elsewhere in this book. This artwork did not have an intended aesthetic function. Beardsley considers it and other works like it to be a comment on art rather than art. However this critique is inadequate because it requires an arbitrary distinction between artworks and commentaries on them.

The formalist theory of art says we should pay attention to the formal properties of art. This means the form as opposed to the content. For the visual arts, form could be shape, color and contour. For music it could be tempo, rhythm and harmony. Formalists don't deny that art has content or that it can represent things in the world but they say that those things are not essential features of a definition of art.

There are two types of conventionalist theory of art. The first is institutional. The second is historical. The institutional theory says that an object can only become art in the context of an institution (hence the name) called the "artworld". The artworld could for example consist of people like art critics and art historians. Modern art like Duchamp's *Fountain* and Warhol's *Brillo Boxes* can be art under this definition because the artworld accepts them as art. According to George Dickie, an object is art as long as it is an artifact and has been considered as such by a person acting on behalf of a certain institution, i.e., the artworld. One critique of this theory is that these definitions can be circular.

Historical theories of art state that for something to be art, it must bear some relation to existing works of art. In other words, art must be similar to what has come before it in some way. The person most closely allied to this view is the philosopher Jerrold Levinson. Levinson argues that a work of art must be intended for regard as a work of art. It must be explicitly conceived for this purpose, given the attention, contemplation and emotional openness of the artist. If it isn't intended in any of these conventional ways, then it cannot be art.

Given all the difficulties people have coming up with definitions for art, there are some who basically throw in the towel and say we should give up. This is known as the anti-essentialist theory of art. One of its proponents is Morris Weitz (1916-1981). He says that there will never be a list of features that will fit every possible artwork and so we should instead leave art as an "open concept". He states that when a new work is encountered that challenges the existing definition, we should either extend the concept or close it and create a new one to deal with the new case and its properties. Weitz believes that the question over a new artifact is not factual, but decisional. In what follows we will describe some more specific examples of these theories as well as some new ideas, as advocated by individual philosophers.

Morris Weitz, Essentialism, and Anti-Essentialism

Much of contemporary art is created for reasons other than beauty. Artists in the modern and postmodern era create art to make political statements, to express their own emotions or to make us think, as is the case with concept art. The anti-essentialist view of art that arose in the mid-twentieth century reflects this idea that art is created for many reasons and as such it cannot be defined. Weitz makes two arguments for the anti-essentialist case. The first is that art is inherently revolutionary. Anytime art is defined a particular way an artist will come along and create art that will violate the definition. Secondly, it is better to consider art as a collection of objects that are related to one another rather than to try and come up with a set of necessary and sufficient conditions. If a new type of art-like object arrives on the scene, we can determine if it is art by seeing if it resembles other collections of existing art objects. If it does, we can classify it as belonging to a particular style or movement. If it does not, we may need to put it in a category of its own. This has been referred to as the family resemblance theory of art.

Noel Carroll and the Historical Narrative Approach

Noel Carroll is the Andrew W. Mellon Professor of Humanities and Professor of Philosophy at Temple University. He advocates the narrative approach to defining art, which involves telling a story about how new art evolves from what came before it. The starting point in this approach is to have a genealogical “ancestor”. This is a style that people already agree is art. One then must show how the current art, which is in question, descends from this ancestor. To do this involves telling a story or narrative. These stories are no different than the gallery handouts, interviews, lectures, reviews, docent talks etc. that are usually given to introduce new art to an audience. The relation between the “parent” and “child” need not be specified in terms of resemblance, i.e., similarities and dissimilarities. It can be described in terms of its descent or its genealogical history. These two approaches, narrative vs. resemblance, are the same as those in the field of biological systematics where pheneticists sort species on the basis of essential similarities, vs. cladists, who classify taxa based on a mechanism of common descent.

Carroll provides an example using the artist Stan Brakhage, who makes abstract films without recognizable figures. One might dismiss such work as a chaotic mess and say it is not art. The narrative to prove that it is would go something like what follows. Most films are made with a central story, characters, plot and themes. Since we pay attention to these things, we often miss the perceptual characteristics of films. The artist in this case wants the audience to pay attention to these features. In order to do this he removes the story and pictorial content and reduces the film to a sequence of abstract shapes. This compels viewers to attend to visual form. According to Carroll, if this narrative is historically accurate and it provides us with the best explanation of Brakhage’s films, then we have little alternative but to consider it as legitimate art.

Arthur Danto and Art as Relation to Culture

Another contemporary view of art is on how it relates to history and culture. In this view the object is defined based on an ongoing narrative and theoretical discussion about art by historians, scholars, artists and others. Arthur Danto describes Andy Warhol's famous 1964 installation *Brillo Box* as being no different than any other Brillo boxes that have been mass manufactured by the millions (Figure 2.1). What set them apart are the idea and the intent behind the work and how others consider it. Art historians now see this collection of boxes not as something one might find behind a supermarket but as an artwork because it is making a comment on consumer culture. Art in this view is about the idea behind it, how the artist thought about it and how others later think about it after it is created.

Figure 2.1. An example of one of the boxes used in Andy Warhol's 1964 installation titled *Brillo Box*. Image in the public domain.

Denis Dutton and Universal Features

Denis Dutton (2009) goes back to the earlier view of art as being defined through features. He proposes twelve universal features of art. Each of these features along with a short description and example are shown in Table 2.2. In this view no single one of these features may be essential but some subset of them could be. We may be able to classify an abstract expressionist painting as satisfying features 3, 4, 7, 8, 11, and 12 but not 1, 2, 5, 6, 9, and 10. The painting may have a recognizable style, be novel, have a frame around it, be the unique expression of an individual, correspond to an existing art movement and provide the observer with imaginative content. However, it may not produce direct pleasure to everyone who sees it, may not require much skill to create, may be difficult or impossible to critique, does not represent any recognizable object or scene, is not be imbued with emotion, at least for some people, and does not require any exercise of perceptual or intellectual skill. But does this mean that it is not a work of art? This notion of a concept in which not all features are necessary is called a cluster concept (Gaut, 2005).

Table 2.2 The twelve universal features of art according to Dutton (2009).

Features	**Description**	**Example**
1. Direct pleasure	The art object is valued as a source of pleasure in itself and not for any practical purpose	Enjoying listening to a performance of Beethoven's 9th Symphony
2. Skill and virtuosity	The making of the object or performance requires the use of specialized skills	Being able to perform a complex ballet only after years of training
3. Style	Art forms have a recognizable style	Baroque architecture
4. Novelty and creativity	Art is valued for its novelty, creativity, originality and capacity to surprise an audience	A novel where a police investigator is revealed at the end of the story to be the murder
5. Criticism	A critical language of judgment and appreciation	A Broadway play that is given a bad review in the New York Times
6. Representation	Art represents or imitates real and imaginary experiences of the world	An oil painting of Abraham Lincoln
7. Special focus	Art is separated and made a dramatic focus from ordinary life	The frame around a painting
8. Expressive	The ability to express the	A lost play that is

individuality	artist's unique individuality	attributed to Shakespeare based on its use of language
9. Emotional saturation	Art is imbued with emotion	Laughing at a funny scene in a romantic comedy movie
10. Intellectual challenge	Art requires the exercise of perceptual and intellectual skill	Determining what a character in a novel might do next based on their motives
11. Art traditions and institutions	The history and traditions behind a work of art and the institutions that support them	Understanding abstract expressionism in order to make sense of a Jackson Pollack painting
12. Imaginative experience	Art provides an imaginative experience both for the art producer and consumer	Knowing that a sculpture of a person is not a person but an imaginative creation of that person

Evaluating Theories of Modern Art

Adajian (2012) provides an extensive evaluation of art definitions. We will describe his approach in this section. To begin with, he believes art needs to satisfy a set of eight conditions outlined in Table 2.3. Compare these to the twelve provided by Dutton earlier. Traditional definitions of art tend to fall into three categories. These are the representational or mimetic approach stating that art copies or represents, the formalist approach with formal or essential defining features and the expressive approach saying art is expression. One can easily find fault with these. Instruction manuals are representations but not artworks, human faces and gestures are expressive but not art and natural objects and artifacts produced for the home have formal properties but are not artworks.

We must be skeptical about definitions for a variety of reasons. The Wittgenstein argument says that definitions of many things are often not possible. In this case we can keep art as an "open" concept, extending it to cover new cases, or closing it and creating a new concept to deal with such cases (Weitz, 1956). A second argument is that definitions are embedded in a larger philosophy and need to be judged in the context of those philosophies that have their own metaphysical and epistemological concepts. A third argument comes from what was covered in the introductory chapter, namely that there has never been a stable, long-term understanding of how the arts should be organized. If we cannot agree on how one art relates to another art, then it will be difficult to form a definition of art.

Table 2.3. Criteria for a definition of art. After Adajian, (2012).

	Criterion	Description
1.	Universality	Art exists in every known culture.
2.	Alienism	Art might exist in non-human species and on other worlds.
3.	Non-aestheticism	Art can have ceremonial, religious or propagandist functions.
4.	Aesthetic interest	Art is intentionally endowed by its maker with qualities that distinguish it from everyday objects
5.	History	Art has a history. Genres and tastes change over time.
6.	Institutions	There are institutions in some cultures that focus on artifacts and performances with high aesthetic interest lacking any practical use.
7.	Institutional Mixing	These institutions sometimes classify art objects without apparent aesthetic interest with entities having a high degree of such interest
8.	Non-artworks	Many things other than artworks, such as natural phenomenon can have aesthetic properties.

The classical philosophical definition, with its necessary features is not the only way we can think of concepts. People tend to think of concepts as prototypes (generic members of a class; a sparrow as a bird) or exemplars (specific examples that come to mind). However, adopting one of these classification schemes may tell us more about how people think about art but it does not guarantee that we will come up with the correct definition. Some people argue that defining art is simply not necessary and that we should focus on how to account for each individual art form instead of trying to account for all of them.

Recall the family resemblance account provided above. This approach has been offered as a way to get around definitions by saying that a new artwork resembles other artworks and so one would group it together with the other similar cases. In the cluster version of the resemblance account the artwork is said to have a list of criteria, none of which are necessary conditions for being a work of art, but which are jointly (together) sufficient for being so. One problem with this approach is that specifying the criteria amount to a definition anyway (Davies, 2006). In other words, saying the ways in which one thing is like others is tantamount to providing a definition.

Adajian (2012) provides a critique of both the institutional and historical definitions of art. The institutional approach says that the artworld institution must accept something for it to be a work of art. However, it is questionable whether any art can be created outside of an institution. Also, the artworld can be wrong in assigning something art status. There are also problems with the historical approach. Just because an artwork resembles an ancestor does not mean that the ancestor is art either. In these cases we would be comparing something that we don’t know is art to something that isn’t art. We would then need to prove a resemblance between our ancestor artwork and some predecessor before it, running into an infinite regress.

Aesthetic definitions have their own problems. They have been criticized as being both too narrow and too broad. They are narrow because they cannot explain conceptual works that lack aesthetic features. They are broad because they cannot account for beautiful products like furniture, automobiles and smart phones that are intended to be beautiful but which are not artworks.

Conventionalist definitions do well in explaining modern art but have difficulty in accounting for art in non-Western traditions. They also have difficulty with the use of aesthetic terms that are frequently applied to objects in nature, human faces and bodies, and abstract entities like mathematical equations. Conversely, aesthetic definitions are better at describing traditional art but worse at describing revolutionary or modern art. It might be worth looking at collections of art defined by conventionalist methods. If there are no common underlying principles or aesthetic features that have emerged in these groups over time then a new method of classification may be needed.

Philosophies of the Individual Arts

The Philosophy of Painting

Newall (2014) provides a clear overview of the issues in the philosophy of painting and we summarize what he writes here. Paintings can represent objects many different ways, through visual depiction or the use of explicit or implicit symbols. Depiction in the simplest sense is a painting or drawing of an object or scene that in some way resembles that object or scene in the real world. An example of explicit symbols is actual text or writing. An implicit symbol would be, for example, a white dove signifying peace. There are several ways in which non-photographic depictions occur. The first of these is described by resemblance theory. Its claim is that a picture of X depicts the real X because it resembles it. In other words, it shares some features or properties in common with the X in the real world (Abell, 2007). The second is conventionalism, which states that pictures are symbolic and are like words or other symbols in the way they represent (Goodman, 1968). The third view, called visual response theory, is that a picture depicts because it creates a certain type of visual response. This is a pattern recognition process that happens similarly to the way we would recognize the actual object (Lopes, 1996).

In Wollheim’s (1987) visual response theory we are simultaneously aware of the object depicted and the painting itself. In other words, when looking at a Van Gogh painting of a tree, we are aware of a tree and at the same time aware that we are looking at the surface of a painting with brushstrokes on it. We know that it is a tree and that it is a painting of a tree simultaneously. This process has been called “seeing-in”. An exception to this are trompe l’oeil paintings or illusions in which are fooled into thinking something is real and not a painting, as might be the case in a hyper-realistic wall painting viewed from the right vantage point.

Paintings can vary considerably in their realism. Much of European art was realistic from the Renaissance until the nineteenth-century. Although the style even during this time period could vary considerably, with neoclassical styles more realistic than impressionist styles. How can we account for these sorts of differences in realist depiction? There are two main theories. In habituation theory, a painting becomes realistic once we habituate, or become familiar with the style. The second are information theories. In this view, a depiction is realistic to the extent that it incorporates various features of the real object. For example a painted tree is more realistic to the extent that it reproduces the right shades, color, texture, and other characteristics of the real tree (Sartwell, 1994).

But should we value realism in painting? In the modern era this is considered a matter of personal choice. As noted earlier Plato thought realism was bad because it was a "copy of a copy", reality being itself imperfect compared to the ideal world of forms. Plotinus believed we could actually get around some of the "imperfections" in the actual world by painting things not as they are, but as they should be, representing not real beauty, but ideal beauty. It is not quite clear how this may be achieved, but if someone thought that say symmetry was a property of ideal beauty then a painter might achieve this by making a woman's face more symmetrical than it really was.

Form refers to those parts of a painting that have content. In a painting of a house, the form would correspond to the two-dimensional geometric shapes of the house like rectangles and triangles. Form has also been used to refer to the abstract three-dimensional aspect of the house, which would consist of things like cubes and pyramid shapes. Wolfflin (1950) argues that even in very realistic paintings, artistic differences in style can be determined, whether those be of an individual artist (Degas or Manet) or of a school (Dadaism or Pointillism). He says style is manifested in 'representational form'. An example would be the difference between the linear and the painterly. In a linear style, the focus is on the outlines around shapes, taken to an extreme in cartoons or manga. Painterly artworks are about filling the interior of objects, with less concern for edges and outlines. Another example is treatment of depth. A planar approach to depth is one where few depth cues are used and the shapes appear flat, as in some modern art. A recessional approach to depth is one where these cues are used and objects in the painting appear to recede into the distance. Wolfflin distinguished between styles using these forms. Baroque style in his account is characterized as painterly and recessional while Renaissance is linear and planar, etc.

Although this approach can explain the difference between the two above-mentioned styles, it cannot account for the differences between the many schools of the modern era. This is in part because abstract art does away with most aspects of form. Picasso, Mondrian, Malevich and Kandinsky cannot easily be distinguished by representational form given their abstract two-dimensional quality. Critics of this approach have said that even these modernists can be told apart because the "flat" forms do separate somewhat based on transparency, overlap and shadowing. We are also able to perceive textures or features in these forms. So depth and figure are present in these works, they are just more difficult to discern (Greenberg, 1993).

We will next discuss the surface properties of paintings. Inflection is the term used for an awareness of surface characteristics in paintings and how those affect the perception of representational forms. In pastels, the roughness of a rock's surface can be depicted by running the pastel over a sanded surface, leaving patches of the undersurface to show through. Visible brushstrokes also add to our perception. One can see the energy and movement of the artist in these strokes. A field of grass could be depicted by multiple linear strokes of the brush, with variations in direction, applied pressure and so on. Much can be induced from stroke patterns. A light application indicates hesitancy, a bold application confidence. Newall (2014) refers to this as 'index' and it can be seen historically in the action painting techniques of Pollock, Kline, and de Kooning. Rosenberg (1962) argues that these techniques are a form of personal expression, reflecting the artist's mental state and that one can learn to read them as such. Later, in the mathematics chapter, we discuss how an algorithmic analysis of stroke can serve as a means for determining provenance.

There are aspects of brushwork that go beyond the painter's control. Paint can flow, drip, spread, and harden in different ways that the artist does not always intend. Some artists like Rauschenberg allow loss of control as a factor in some of their pieces. In fact, there is something to be learned in this. Some artists are aware of these "happy accidents" and they can be the inspiration for new styles or techniques (Elkins, 1999).

The Philosophy of Music

Philosophers studying music have addressed questions regarding the nature of music and how we experience it. Music is a performance art and unlike paintings that are unchanging, is never exactly the same with each rendition. This allows for different interpretations. Another issue regarding music is that unlike many of the other arts, there is no obvious semantic or meaningful content. We can't easily identify objects like "trees" or a "sunrise" in music. Another interesting question is how music is able to stimulate such strong emotions in us while being fundamentally abstract. The focus here will be on 'pure' music: that without vocals, because in these cases there is no meaning added.

What is music? Is it the musical notation, as written down in a score? Is it the way it is performed on an instrument? Is it the pressure waves in the air? Or is it the activity in your brain while listening? Music must be more than just organized sound because speech is also organized. It must also have 'tonality' or other musical features like pitch and rhythm and addition some aesthetic component (Hamilton, 2007). It is also usually produced with an instrument. For definitions of basic musical features, see the section on music in the psychology chapter. All kinds of sounds though are included in music, so what counts as a fundamental feature of music remains to be resolved. Poetry is an instance of a sound-based aesthetic art that does not require musicality, and music can be played with one's body, which seems to stretch the definition of an instrument. So current definitions of music are still vague.

Ontology is that branch of philosophy that deals with what entities exist and how they are organized based on similarities and differences. In the idealist view, musical works are mental entities. Collingwood (1938) and Sartre (1940) argue that they are imaginary objects and experiences, taking place inside our heads. The problem with this view is that there can be as many types of music as there are people listening to it and that one could have the same imaginary experience listening to music or to seeing a movie. Davies (2004) believes musical works are the actions of their composers. This is also problematic because it downplays the actions of the performers.

In the nominalist perspective music works are collections of particulars, such as scores and performances (Caplan & Matheson, 2006). This is one of the least problematic definitions but cannot account for all of the possible performances in which a wrong note is played. In Platonic views music is an abstract entity that does not exist in space or time but comes into existence based on human action (Dodd, 2007). In contrast to these views are those who believe in anti-realism. They deny that there are any such things as musical works (Cameron, 2008). Some of this discussion is over the language we use when referring to things like music. In the end, we must admit that it is a very complex art form, one that is difficult to define, and that we are left with operational but imperfect definitions to go on.

Another philosophical topic is on the relation between music and emotion. There are a number of questions here. How does music express emotion? Why and how do we respond emotionally to music? People express emotion, but a piece of music isn't human so how could it be emotionally expressive? A way around this is to say that people express, but music has expressivity. The latter is related to the former but they are not the same. One way to link these two is through the audience. According to 'arousal theory', the expressiveness of a musical piece reflects its ability to arouse emotion in a listener (Matravers, 2011). There are a number of objections. One is that an emotion (like fear) requires an intentional object like something threatening (a bear). There is no such object in music; therefore music should not elicit fear. Another objection is that many listeners are not aroused or emotional when listening to music. A somewhat simple response to this has been to restrict the case to those who do feel it.

In associationist theory, there are certain features in music, such as a slow tempo, that are associated with certain emotional states, like sadness. However, people can have different emotional reactions to the same emotional feature and there can be multiple musical features that elicit the same emotion. The expression that music is "the language of emotions" suggests that there are rule-governed structural aspects of music (aspects of syntax), that can be mapped onto emotional states (Lerdahl & Jackendoff, 1983), but there is as of yet no detailed model of this might work. There are large differences between the syntax and semantics of music and of language and it is not clear how to make linkages between the two.

The next set of questions is about emotions in the listener. Why should we respond emotionally to music when we know there is no actual person experiencing it that we can empathize with? This is known as 'the paradox of fiction'. Some downplay our emotional reactivity, not by denying we feel emotion but that these feelings are a smaller part of our total response to music that presumably involves perceptual, cognitive and other components (Sharpe, 2000; Zangwill, 2004). Kivy (1999) says that we confuse the pleasure of music with the feeling of the emotion that is expressed. However it is possible to have responses to situations that are similar to those in music where there is little or no cognition involved. For example we react similarly to a sudden blow to a drum as we would to a thunderclap. Likewise, we respond to tension and release in music the same way we might respond to a balloon being over-inflated.

Another interesting question here is why we seek out music that arouses negative emotions in us. This is known as the ‘paradox of tragedy’. In the catharsis account, listening to sad music helps us to get rid of these emotions or to deal with them (Levinson, 1982). This might be the case, but it still fails to explain our persistence in seeking out such music and the enjoyment we get from it. It is possible that we enjoy some negative states, perhaps outside of the context that causes them. For example we may enjoy feeling sad listening to Mozart’s *Requiem*, which is about death but we would not enjoy feeling sad in response to the death of our father (Walton, 1990). According to the analytical rumination hypothesis depression helps us to focus and solve the problem causing the negative state, which is an adaptive response (Andrews & Thompson, 2009). A prediction of this theory is that we would become more introspective in response to sad music compared to other types of emotional music.

Let us now turn to the issue of understanding music. When we listen to music we don’t just hear sounds. We have an understanding of what music is made of: things like notes, melody and movements. In addition we can identify instruments, know the names of the singers and songs, etc. People vary in the extent of this understanding. Jeff’s understanding of Led Zeppelin for example may greater than that of his sister Susan. We do not need to have a technical understanding of musical terms in order to appreciate it, but this does lead to a deeper understanding and allows us to share it with others. An intuitive knowledge of music includes knowing about individual tones that have relations to others in a musical space. The tones can go “up” or “down” in this space. It also involves knowing about movements like when a melody wanders and then comes back to its starting point. This understanding may be metaphorical in the sense that we know other things like birds that can fly up and down, or come back to rest (Budd, 2003; Davies, 1994; Scruton, 2004).

The Philosophy of Dance

This discussion of dance will focus on Western dance performed for an audience in a theater or concert setting, with the understanding that there are many forms of dance for reasons other than performance, such as religious ritual. As has been the case in our other essays on the specific arts, we will focus on what dance is and how it is perceived and appreciated. The study of dance takes place in fields outside philosophy: by historians, anthropologists, and dance studies scholars so there are alternate perspectives to the one provided here (Albright, 2011; Hanna, 1987).

Dance like music, is nonrepresentational. Unless accompanied by song, there are no words and so translating movements into symbols, if possible, is difficult. Even if there is a score, it may just serve as an inspiration or starting point rather than a template (Franko, 1989). One way to approach dance is to consider it as an expressive art form that involve action (Beardsley, 1982). Khatchadourian (1978) believes that dance consists of movements that are not actions because they are not intentional in the normal sense, meaning directed toward making something change in the real world. He states that they are non-action voluntary activities; movements that represent certain imagined actions of imagined characters and situations. In this view dance motions represent real motions in a metaphorical way. However, all dance movements need not be symbolic (McFee, 2011).

Like music, dance can change in different productions and performances. The score for a dance piece can also change. Goodman (1976) characterizes dance as an “allographic” art, in that there is no stable and singular art object that remains constant for historical analysis, as with paintings, which are “autographic”. He believes however that dance can be notated even in cases where there is no score. A score can, in his view, capture some of the essential properties of a performance, even if it misses out on some of its subtleties and complexities. A choreography specifying the locations and movements of the dancers would seem to fulfill this requirement. Armelegos and Sirridge (1978) however, argue that such notations omit features like lighting, music, costumes and the contributions of individual performers.

McFee (2011) provides seven features that he thinks constitute a dance “work” of art. These are shown in Table 2.4. Van Camp (1980) argues against points number three and four. She believes that the dancer “creates” in some cases rather than just performs or interprets. The dancer can for instance supply changes in the movements not in the choreography. In this case he or she is “creating” the dance in the same way the author of the dance does. There are non-essentialist philosophers who don’t believe that dance can be boiled down to critical features. They argue from a pragmatic and pluralist position and say that dance emerges from interactive and relational behaviors between people like choreographers, performers, audiences, critics and historians. Dance can thus be considered as ways of talking and acting between various members of the dance art community (Van Camp, 2006).

Table 2.4. The seven essential features of dance, after McFee (2011).

	Title	**Description**
1.	Performance	Performable and re-performable with a history of production
2	Representation	An abstract structural representation with particular examples of how those are instantiated, i.e., a “type” and “token” correspondence
3.	Choreography	Work created by a choreographer with a historical identity, meaning, and continuity

4.	Dancers	Performance and interpretation is by dancers
5.	Artistic Properties	An object with perceptible artistic properties
6.	Institution	An intentional objecs that has an institutional context under a concept of art
7.	Reconstruction	A re-constructible and re-performable object

There are many connections between dance and other art forms. For instance Igor Stravinsky composed the music for *The Rite of Spring* with the dance company director Sergei Diaghilev. Shouldn't we then consider this to be a hybrid music-dance form than just a dance alone? Ballet could be a mixed form, combining elements from dance, music, drama, mime, costumes, décor, and so on. In fact, this may be the reason it took so long for dance to be recognized as a distinct area by aesthetic thinkers (Carter, 2005). There are a number of similarities and differences between dance and these other arts. Both singers and dancers use their own bodies to express the piece in front of a live audience. Rhythm is a common feature of dance and music. Dance though, does not always have a set script or notational formula, as is the case in theater and music. Music tends to be recorded more than these other arts. Musicians also use instruments while song, dance, and theater are expressive through the body only.

In what ways does dance "represent" things? We can say that a dancer stands for a character and a ballet as a whole represents a story. Some of the ways representation can occur include gesture (a girl holding her hand to her heart to signify love) and lexical information like the title or description of a performance. But this is not the case in many forms of modern dance where the individual and collective movement of the dancers is more abstract. Dance as it is performed now need not be imitative, either of nature or human events, in the Platonic sense. There are four ways that dance can represent based on the philosophical literature. These are: 1) subjectivist theories that describe expression as through the felt emotion of the performer, 2) naturalist theories in which the specific bodily movements express, 3) expressionist theories in which the content is expressive, and 4) semiotic theories that say it is in the formal dance structure.

How does an audience appreciate a dance performance? Audience members are said to have a kinesthetic response to dance. This means that their bodies in some sense make or imitate the dancer's moves. As we shall see in the neuroscience chapter, the parts of the brain that move the body are actually activated but not expressed when watching dance. It is also likely that mirror neurons, which allow us to empathize and imitate other's motions, are active under these circumstances. Montero (2013) believes that proprioception (awareness of our body's location in space) is a type of aesthetic sense. This sort of cooperation between neuroscience and philosophy is exactly what is needed in the arts (Seeley, 2013).

The Philosophy of Literature

Although it might seem new, the philosophy of literature actually dates back to Aristotle's *Poetics*. In this writing he laid out the nature of poetry with its aims, types, and objects and then provided an analysis of tragedy. He defined the different parts of a tragedy, including the plot, characters, and actions, and then compared it with another kind of poetry, the epic. However, in the intervening years, there has been little in the way of this scholarship until recently. Philosophers now are taking this genre seriously. In what follows we will outline some of the answers to this area's big questions following the organization and content laid out by Peter Lamarque in his 2009 book, *The Philosophy of Literature*.

After Aristotle the first thinker to write on this topic again was the Roman poet Horace in *Ars Poetica* (18 B.C.). He saw poetry as not just having beautiful language but as a means of learning. He thought that words should be both pleasing and useful. Hegel had great praise for poetry, thinking it to be the highest art form that gave way to "realization". John Stuart Mill referred to poetry's "higher pleasures". Of course literature is more than verse. Prose works like the novel and the short story need also be considered but these didn't arrive until much later in history.

As an art form literature ought to produce an aesthetic experience but clearly there is more to it than that. One of the functions of literature is semantic or conceptual, to get us to think about important ideas. It also has other aims, to get us to experience emotions, to provide realistic depictions of the world, to get us to laugh, etc. It often uses rhetorical devices like alliteration, imagery, repetition, rhyme, and meter to induce these effects. A philosophy of literature should fulfill six criteria, according to Lamarque. These are described in Table 2.5.

Table 2.5. The six criteria for a philosophy of literature. After Lamarque (2009).

	Name	**Description**
1.	Breadth	It must encompass all literary forms, including poetry, novels, short stories and more.
2.	More than linguistic analysis	It must explain literature in more than just linguistic properties. It must go beyond syntax, semantics and rhetoric
3.	More than formalist	It must not reduce literature to any one aspect of literary pleasure like imagery or plot structure
4.	More than hedonism	It should not purely hedonistic. Literature is more than just pleasure.
5.	More than intuition	It should be more than intuitive or "natural" reading. Experience and training add to what can be learned from reading
6.	Autonomy	Literature is a practice with its own traditions and conventions

What exactly is literature? The question is more complex than it seems. Any definition must be able to explain literature as an art form and not something that is just read. It must go beyond saying it is something that is "well written". If we were to try and come up with an essential feature of literature the task is difficult because the different forms of literature are so varied. It is like asking what a haiku and a novel have in common. Let us review various attempts to define literature. Plato thought literature and arts in general are mimetic, that they imitate reality in some way. In pragmatic theories literature brings about some effect in the reader like pleasure. Expressive theories say the point of literature is to express the author's thoughts and feelings. Autonomy theories say that literary works are not part of the world, not a copy of the world, but a world unto themselves.

There are yet more views. The linguistic school states there is something special about the use of language in literature that we do not see in other written works. These can be things like rhythm, metaphors, the sonnet form, etc. The semantic side of this says that literature produces a unique type of meaning. Formalist theories attempt to produce recognizable features such as foregrounding by which we can identify literature. Another approach is to divide literature into an imaginative/creative dimension and a content dimension. The first refers to the fact that they are written in an imaginary and creative fashion, unlike let's say, the operating manual for a dishwashing machine. The second dimension is that it ought to address something like universal themes important to the human condition, such war or prejudice. Suffice it to say that while all of these approaches capture something important about what literature is they are not perfect and there is still no generally-agreed upon definition.

Ontological questions are those about objects and things. What type of "thing" is a literary work? Is it a physical object? An abstraction? Is it something only in the mind of readers? One way of answering these questions is to think about survival and destruction. A painting disappears if it is destroyed. But is a novel destroyed if we burn a book? It would continue to exist in the form of other books. Even if we destroyed all the books it might still live on in the minds of readers. This is the mentalist conception.

The Romantic poets belonged to the expressionist school. To them a literary work, like one of Byron's poems, is an expression of Byron himself, his feelings and thoughts. In opposition to this we have the contextualists, who say that a work must always be considered in its historical and cultural context. These are the conditions the author was in rather than the author himself. The institutional account views the work in terms of the author's relations with other people such a readers and critics. These views help us to isolate the influences on a work. It can be the work considered by itself only as a literary construct, the author him or herself, the context the author lived in or the ways in which people perform an interpretation. It is difficult to determine the author's intent. The meaning derived from a literary work could be what the author intended, or something else. As readers we must be careful not to read too much into a text. We may be attributing things to the author that he or she never intended.

What is an author? It is clearly more than someone who just writes. Someone who writes an email isn't considered an author in the literary sense. The earliest conceptions of an author were of someone inspired by the gods or a literary muse. This view sees the author as a passive receptacle, a person who merely transmits information coming from some supernatural source. Another aspect concerning authors is the extent to which we can use biographical information about them to infer knowledge of characters, themes and other aspects of their work. Literary critics are continually trying to infer Shakespeare's views on marriage, loyalty, honesty and other themes. Biography can certainly guide understanding but literary biographers must be careful not read too much of an author into their work. The saying "All writers ultimately write about themselves" may not be true in all cases.

One modernist take on authors, the so-called "New Criticism" is that we should focus not on how poems relate to authors but on how they relate to other poems. Eliot proposes that every poem must be considered in its historical context, but that it also changes the whole existing order of poems once it attains recognition. In this perspective it is not the author but the character and identity of the work itself and how it is expressed that matter. We can depersonalize the author and postulate a "dramatic speaker" for the work, a type of third-person narrator. In this way the writer is removed from their work and it can be analyzed perhaps more objectively. According to the strong autonomy view a literary work is a self-contained and free standing linguistic structure who language properties alone determine its interest and character.

We can next turn to the practice of reading. Is there a particular way of reading a literary text that differs from other types of writing? Training and experience certainly count for something and the more background information a reader has the more it will affect the depth to which they can interpret meaning. But is the pursuit of what a work means all there is? Reading for pure pleasure or imaginative experience would thus seem to be the domain of genre fiction like horror and fantasy novels, and not literature as art. The distinction here is between knowledge vs. entertainment.

Lamarque (2009) suggests four criteria by which we should read literary art. These are: 1) a heightened awareness of form and structure and the "design" of the whole; 2) an expectation of coherence and inner connectedness; 3) an expectation that the work presents a subject of some interest, either through narrative content, imagined emotion, or metaphoric illustration; and 4) an expectation that the work exhibits and develops organizing principles or themes that provide unit and value in the work beyond the immediacy of the subject, inviting reflection on matters of more universal human concern.

What makes a literary work fiction? To begin, not all of fictional work is considered literary. Some critics do not consider genre works, like whodunit, spy and science fiction as literature (as art). Conversely, not all literary works are fictional. These would include things like history, biography, and belles lettres. In the most basic sense fiction is made up or invented. It is the product of the imagination and not truth. This might seem straightforward but there is a thin line between fact and fiction. There are made up stories based on fact and factual stories told as if they were fiction. It can be difficult to tell the difference between these.

Does great literature give us "truth"? Well, not in the same way science does. Great literature can give us truths, but these can't in most cases be verified the way a scientific proposition or hypothesis can. A literary form however, gives us much more than glimpses of truth. Poetry can get the reader to develop new perspectives on the world, to generate emotional or sensory experiences, to get us to think about a subject, to exercise our imagination, to provide insights into human nature or to impart a moral lesson. So even if it does not impart truth directly, it can encourage and provide us with the means to seek the truth.

The Philosophy of Architecture

The philosophy of architecture may seem like a new discipline but it has roots going back centuries if not millennia (Feng, 2012). Examples of ancient treatises on architecture include *The Ten Books on Architecture* by Vitruvius, *Canon of the Five Orders of Architecture* by Giacomo Barozzi Da Vignola, and *The Four Books of Architecture* by Andrea Palladio. The philosophy on this subject covers a vast panorama of topics and touches upon many areas like ontology, ethics, politics, technology, and rights. Our focus here will be on introductory definitional issues and aesthetics. As a subject for Western philosophy, architecture is the neglected stepchild. It has received relatively little sustained attention from thinkers in the field compared to the more traditional arts like literature and music. But that seems to be changing. Architecture like abstract pictorial art or music may be considered non-representational (Scruton, 2013). However, it can express or refer. Like literature, it may also tell a narrative in the design of pathways that allow people to move across spaces over time.

To start then, what is architecture? The discipline has changed so much over its long history that it becomes difficult to find defining features. It certainly involves engineering and related design techniques but must be more than that since there is an aesthetic component that involves ideals and taste. In other words it is more than just "building buildings". Not all philosophers consider it an art form. It becomes difficult also to agree on what exactly constitutes an architectural object. Does such an object have to have walls? A roof? The least that can be said is that the resulting structures are designed for human use.

Starting with the essentialists, we can ask what are the defining features of an architectural object. The Roman Marcus Vitruvius Pollio (known as Vitruvius) in his *Ten Books on Architecture*, proposed three. These are firmitas (structural integrity), utilitas (practical function), and venustas (beauty). Firmitas means that a building should remain durable after extended use and exposure to the natural elements. Modern designers are getting better at predicting a building's lifespan. Many large structures are now designed to last for over five hundred years. Utilitas is the ability to predict and respond to the needs of the intended inhabitants or users. Venustas can be created by the use of attractive materials, the level of craftsmanship or attention to detail. Beauty was more of a focus in building design prior to the twentieth century. This decline may be due to mass production and the use of cost effective building materials or to the public's increased concern with modern amenities like elevators and air conditioning.

The term parti pris or just parti is another definitional idea in architecture. This French term probably originated in the Ecole des Beaux-Arts, the nineteenth-century architecture school. Translated it means “departure point”. It stands for the “guiding idea” or “big idea” for a design. It has less to do with engineering and financial issues and more to do with terms like scaling, mass, and transparency. For instance the goal of an architect could be to design a house that is transparent, frames views, and lets in light.

Davies (1994) argues that most architectural products are utilitarian only, without any aesthetic intent. Stecker (2010) argues that there are always a subset of such objects that are considered art. He notes also that architecture at least from the eighteenth-century onwards has been classified as a type of art. See the introductory chapter for more on changing views of architecture’s status through history. It may make sense to distinguish between two types of architecture, those with and without aesthetic intent, and to classify these separately. This classification may need to go beyond what the designer thought and to include public intuitions and social and cultural norms.

As is the case in other areas of aesthetics, formalists believe that the beauty of an architectural object arises from certain properties of form. For example a pyramid shape is a type of form that one might use to determine if a structure was beautiful. Forms certainly characterize the many styles of architecture (Table 2.6) but it is unclear whether there is some collection of forms that uniquely determine beauty. In the anti-formalist camp are the functionalists. They hold that things like historical context and usage are important. To give an example, Thomas Jefferson’s University of Virginia campus may be judged as stately or dignified based on its neo-classical design, its place in the history of American and university architecture and its continued use as an active school campus (Fisher, 2015). The neo-classical design can be considered purely as a historical movement in this case, independent of any forms.

Table 2.6. Major architectural styles. After Cole (2006). For an alternate and more detailed organization see Melvin (2006).

Period	Style	Example	Architectural Features
3200-30 BCE	Ancient Egypt	Pyramids at Giza	Pyramids and temples designed to house rulers tributes to the Gods. Monumental and immense forms to last for eternity
2000-333 BCE	Babylon, Assyria, Persia	Persepolis, Iran	Stepped temples (ziggurats) palaces and temples of the former Mesopotamian culture
300 BCE-1750s	Early & Classical India	Temple complex at Bhubaneshwar	Buddhist stupas to house remains of religious leaders and the stambha, a freestanding monumental column
1500 BCE- 19th Century	Early & Dynastic China	The Forbidden City, Beijing	Rectangular monasteries of timbre construction and pagoda towers. Planning of entire cities.
Pre 6th-Century BCE- 19th-Century	Classical Japan	Five story pagoda at Nikko	Shinto shrines and Buddhist temples.
900 BCE-	Pre-Columbian	Pyramids at	Pyramids, platforms, temples, squares, ball-

1532 CE		Chichen Itza, Mexico	courts and sacrificial altars. Processional roads
7th-Century-1st-Century BCE	Preclassical	Lion Gate, Mycenae	Minoan, Mycenaean and Etruscan civilizations. Corbeled dome tombs
Mid 7th-Century-1st-Century BCE	Ancient Greece	Parthenon at Athens	Peristyle column temples with pediments. Doric, Ionic and Corinthian capitals
3rd-Century BCE- 340 CE	Ancient Rome	The Colosseum, Rome	Basilicas, atriums, columned temples, arches
313 BCE-1453 CE	Early Christian and Byzantine	Hagia Sophia, Constantinople	The basilica, a rectangular assembly hall used as a market, law court or other purpose. Churches
632-1800 CE	Islamic	The Alhambra in Granada, Spain	The mosque, pointed arches, domes, minarets and enclosed courtyards
1000-early 13th-Century	Romanesque	St. Marks Church in Venice, Italy	Roman revival style. Barrel vaults
Mid 12th-Century-1530	Gothic	Chartres Cathedral, France	Pointed arch, ribbed vault and flying buttress
Early 15th-Century-1630	Renaissance	St. Peter's Basilica, Rome	Reintroduction of classical forms. Cathedral domes, villas and gardens. French Chateaus, Elizabethan Prodigy Houses, Jacobean architecture
17th-Century-Late 18th-Century	Baroque and Rococo	Palace of Versailles, France	Broken pediments, convex and concave walls, elaborate ornamentation
Early 18th-Century-Early 19th-Century	Palladianism	Chiswick House, London	Based on the work of Palladio and Inigo Jones, restrained classical style
Mid 18th-Century-Mid 19th-Century	Neoclassical	Capital Building, Washington, D.C.	Return to ancient Greek and Roman influences
Late 18th-Century-Early 19th-Century	Picturesque	Culzean Castle, Ayrshire, England	Inspired by the 18th-century Romantic movement. Also known as Georgian or Regency style. Incorporates landscape design. Gardens, estates, gazebos and fountains. Cottages

Inherent in the functionalist account is that an object is beautiful if it is fit for its intended function (Parsons & Carlson, 2008). The idea of functional beauty goes back to early thinkers, including Berkeley, Hume and Kant. A modern take is that the aesthetic is dependent on an architect's ability to design a functional solution to a problem. Advocates of this approach do not all say that form should *always* follow function as there are often other design considerations like ornament that don't fall under this category. Another challenge is that ruins are often considered beautiful but serve no function.

Architectural appreciation is believed to occur at two levels, the aesthetic and the utilitarian. The first is about the beauty of the judged structure, the second about its functionality. Our abilities to perform this last judgment are based on knowledge from multiple sources, among these reading and education, the opinions of others and experience with the structure. Being able to understand and classify the different styles of architecture, for example, those shown in Table 2.6, is a crucial part of appreciation (Leder et al., 2004). Aesthetic appreciation can be performed independent of our knowledge of utility for a structure but the two are certainly related. Knowing about the Roman Coliseum, its design and layout, and what occurred there will certainly shape our perception of its beauty.

There are numerous other issues in the philosophy of architecture that we don't have the space to discuss here. These include perception of architectural failure, preservation of ruins, perception of built vs. natural environments, and the relation between architecture and the environment. A greater synergy is needed between traditional architectural professions and environmental psychology. The purpose of this field is to study how environmental factors such as light, color and traffic patterns in natural and artificial environments affect our perception and behavior.

The Philosophy of Film/Cinema

The philosophy of film is now considered an established sub-discipline of the philosophy of art (Wartenberg, 2015). Work was done in this field when film first emerged as an art form in the early decades of the twentieth century. Not much growth occurred in the field until the 1980's at which point there was new interest. Some of the reasons for this renaissance are probably the increased popularity of film in popular culture and changes in academia that now allowed it to be considered a serious art form. A philosophical anthology of film and motion pictures published in 2005 and a book on the subject by the philosopher Noel Carroll in 2007 testify to how solidly entrenched it is now as a topic of study. Film is considered on a par with painting, music, theater and dance as an art form worthy of academic attention. There is also growing interest in the study of film within the field of psychology. We will have more to say on that perspective later.

Is film or cinema an art form? What distinguishes it from the other arts? Early studies of the medium focused on the technical devices, like close-ups, flashbacks and edits. These techniques are what separate film from theater. Munsterberg (1916) argued that these are all objectifications of mental processes. A close-up, for instance reflects the act of paying attention, while a flashback refers to reliving a past experience as a memory. Bazin (1971) believed what makes film unique from the other arts is its ability to portray the actual nature of the world, in much the same way photography does. He advocates realism as a film style, characterized by its use of extended shots and deep focus. Filmmakers working in this tradition include Jean Renoir and Orson Welles. In contrast to this would be films whose focus is on the image, not on reality.

Emotional engagement is an important aesthetic element of film. If a film is not engaging, it will hardly be judged good or beautiful. But this has philosophical relevance also. For one thing, why should we care about characters that are fictional? The same question of course applies to poetry, literature, and theater. One answer to this is that we identify with them. It seems easier to identify with idealized individuals who are more attractive, intelligent and brave than we are. We may put ourselves in their shoes, imagining that we are undergoing what they are on the screen. However, we experience a great many things in films, so identification is probably not the entire story. Films get us to imagine events taking place, especially events we care about and would like to see (or not see) happen. Engaging films make us care not just about the characters but about important outcomes like political revolutions or the extinction of humanity.

How do we engage emotionally? According to simulation theory, imagining while watching film involves having our emotional reactions “off-line”, to use a computer analogy. A person in this state might feel angry in response to what is happening on screen, but wouldn’t act on this anger the way they might in a real world situation. This brings us back to an issue discussed in the philosophy of music, which is why someone would want to listen to depressing music but not be depressed in the real world. In cinema we can ask why it is we like to experience any negative emotion while watching it on screen but not in real life. Why for instance, do we enjoy seeing horror films? Simulation theorists say it is because we enjoy being scared knowing we are safe during the experience. A problem with this view is that it is not clear if or how we experience emotions off-line.

An alternate philosophical account to simulation theory is thought theory. In this view, we can have an emotional reaction to a thought. Watching a movie makes us think and this thinking then produces an emotional reaction. For instance, imagine seeing an evil villain about to set off a nuclear bomb in a city. The thought of millions of people about to die as a result of this act makes us angry. We then want to kill the villain, or at least stop him from performing the act. Realizing this, we don’t act on our impulses. There are problems with thought theory as well. There are many mental states that elicit emotions, including belief. We cannot have full-blown beliefs in response to film because it is fictional. Yet, we still experience emotional engagement. Thought theory cannot account for this (Plantinga & Smith, 1999).

Let’s next address the issue of perspective in films. In the “Imagined Seeing Thesis” viewers imagine themselves as seeing the action through a sort of window that allows them to tell what is happening in the fictional world. But this thesis fails to account for what occurs when there is a camera movement, a split-screen, or a dissolve to the next scene. Perhaps in these situations, the observers imagine themselves as seeing “edited” images that come from within the fictional world itself. In other words, they imagine that they are seeing an image that is being fed to them from a camera attached to a helicopter or from a car in a car chase scene. But this account runs into difficulties because part of the job of film is to make the camera "disappear". If people perceived film this way they would no longer be under the illusion that what they are watching is real.

The Philosophy of Creativity

Immanuel Kant and the Creative Process

Kant (1724-1804), in his *Critique of Judgement* devotes several sections to artistic creativity. He writes that genius is the skill that gives rise to artistic products. In his view, artistic talent is a natural, innate quality that some people are born with. In modern day terms, we might say it is genetic or "hardwired". Kant seems to think this innate talent, which itself comes from nature and which imitates nature, cannot be described by rules. Originality is the primary quality of this skill. The art works produced by genius now serve as models for others to imitate; he calls them exemplary. Curiously, Kant next seems to say that the artistic genius cannot know how creative ideas enter into his head. He suggests that the rules or method by which he or she gets creative inspiration cannot be communicated to others.

Let's evaluate some of these ideas. To begin, there is no reason to expect that artistic talent is entirely innate. Artistic skills can clearly be taught and like most psychological traits are an interaction between genetics and environment. At least some aspects of artistic talent can be rule-governed and described. Neuroscience is showing us what happens in the brain during creative processes and we can formulate cognitive or information-based models of these processes. It probably is the case that we do not have conscious access to some creative thought processes, but there are some aspects that with introspection or training one could become aware of. Kant's notion that the source of creativity is unknown seems to come from the Platonic idea of the muse or the artist as a receptacle for the supernatural.

Kant next points out the difference between genius and imitation. Geniuses generate new ideas, while those seeming to lack those skills can create similar works by imitating the products created by the geniuses. He contrasts methods of science with the arts. Isaac Newton's discovery of the laws of physics can be broken down into a stepwise and logical sequence that can be communicated to others. This however is not true in the arts. The poet Homer cannot himself know how his artistic thoughts enter and assemble themselves in his brain. Science in this manner can always progress, while the arts are limited. Kant remarks also that aesthetic taste and artistic genius are independent. A work of art may be the product of genius but be without taste. Conversely, in another situation we may have a person with aesthetic taste but lacking in genius. This last proposition is somewhat strange because an aesthetic sense seems necessary to create something that itself should be aesthetic. But as modern art shows, beauty can be a secondary or nonexistent part of art.

Kant next gets quite specific about the forces behind artistic creativity. He names a soul or *Geist* as the animating principle in the mind. This Geist operates on a substance, called a *Seele*. These two forces seem to be the equivalent of energy and matter in physics. He says this imaginative force is a productive faculty of cognition. Productive material can be borrowed from nature and be worked up into something else that surpasses nature. As an analogy, one might see a beautiful view of a natural scene and then create a painting of the scene that surpasses nature. Kant also seems to get at an associative process, whereby when thinking imaginatively one generates kindred representations that provoke even more ideas. This last idea gets at the modern conception of a semantic network in a memory system where nodes represent concepts and spreading activation between nodes occurs along links. Thoughts of one idea can then trigger activation in related nodes in a process called spreading activation. These types of networks can be used to explain priming effects as well as free association and creative reasoning.

Arthur Schopenhauer. Flow and Madness

The German philosopher Schopenhauer (1788-1860), in *The World as Will and Representation,* has a lot to say about an artist's personality traits. An artist is someone who is able to lose himself or herself in the moment contemplating an object or scene. In this manner, they forget their own individuality or will and exist only in a state of pure subjective consciousness. The perceiver can no longer separate themselves from their perception and the two merge to become one. In this state, they can mirror the object and see its true ideal state. This ideal state seems equivalent in many ways to Plato's ideal forms. A man of artistic genius in this contemplative state says Schopenhauer, can leave out their own interests, thoughts and aims, and become a pure knowing subject. They will be able to sustain this state of mind for a long period, presumably as long as is needed to create a painting, sonnet, or symphony.

This state bears remarkable resemblance to the psychological state of "flow" that has been empirically validated across a number of experiments (Csikszentmihalyi, 1992). Flow is the mental state of being fully immersed in a feeling of energized focus while performing some activity. The activity need not be artistic, but could be most any challenging behavior, like sailing or playing basketball. It is a complete absorption in what one does. In flow the emotions are harnessed in the service of performing and learning. There is a reported spontaneous feeling of joy that can accompany this state. Nakamura and Csikszentmihalyi (2001) outline six factors as constituting flow. These are: 1) intense and focused concentration on the moment; 2) merging of action and awareness; 3) a loss of reflective self-consciousness; 4) a sense of personal control or agency over the situation of activity; 5) a distortion of temporal experience, one's subjective experience of time is altered; 6) experience of the activity as intrinsically rewarding, also referred to as an autotelic experience. These characteristics can appear in isolation but only in combination do they constitute a flow state.

Schopenhauer next describes the character of an artistic genius. He says they have a restless, zealous nature and are constantly searching for new objects worthy of contemplation. The "common mortal" on the other hand is satisfied by the common present and engaged with the normal and daily experiences of life. The ability to imagine is present in the artist but this is not their defining feature as there are many non-artists who are also imaginative. The artist according to Schopenhauer is poor at mathematics, because this discipline requires reason and memory. It is abstract and the focus is not on the perceptual object that is the source of artistic inspiration. Conversely, he states that mathematicians feel little positive regard for works of art. Artists will tend to think more about their own interests and less on the people around them and so will in situations tend toward soliloquy and revealing things that would best be kept secret.

Regarding artists Schopenhauer believes they have a touch of "madness" in them. In his frequent visits to lunatic asylums, he reports individuals endowed with "unmistakably great gifts". The incidence of such artistic skill seems in his view to occur in much greater frequency among the mentally ill than among the normal population. The normal individual he says can exhibit artistic perception for limited periods of time, otherwise he could not appreciate art, but they cannot feel it to the same intensity nor sustain this perception for as long as the artist.

These are interesting observations, but are they supported by modern science? Are artists really bad at math? One myth in popular culture is that there is a relation between mathematics and musical ability, presumably because music can be described so well mathematically. Studies however show only a modest relationship between the two (Vaughn, 2000). There is additionally the so-called "Mozart Effect" in which listening to music can enhance a child's math or other cognitive functioning. Research shows that music can enhance some math skills. In particular, music targets one part of the brain used in spatial-temporal reasoning, which is useful in mathematical thinking (Zhan, 2002). Also, training in music, dance or other arts can improve the brain's attention system, which can in turn improve cognition, including mathematical cognition (Posner & Patoine, 2009). So the notion that all artists are bad at math is misleading. Contemporary research shows that art and math abilities call on some of the same cognitive resources and that practice using these component skills can produce improvements in both artistic and mathematical ability.

What about the link between creativity and mental illness? As we report later in this book, there is a correlation between certain measures of creative thinking and bipolar disorder. Other studies show correlations between creative occupations and people with mental illness such as schizophrenia, major depressive disorder, anxiety disorder and ADHD (Batey & Furnham, 2009; Kyaga et al., 2011). In some cases, mental illness has been found to aid in creativity but there is also strong evidence that mental illness does not need to be present in order to be creative (Roberts, 2012). There are plenty of successful creative individuals who are free of any type of psychological disorder. So Schopenhauer's comments on this linkage seem better supported by modern empirical evidence.

Robert George Collingwood and Emotional Expression

R. G. Collingwood was introduced earlier. In *The Principles of Art*, he outlines his views on emotional expressivity and artistic creation. According to Collingwood, art is about the expression of emotion. If an emotion is unexpressed, he says we feel helpless and oppressed. If it is expressed, we feel better, in accordance with the psychodynamic cathartic idea of "letting off steam". To the artist however, the emotional expression is not about displaying the normal behavioral signs of an emotion like shouting when feeling angry. It is about portraying a set of circumstances or situation such as a play, novel, or musical performance that will evoke that emotion in others. Proper expression to Collingwood is the lucid and intelligible conveyance of the emotion the artist feels so that the audience can experience it in a similar way.

The act of creating art is more than this. It is a form of self-discovery. The expression of the emotion allows the artist to better understand his own emotional states. By making the emotions clear to his audience, he is also making them clear to himself. Collingwood also states that artistic creation is not a means-end process. The artist cannot at the outset know what he wants and only discovers this by engaging in the act of creation. Collingwood believes the artistic product is both a physical and an imaginary thing. A painting exists as a set of pigments on a canvas. A symphony exists as set of waves travelling through the air. These can be considered as the artwork. But it is also the imagination of the painting or the song inside the artist's head that counts just as much.

An audience according to Collingwood must reconstruct in their own minds the artist's imaginary experience. The artist should always take this reconstructive process into consideration. If he fails to make the listeners see or hear what was in his creative imagination, then the artwork has to some extent failed. If a work is too complex and the artist anticipates this by simplifying it so that it is understood, then he is more of a success in his profession. In this sense, there is collaboration between the artist and his audience. In modern day terms, one might say there is a feedback loop or synergy between the two, so that they mutually influence one another.

There is another audience that influences artists and that is the audience that comes before their work rather than after it. This "audience" may be considered the culture of art, art instructors and fellow artists. No artist according to Collingwood exists in a vacuum. They are influenced by the styles and genres of their time and they learn their craft from teachers and colleagues. These individuals provide the artist with the necessary skills and also serve as a source of feedback, telling them what works and what doesn't. The creation of art thus involves collaboration on the "supply" and "demand" sides of the equation, to borrow terms from economics.

The strength of Collingwood's theory is that it is both emotional and social. It explicates the ways in which emotion is used in the artistic process. It also explicates the types of social relationships that determine art production. However, it does not say much about the role of cognition in creativity. Thinking is a large part of art. Take for instance a playwright. She may wish to convey a theme like jealousy and must do this by creating actors with different motivations and a plot in which these motivations conflict with one another. There is an enormous amount of thinking necessary to realize this. Collingwood neglects this information-processing account of creativity.

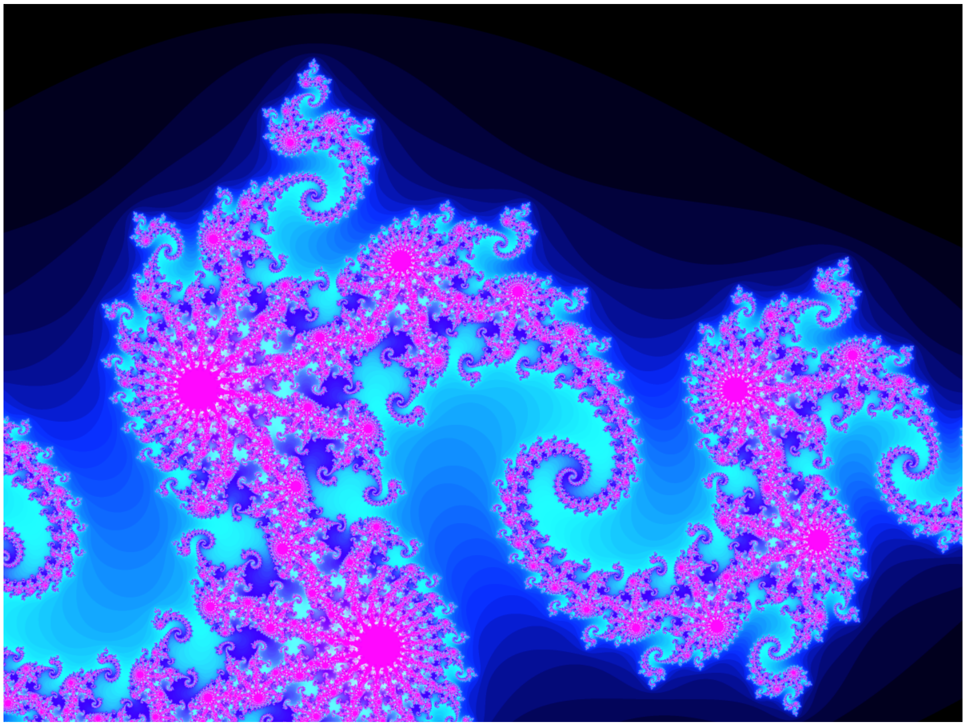
He additionally implies that the creative process happens as one goes along, "on the fly" so to speak, as part of an emotional self-discovery process. This is probably the case in most artists. But he says little about the role of planning and foresight in creative action. Our playwright, if she is to succeed will need to work out character sketches, a plot sequence and stage layout, not to mention the ways in which actions in the play will express the various themes. This and a large amount of other preparatory work would need to occur before she begins to even write the dialogue. Much of this is cognitive in nature, or an interaction between cognition and emotion. Collingwood, by focusing on emotional discovery, fails to explain how these processes might work.

John Dewey. Art in the Machine Age

The American philosopher John Dewey (1859-1952) discusses artistic expression in the modern age in his essay *Art as Experience*. As everything in the modern world is mass manufactured, he says artists try to make themselves unique so that they stand out. They exaggerate their separateness to the point of eccentricity, producing items that are independent and esoteric. This is an attempt to express their individuality in opposition to the culture of mass production. This point may take on even greater importance in the future. Software programs and robotic innovation in the next few decades may be able to create art that equals or exceeds human level achievements. This can be seen as an opportunity to collaborate with machines to create new types of art. Some artists are doing this now, working in a field called algorithmic art.

Algorithmic art involves the design of art using computer programs or algorithms. It is a subcategory of the larger field of generative art, which is art created by autonomous systems. An example involves the generation of fractal patterns, those that are self-similar at different scales (Figure 2). Algorithmic art actually has a longer history than one might think. Artists like Michael Noll began creating such works in the 1960s, printing their works using computer plotters. Given increases in computational power the possibilities have only grown since then. Scott Draves started the Electric Sheep project that generates abstract moving visual artwork on a computer screen. It is run by thousands of computers that communicate with one another across the Internet to generate morphing abstract animations (electricsheep.org).

Figure 2. A Julia set fractal pattern generated by a computer. Will computers replace artists in the future?



Dewey also makes the interesting observation that variance in styles among artists is not so much because of differences in technical skill but because of different ways in which artists see the world. One artist might see the world in terms of color relations and explore color differences. Another might be focused on capturing textural qualities. The thought required to explore these different visions Dewey writes, is more demanding than the thought required by so-called "intellectuals". A machine, because it can specify things in detail, can probably in Dewey's estimation execute standard artistic techniques better than people. He points out that there are artists like Cezanne who are not ranked great in technique just as there are great piano performers who are prized for their technique but lack aesthetic or creative skill.

To create good art, Dewey states, requires an act of love or passion. However if we are overwhelmed with passion art will suffer. If we are in the throes of extreme rage, fear, or jealousy, the art will not be aesthetic. Aesthetic works need to be the result of a controlled process. Emotion ought to contribute to this process, but not overwhelm it. The creative act according to Dewey is the result of creating, perceiving what we have created and then using the resulting aesthetic judgment to further modify the result. Creation consists of multiple cycles of these perception-action loops that iterate until the product is deemed good enough to stop. Taken together we can conclude that the creative act involves perception, emotion, cognition and action all working together as a cohesive whole. Dewey acknowledges that one must have a plan or vision before starting out but that this plan can be subject to revision during the process. He notes that some architectural projects like medieval cathedrals may have started with a plan that was then altered as time went on. The plans grew as the buildings themselves grew.

Theodor Adorno. Art and Psychodynamic Psychology

Theodor Adorno (1903-1969) is a German social theorist. In his essay *Aesthetic Theory* he spends a considerable amount of time critiquing Freud's psychodynamic theory of art. Freud saw works of art as projections of the unconscious mind. This part of our mind is filled with animalistic desires and wishes, a sort of seething cauldron that always seeks to express itself. Art in this perspective may be seen as a defense mechanism or outlet for these desires. In Freudian theory a defense mechanism is a mental process that performs some act designed to reduce tension caused by conflicts between the unconscious and other parts of our psyche that are more rational or ethical.

Adorno writes that art is more than just a defense mechanism and should not be reduced only to the desire to express impulses. Unconscious drives are one impulse among many. Artists may seek to express themselves for all sorts of reasons like social or political commentary and the desire to produce something of beauty. Imagination in Freudian theory may be seen as a type of escape from reality, playing out of dream content while awake. But imagination according to Adorno is much more than escape. It can be seen for example as part of the way in which we solve problems. The projection of unconscious content into art is not what is most important about it. Adorno says that music as a defense mechanism against impending paranoia may be correct as a clinical diagnosis but it does not inform us about the quality and substance of a musical composition. Music, like other types of art can be submitted to an objective analysis of its structure.

Bringing it All Together – Philosophy Chapter Summary

As we have seen thus far in this chapter it is impossible to succinctly summarize ideas like beauty, art, or creativity. These are complex concepts and different authors have different opinions about them in addition to addressing different aspects of each subject. One theme we have seen is the relation between parts and wholes. Beauty has been considered a way of bringing parts like colors in a painting or tones in music together in such a way that the whole is pleasurable. Beauty also seems to satisfy our desire for unity, the union of a person with nature, with another person, or with God. We also see in studies of beauty a debate about whether art is practical or not.

Early thinkers like Plato and Plotinus had a very general notion of beauty, equating it with "the good" or with perfection. Later thinkers like Hutcheson emphasized beauty as being a balance between the simple and the complex. One very important notion is that beauty can engage different aspects of the mind. It can be perceptual (seeing, hearing), conceptual (involving thought), emotional (happy, sad), and even spiritual (religious feelings like transcendence). Beauty can also have a motoric component (movement of the body), as beautiful music may make us want to dance or beautiful architecture may compel us to walk through a created space.

Kant and Burke introduced us to the notion of the sublime, which is either a specific type of beauty or a separate state of being that is inspired by nature. The sublime makes us feel small and instills us with awe. If art is imitative of nature and can portray natural scenes realistically then it can certainly has the capacity to induce such a state.

Moving forward to the modern era we find a debate over whether beauty can be studied scientifically. If beauty is completely subjective it cannot be understood because everyone will experience it differently. If it is objective it can be understood because there will be commonality of experience. Mothersill believes this isn't possible but modern researchers in empirical aesthetics have shown that one can study art scientifically and have addressed both universal aspects of art and individual differences.

According to the tension-resolution model, beauty is the result of building up a tension that is then resolved. Beauty in this view creates an ambiguous or mysterious state that invites exploration. Gardner gets at this idea when he says that art is interesting, memorable, and inviting. Beauty in this view can't come too easily; it requires work on the part of the observer to generate a resolution.

Philosophers like Scruton have thought about the relation between truth, beauty and the good. Some thinkers have equated these three ideas believing that a beautiful object is not only pleasurable but shows us what is right and true. However there are cases that demonstrate beauty can mislead us and instead bring about falsehoods and negative moral ends.

Next we turn our attention to art. Plato saw art as imitation. It could imitate nature, which in his view has imperfections. Alternatively, it could imitate the ideal, which is perfect. He also saw art as capable of arousing passions. The Russian novelist Tolstoy saw the purpose of art as transmitting universal religious sentiments that would prevent the division of humanity. Note the similarity here to our earlier discussion of beauty as that which unifies parts into harmonious wholes.

Croce saw art as a communication between artist and observer, in which case it can arouse passions but also ideas. Again, we see a relation here to our earlier discussion of beauty as activating emotions, cognitions and other aspects of the psyche. Croce also brings back the debate of whether art is practical in the form of crafts, or without a purpose. Rand saw art as a purpose unto itself, worthy of contemplation and appreciation. In her view art makes values concrete and should inspire us to be great.

In the modern period we see the introduction of abstract art that is nonrepresentational. This brings up the issue of whether form alone in the absence of meaning is enough to convey aesthetic qualities. It certainly seems to as there are many forms of art like dance and music that are non-symbolic.

Contemporary philosophers have argued at length over whether art can be defined. There are various views on this topic. Some believe art is what any individual or institution takes it to be. Others argue that it must have a relation to existing art and a historical narrative. Still others like Weitz and the antiessentialists believe that art cannot be defined based on a list of features and that it should be an open-ended concept to accommodate new forms as they are created.

Contemporary thinkers see art as fulfilling many purposes. For example, it can make a political statement or serve as social commentary. It can express the emotions of the artist, or it can make us think, as concept art does. Dutton is an essentialist and provides a list of features, some subset of which may always apply to an artwork.

Philosophers have also analyzed the individual arts. In painting the issue of resemblance or imitation comes to the fore, especially with realist art. But what degree of abstraction is optimal? Artists can deviate visually from the real in many ways. Music brings up many questions among them how exactly it elicits emotions in listeners. Researchers are currently examining the relation between certain properties of music like tempo and elicited emotions like sadness. Dance seems to express emotion through action alone.

Philosophers of literature have argued that poetry is a form of learning and of realization. Novels get us to think about important ideas. Literature can be imitative, in which case it reflects real world scenarios much like realist painting does. Alternatively it can be expressive in which case it stimulates feelings. Architectural objects are difficult to define but the Roman Vitruvius saw structure, function, and beauty as the three criteria or goals of the field. In film as in poetry, literature and theater, there is the question of how it is we relate to fictional characters and why we seem to enjoy negative emotional experiences such as horror movies.

The third major topic of this chapter is creativity. Now rather than focusing on the receptive side, we look at the artist who produces creative works. Kant speculated on the nature and nurture of creative genius and came down on the side of innate genius or giftedness. Modern research however shows that artistic talent is both the consequence of genetics and training. Kant further saw that originality and novelty was what separated the ordinary artist from the extraordinary.

Schopenhauer believed that artists needed to be lost in the act of creation. A similar concept known as "flow" has been proposed and studied in a modern context by the psychologist Csikszentmihalyi. The modern concept of flow is a state of complete absorption in an activity accompanied by a sense of satisfaction and happiness. There is a correlation between creativity and mental disorders but one does not need to be "mad" in order to create successfully.

Collingwood and others have stated that an audience deconstructs an artist's intent. In this perspective art can be seen as a message. An artist creates a work, imbuing it with their feelings, ideas, and values. The observer must then interpret the work and extract these things from it. When this happens art serves a communicative function. Both Dewey and Collingwood mention that the act of creation must be a balance between emotions and more cognitive, controlled processes. Freud saw art as a projection of the subconscious mind, with expression and emotion as the driving motivational forces. Adorno disagrees and mentions other motivations for creating art.

Philosophers have made significant contributions to our understanding of aesthetics, art, and creativity. Many of the more exciting contributions of this field are contemporary, as is demonstrated by our division of theories into classic and modern periods. One of the strengths of philosophy is in its capacity to help define important terms and to formulate theoretical frameworks that can then be tested empirically. Philosophers are good at seeing the “bigger picture” while the nature of science is that it must sometimes have a more narrow focus.

Chapter 3 - Mathematics and Physics

Mathematics and Physics – We're Counting on it

In this chapter we get down to basics, looking at how the world of numbers is related to beauty, art and creativity. We begin with ratios, the relative amount of one thing to another. There are pleasing musical ratios, notes that when played together sound harmonious. The golden ratio and other ratios are then examined in applications to geometry, art, architecture and the human body. The line and the curve are a basic visual element and have been put to complex and imaginative use in Maori tribal tattoos, textile patterns, decorative ironwork and arabesque designs. Polygons aren't something we just learn in math class. Squares, rectangles, other regular polygons, the cross, circle, and the ellipse are the basis for artistic design, especially in in architecture. We next look at other more complex mathematical patterns such as fractals, as well as solid, three-dimensional figures that can be described mathematically.

Symmetry is a prominent feature in natural and constructed figures and has been put to extensive use in Japanese kamon and Chinese iconography. Linear symmetries result in the seven friezes and seventeen wallpaper groups that can be found in the decorative ornament of all world cultures. Symmetries can also help us to understand tilings and tessellations, patterns that occur when a polygon is used to fill up the two-dimensional picture plane. The most prominent and beguilingly beautiful use of tiling patterns was by the Islamic cultures that used them to decorate courtyards, temples, and palaces. We next in this chapter examine some more abstract concepts, which are the notions of order and complexity. Contemporary research suggests that people prefer patterns of moderate complexity. Physics uses math to describe the natural world and to be sure the natural world is full of beauty. We will look at unfamiliar examples however, including Chladni patterns, Lissaious figures, harmonographs, and Rayleigh-Benard cells, as well as more familiar ones, like astrophysical phenomena. This chapter ends with a surprise: the history of art told from a physics perspective.

Ratios

Musical Ratios

Play a note by plucking a string on a guitar and listen. Now place your finger half way down the length of the string and pluck it again. How has the sound changed? You will hear that it is higher in pitch, in fact twice as high in pitch. This new frequency is the same note, but one octave higher, an octave being a doubling in frequency. If you examine a piano keyboard you will see that the musical scale spans an octave with seven whole tones (doh, ray, me, fah, so, lah, tee, and then doh again) in black and twelve semitones in white. This the Western musical scale. Non-western musical scales can be based on a different number of notes and frequencies.

The ancient Greek philosopher Pythagoras was the first to discover that certain ratios of frequencies sound good. The octave is a ratio of 2:1 and any two notes in this relationship sound consonant or pleasant when played either in sequence or together. The same is true for certain other frequency ratios like the fifth, which is in a ratio of 2:3. Table 3.1 shows other scale intervals with their names and note designations. Looking at these ratios you will see that they are all of whole numbers. Frequency ratios not made up of whole numbers, i.e., those with decimal points following them, sound dissonant, or unpleasant. This led Pythagoras to conclude that there was something special about whole numbers, that they were actually sacred in some way.

Table 3.1. Musical Scale Ratios Table. After Skinner (2006).

Name	**Ratio**	**Note**	**Comment**
Tonic (first or root note)	1:1	C	Unison – the same note
Second	8:9	D	
Minor Third	5:6	E flat	
Major Third	4:5	E	
Fourth	3:4	F	
Fifth	2:3	G	
Minor Sixth	5:8	A flat	
Major Sixth	3:5	A	
Minor Seventh	9:16	B flat	Called the dominant seventh
Major Seventh	8:15	B	
Octave (8 notes above)	1:2	C	The note one octave higher, double the frequency
Twelfth	1:3	G	A fifth over the octave

The Golden Ratio, Phi

The Greek letter Φ (phi) has the value 1.6180339887… It has been used in various ways in geometry to achieve what are considered pleasing dimensions. Phi has been referred to in many ways throughout the years, including the golden mean, the golden number and the golden section. This value can be used to divide a line or rectangle into two unequal parts, such that the proportion of the two is the same as the proportion of the larger part to the original line. So if we start with a line AB and place Y at the golden ratio we can express the ratios as follows:

A____________________________Y__________________B

AY/AB = YB/AY

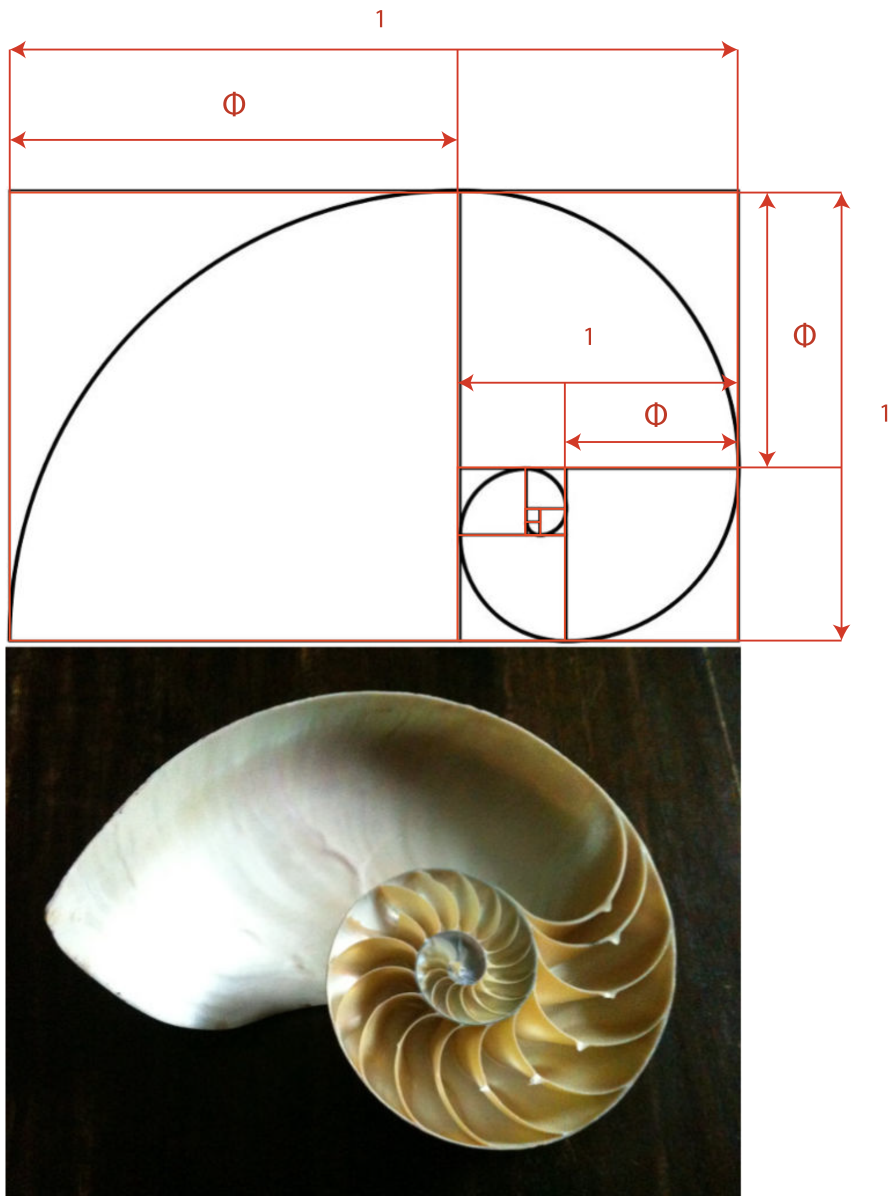
In words, the length of line AY divided by the length of line AB is equal to the length of line YB divided by the length of AY.

The decimal portion of phi recurs forever, so it can never be stated with exact precision in decimal form. As such, it is called an 'irrational number'. Irrational numbers cannot be expressed with either a set ending or a repeating pattern in the decimal portion of the number. Another well known example of an irrational number is π (pi), which is 3.1415926…

Phi has been applied in many of the arts. The dimensions of the Parthenon in Athens were constructed using it. One example is that the structural beam on top of the columns is in a golden ratio proportion with the height of the columns. Michelangelo appears to have made use of phi in his painting *The Creation of Adam*, in the Sistine Chapel. The Renaissance artist Raphael used it in his wall painting *The School of Athens*. Leonard Da Vinci created the illustrations for a book called *The Divine Proportion*, written by Luca Pacioli and first published in 1509. This book refers to the use of the golden ratio in art and architecture with drawings of it in geometric solids, and even typefaces. The architect Le Corbusier used the golden ratio when constructing his 1916 *A Villa* and is an advocate of applying it in architectural design. Phi can be found also in posters, furniture and even appliances like coffee machines (Elam, 2001).

Research has shown that beautiful faces often conform to a mask of phi ratios (Pallett, Link, & Lee, 2010). Golden ratio proportions are purportedly found in the human body, the human hand and foot, and the DNA spiral (Meisner, 2014). Phi appears in nature as well as in the body proportions of various animals. A spiral fit to golden ratio rectangles conforms to that of the Nautilus shell spiral, which is considered beautiful (Figure 3.1). However, the Nautilus shell's spiral fits the golden ratio spiral better when it is based on 180° turns, not 90° turns as is more commonly depicted.

Figure 3.1. The Nautilus shell spiral is based on the golden ratio.

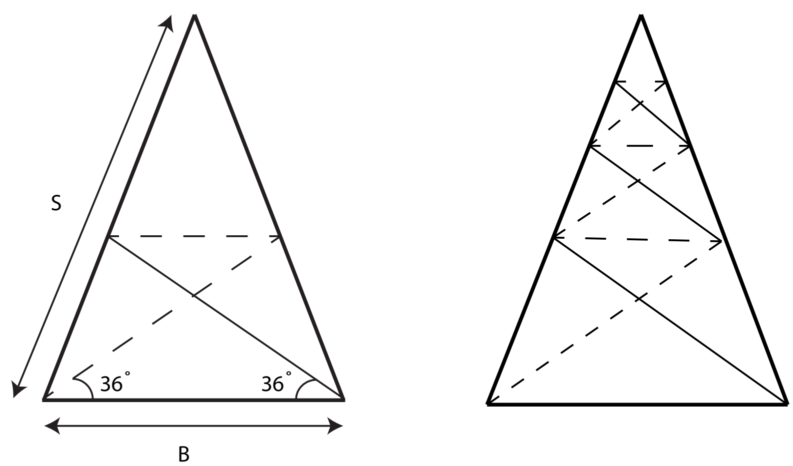


Phi was investigated in one of the earliest studies in experimental psychology. The German scientist Gustav Fechner in 1876 measured the dimensions of many common objects like books, boxes, newspapers, buildings, etc. He found their average rectangle ratio came close to phi. He also found that people preferred rectangular ratios near this value. Many other researchers have studied preference for this ratio, including Lalo (1908). However, contemporary research on this subject shows that the effect is variable and that sometimes ratios other than phi are preferred. Friedenberg (2012) in two experiments using right and isosceles triangles found participants prefer more compact triangles and not those with golden ratio values. For an overview of much of the psychological research on the golden ratio see Green (1995).

Golden Triangles

Phi can be used to construct more complex geometric shapes like triangles, rectangles, pentagons and pentagrams (a five-sided star). Here, we describe how it can be used to create a triangle. If we start with an isosceles triangle with two base angles equal to 72°, then the value of the apex angle will be 180 – (2 x 72) = 36° (see Figure 3.2). This can be called a “special triangle”. Two new special triangles can be created if we bisect (divide in half) the base angles using a solid and dashed line as shown. These two new triangles have their apexes in the base corners of the original larger triangle. Because they bisected these original base angles that were 72° they are 36°. This is what makes them new small special triangles. This process can be continued as many times as desired, moving up the triangle and making smaller and smaller special triangles each time, shown in Figure 3.2. The special triangle is also called the “Golden” or “Sublime” triangle. This is because the ratio of the long side of the triangle S, to the length of the base B, is equal to the golden ratio: $S/B = 0.5(1 + \sqrt{5})$.

Figure 3.2. A golden ratio isosceles triangle. After Barrow (2014).



The Fibonacci Series

Another less famous Leonardo is Leonardo of Pisa who in 1202 published his "*Book of Calculations*". It is here that he introduces what has since been called the Fibonacci series (he was known as Fibonacci). Each term in this series is the sum of the previous two terms. The series effectively "grows" by reference back to its "parent" numbers. This progression is shown below:

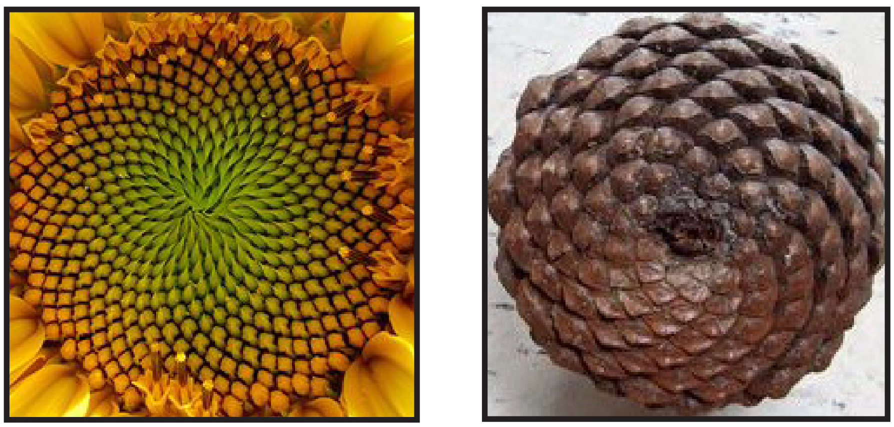
0 + 1 = 1
1 + 1 = 2
1 + 2 = 3
2 + 3 = 5
3 + 5 = 8
5 + 8 = 13
8 + 13 =21
13 + 21 = 34
21 + 34 = 55
34 + 55 = 89

The series and the golden ratio are related as can be seen if we divide each number by its immediate predecessor:

3 / 2 = 1.5000
5 / 3 = 1.666
8 / 5 = 1.6000
13 / 8 = 1.625
21 / 13 = 1.615
34 / 21 = 1.619
55 / 34 = 1.617
89/55 = 1.618 (phi)

Notice that these fractional values fluctuate somewhat before they stabilize and become phi. Perhaps the reason we find phi so beautiful is that it governs natural growth processes. This is shown in the growth of seashells like the nautilus, but we also see it in the growth of plants. The Scottish botanist Robert Simson realized this first in 1753. We now know that that phi is found in the spacing of leaves on a stem, in petal numbers and in the arrangement of seed heads. Figure 3.3 shows phi in the arrangement of seed heads on a sunflower and the growth pattern of a pinecone.

Figure 3.3 . The spiral patterns of a sunflower seed head and pinecone both conform to phi.



Ratios in Architecture

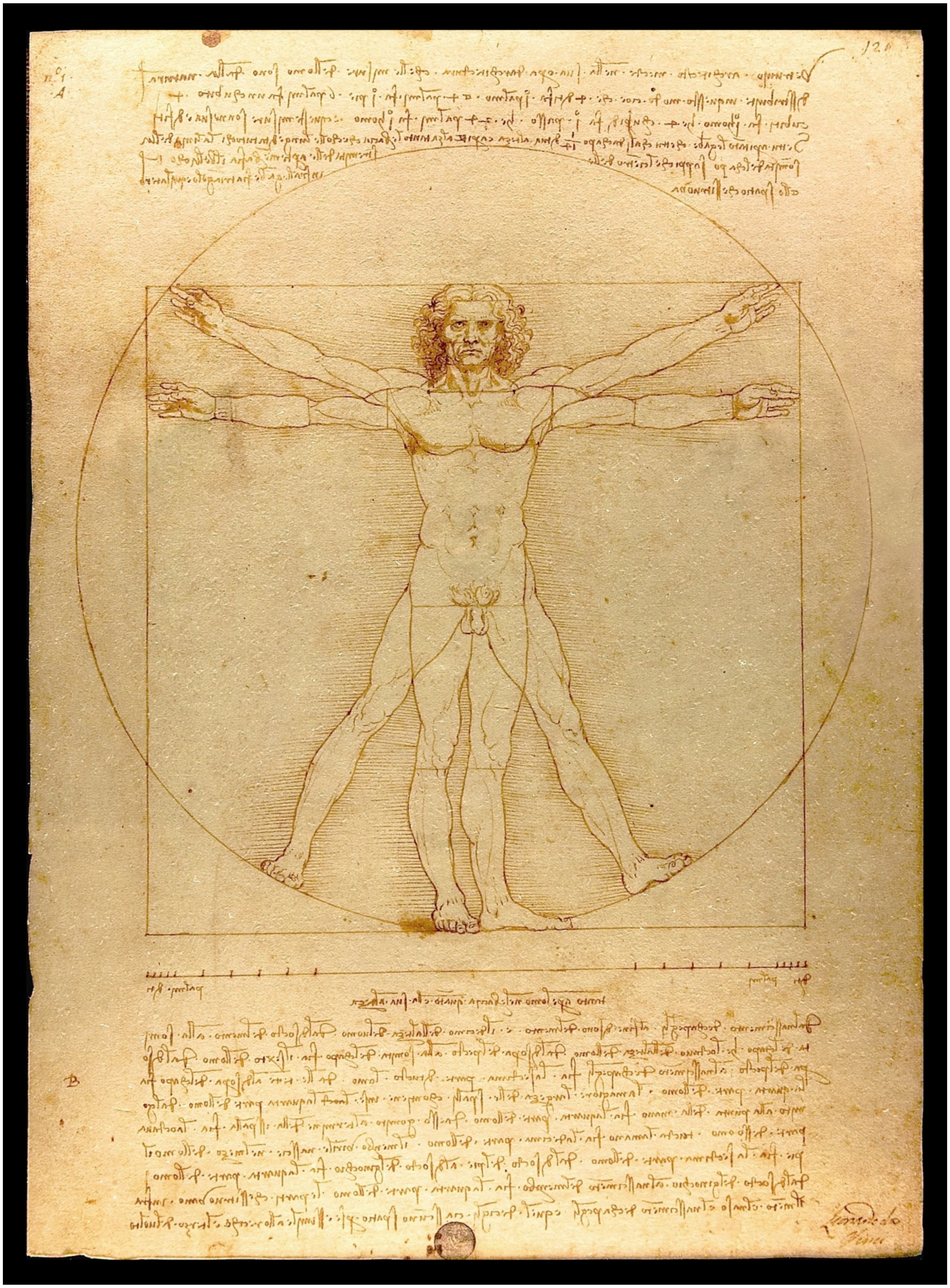
Leon Battista Alberti (1404-1474) was a Renaissance architect. He applied the Pythagorean musical ratios to buildings. There was a belief at that time later expressed by the German poet Goethe that architecture is “frozen music”. Alberti even went so far as to recommend different ratios for different sized floor plans. For small floors he recommended the square (1:1), the sesquitertia (6:8), and the sesquialtera (6:9). For a medium-sized floor the double square (1:2) and the sesquialtera are applied twice (6:9). For large floors it was a triple proportion, a quadruple proportion or a ratio of 3:8. Andrea Palladio (1508-1580) considered one of the greatest Italian architects of the sixteenth century also published a classical work in the field, his *Four Books of Architecture*, in 1570. He was another advocate of applying ratios. Among the dimensions he writes about are the square and a third (3:4), the square and a half (2:3), the square and two-thirds (3:5) and two squares (1:2).

Following this usage there was a decline in the popularity of musical ratios in architecture. The French architect and physician Claude Perrault thought people liked musical ratios simply because they were used to them. Similarly the Italian architect Tomasso Temanza thought that that people were not capable of accurately judging ratios, for instance when judging length to width, length to height, and width to height. He writes that the ratios will change depending upon the visual angle with which they are viewed. The English painter William Hogarth went so far as to reject any connection between ratios in music and architecture. He stated it would be strange that the strings that produce harmony to the ear should produce beauty to the eye.

Body Ratios

The Roman architect Vitruvius devised a framework for the idealized man. He said that a well-proportioned man should have a height equal to the length of his outstretched arms. In this scheme the ideal man could be placed inside a square in which the vertical sides would be equal to his height and the horizontal sides would equal his arm span. He also stated that an idealized male body could be inscribed inside a circle centered on the navel when the legs are extended and the arms are lifted slightly. Leonardo Da Vinci later immortalized this image of “Vitruvian Man” in his drawing of this figure (Figure 3.4). Leonardo also dissected cadavers and analyzed the lengths of different body parts in relation to one another. He came up with a unit of measure called the cubit. In this scheme a man’s height at six feet equaled four cubits, a single cubit was equal to eight palms and one palm was equal to four fingers.

Figure 3.4. Leonardo da Vinci's drawing of male dimensions later became known as the "Vitruvian Man". Image from PublicDomainPictures.net



The German painter Albrecht Durer had his own notions about human body proportions and beauty. He used his middle finger as a basic unit of measure and thought that this should equal the width of the hand and that this should in turn be proportional to the length of the forearm. Renaissance and neoclassical era prescriptions stated that the height of the ear and nose should be the same, that the width of the nose be equal to the distance between the eyes and that the mouth should be one and a half times greater than the nose. How well have these measurements fared? Not so well, it turns out. Farkas, Hreczko, Kolar, and Munro, (1985) measured facial proportions in 200 women, including models, as well as younger men and children. These faces were then rated in terms of their beauty. Many of the neoclassical dimensions did not predict beauty ratings. For instance, attractive models had eyes that were spaced farther apart than those of the neoclassical norms. We talk more about facial features in the psychology chapter.

The Line as a Basic Feature in Art

Research shows that the line is the most influential feature affecting aesthetic judgment. Two aspects of a line that have been studied extensively are angularity, whether it is angled or curved, and orientation, whether it is vertical vs. horizontal vs. oblique (diagonal). In one study by Silvia and Barona (2009) they presented black on white displays of circles and hexagons that varied in their size and location. University students saw these patterns for two seconds each and rated how pleasing they were. The participants liked the displays with the circles more than the angular hexagons. In a second study they used more complex polygons with straight and therefore angular lines, or curved versions. Participants were given unlimited viewing time and again asked to perform a rating. Those with low levels of art expertise preferred the rounded and angular versions equally. Those with higher levels of expertise preferred the curved over the angular versions.

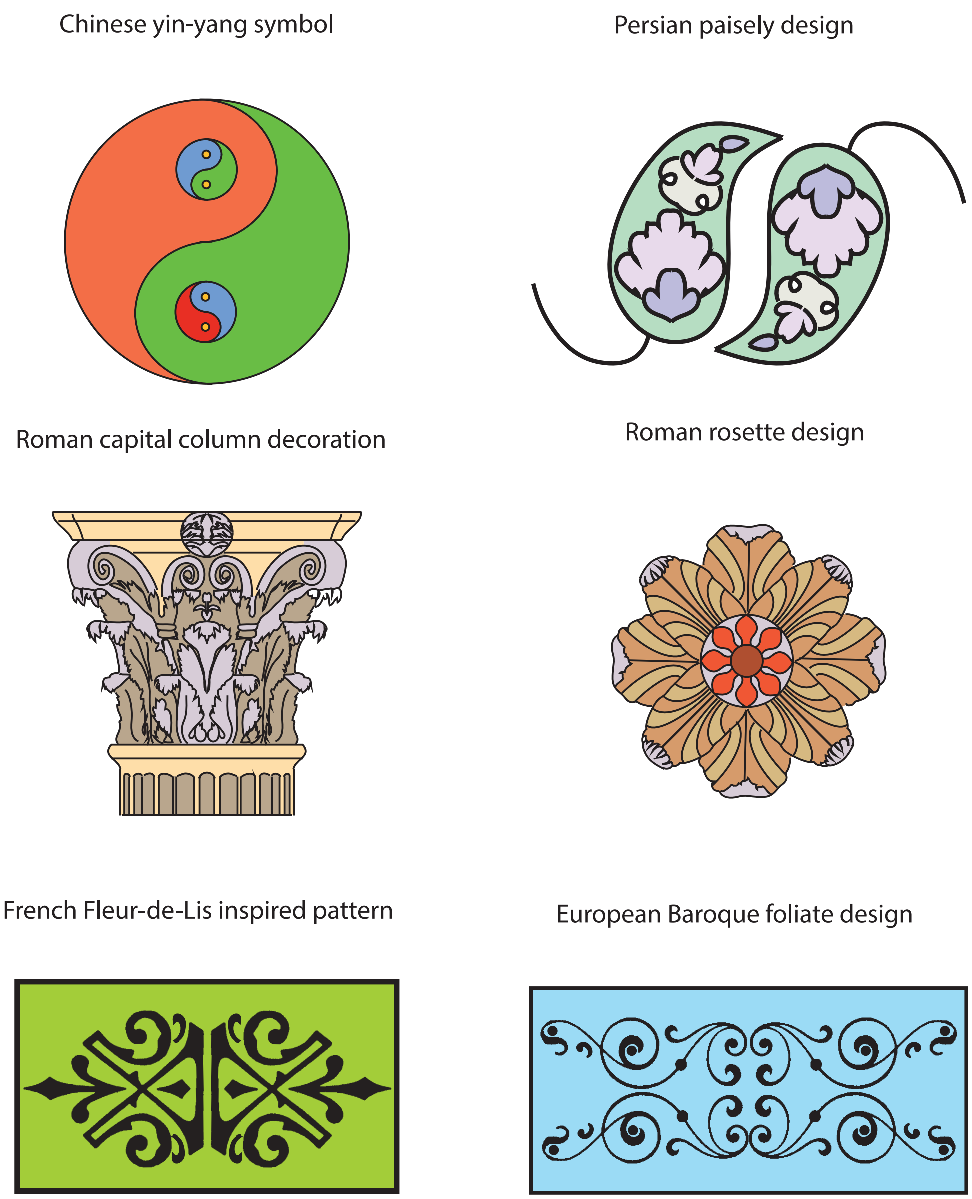
The oblique effect is that perception of oblique lines is poor compared to vertical and horizontal lines. Vertical and horizontal line orientations are believed to have privileged access to the visual system (Latto, 1995). This may be due to the prominence of these lines in constructed environments or to the prominence of the horizon line. This translates into a preference for vertical and horizontal lines over oblique lines in art (Latto, Brian, & Kelly, 2000). Several studies have shown that participants prefer Mondrian paintings at orientations where the lines are vertical and horizontal compared to when they are rotated into oblique orientations (Plumhoff & Schirillo, 2009). Artists seem to be intuitively aware of this effect. In one survey 88 representative 20th century paintings of all types in the Israel Museum contained a prevalence of vertical and horizontal lines compared to obliques. The breakdown for each of these was 45% for vertical, 31% for horizontal, and 24% for obliques (Latto and Russell-Duff, (2002). Vertical lines were used more in portraits and horizontal lines were used more in landscapes.

The Use of the Curve in the Decorative Arts

Many cultures have utilized curved forms in their artwork. Arcs, spirals, circles and flourishes make their way into the decorative arts of all cultures. The design of these works often depends on the use of an underlying grid. In some cases these grids are curvilinear rather than rectangular so that C- and S-shapes can be traced out. Once a grid is established elements can then be added or shaped from it. These elements are recognizable as leaves, flowers, vines and fruit that are then repeated using the principles of symmetry; being translated, reflected and rotated to fill linear, arched or rectangular spaces. The creation of these items reflects their growth in nature and the power of life.

Some of the earliest examples of the use of elaborate curvature in artwork are decoration on pottery from China, the oldest dating to 8,000 B.C. The Maori culture of New Zealand used curved designs to decorate their paddles, canoes, and weapons. They also used curvature, especially the spiral, to decorate themselves in the form of tribal tattoos. Some additional examples of curved motifs in art are the yin-yang symbol from China, the Roman decorated column and rosette and the teardrop-shaped paisley pattern (Figure 3.5). The paisley pattern is an English term for a vegetable motif shaped like a droplet. The design has Persian origins and has been called the "Persian pickle". These were popular in the West in the 18th and 19th century following their import from Mughal influences in India. The paisley is named after the town of Paisley in Scotland, a textile center where the design was manufactured. Also shown are French fleur-de-lis and Baroque style flourishes.

Figure 3.5. Examples of design using curves from art history.



Decorative ironwork was brought to a fine art in 17th century France and Spain. Elaborative patterns were made in the form of gates, grills, and hinges. Care was taken in these constructions to not make them so delicate that they could be broken, as in most cases they were covering windows or entranceways. The openings and spaces between the tracery needed to be large enough to allow light through but small enough to provide security (DeLong, 2013).

The term arabesque refers to patterns of scrolling and interlacing foliage patterns that were used in Islamic art but then also became popular during the European Renaissance. Arabesques with leaves and spiraling stems served as architectural friezes and as patterning on textiles. The Baroque period is known for grandiose opulence and this style was expressed with even greater flourish during the 18th-century French rococo style. Ornament during this period became larger, more curvaceous and exaggerated with shells, nymphs and cornucopias emerging as prominent motifs. These were used to decorate everything from gardens, to furniture, to fountains and even shoes.

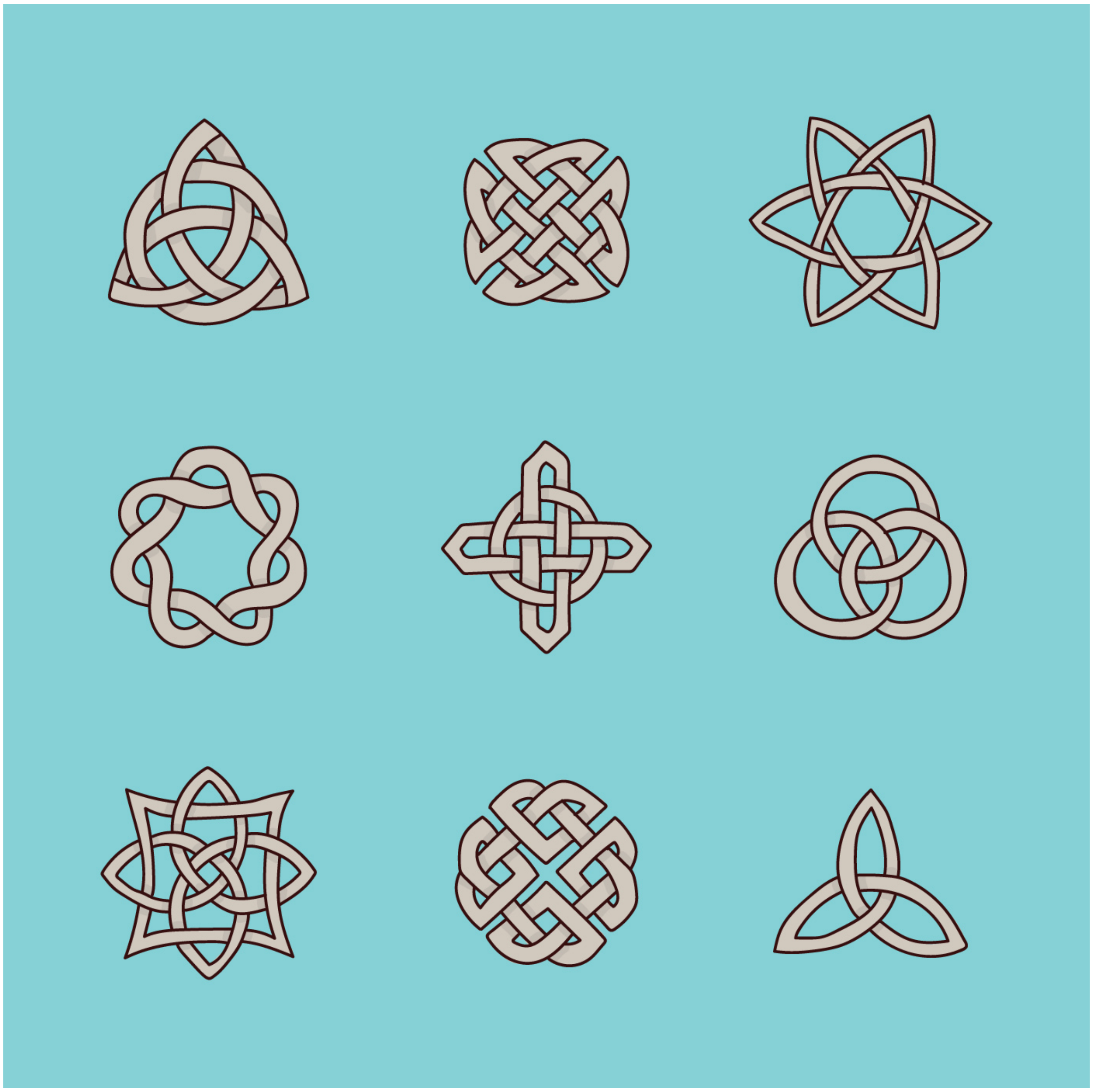
We would be remiss without mentioning the art of calligraphy, which is the artistic application of curvature to writing. Calligraphic styles were developed in Europe, Asia and the Middle East. The typical tools used are the pen and brush with nibs that can be flat, round, or pointed. In Asia the brush with ink is the primary instrument. Calligraphic inks are usually water-based, enabling faster and more expressive work than thicker printing inks. Writing is made on parchment or vellum and various types of papers. Georgian calligraphy has a tradition of many hundreds of years, with three types of script. Chinese and Japanese calligraphy evolved over the centuries into several distinct styles during different historical periods.

Celtic Art, Knots and Spirals

Celtic art is most closely associated with art of the European people from about 1,000 B.C. until the conquest of the Roman Empire. It is characterized by the use of intricate ornament. These were used to adorn a wide variety of objects including stonework, Bronze mirrors, and jewelry. The Celts made good use of geometry with grids, arcs, and circles laid down as the basis for more elaborate workings. They used geometry for page layout and as part of lettering, or what we would now call font design. These can be seen in the awe-inspiring illuminated manuscripts such as the *Book of Kells*. They were also inspired by nature and used many vegetal and flora elements. The Celts even weaved animals like deer, boar, and dogs into more abstract patterning. Our focus here will be on how the Christian Celts used geometry to create spirals, keys, and knots. Bain (1973) provides elaborate details on how to construct Celtic pattern.

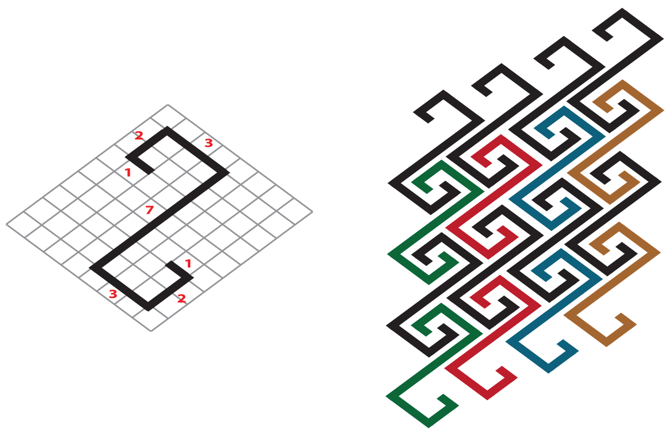
The Celts incorporated knots into their designs. Knots are among the oldest of human creations and have been used as tools and as art stretching back into our early hominid past. They can be used functionally to create things like fishing nets, and as objects that serve both function and form, like baskets and carpets. Tools that require knots have been dated to 300,000 B.C. Knots are also found in nature in the form of DNA's double helix, muscles that connect tendon and bone, and in cables of plasma around astronomical objects like planets, stars, and galaxies in the infrared spectrum (Tetlow, 2013). There is even a distinct subset of topology theory in mathematics devoted to the study of knots.

Figure 3.6. Celtic knot patterns. Free license usage from Vecteezy.com



Spirals are captivating forms that seem to show energy in action. They are found in nature in the form of galaxies and flow patterns in waves, ripples, whirlpools and waterspouts. Some plants like ferns grow in spiral patterns. They are found also in molecular bonds. The Celts often nested spirals within spirals, echoing the fractal organization of nature as is shown in the pattern in Figure 3.6. Celtic key patterns may have been inspired from earlier Coptic designs, although they introduced one key change, by turning those spiral design elements 45°. This now created a series of triangular spaces that could be filled in interesting ways. The method to drawing keys begins with a diagonal grid. These are used as a guide for drawing square spirals made of ‘S’- and ‘C’-shapes. The type of shape is determined by a counting system. The ‘S’ shapes in Figure 3.7 are counted by the number of grid units the line traverses prior to making a 90° turn. These are of type 1-2-3-7-3-2-1. Key patterns were used to completely fill in rectangular spaces but were also applied in bands to form decorative frames. Key type patterns are also found in nature in the way forms double back on themselves. They can be seen in the gyri of the cortex of the brain, in coral and in leaf patterns. Folding is nature's way of packing the most amount of material into the smallest amount of space. They are thus an example of efficiency.

Figure 3.7. Celtic key panels.



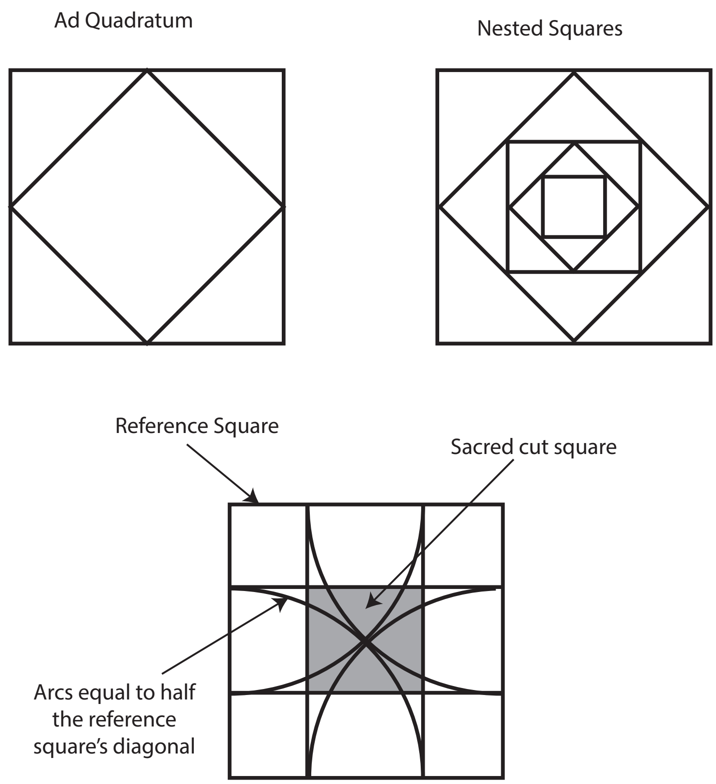
Polygons in Art and Architecture

Regularity in geometry refers to equality. When things are equal they are simpler and simplicity has often been proposed as a principle of beauty (Wilczek, 2015). For two-dimensional figures this means equality of sides and angles. A regular polygon is a planar figure with all equal sides that meet at all equal angles. The simplest regular polygon is the equilateral triangle, with three equal sides and three equal angles that are 120°. Next we have the square with four sides and four 90° angles, the pentagon with five equal sides and angles, followed by the hexagon, heptagon and octagon. For each whole number starting with three, there is a unique regular polygon. In every case, the number of sides equals the number of vertices. We can also consider the circle as the limiting case of regular polygons where the number of sides is infinite. These shapes are in widespread use in graphic design, architecture and art. To name just a few, the pentagon is the chosen shape of the U.S. military headquarters, the hexagon is found as a tiling pattern and octagons are used as stop signs. We present more information on these two-dimensional regular polygons and other types of shape below.

The Square

A number of different square designs have been used in architecture. One is called the Ad Quadratum. This is formed when a smaller inner square is set diagonally inside another so that its corners bisect the larger outer square (Figure 3.8). The side of the larger square in this instance equals the diagonal of the smaller. Another design is the nested square. Here we continually place diagonally oriented squares one inside the other. This is also shown in Figure 3.8. A third example is called the sacred cut and was written about by the Italian Renaissance artist Sebastian Serlio (1475-1554) as a method for constructing an octagon. The sacred cut is made by swinging an arc from each corner with a radius equal to half the square's diagonal. From where each arc cuts the square, draw a line perpendicular to that side of the square. Those four lines then define the center square. The same construction method can be used to extend the squares inward and outward. Examples of these squares can be found in Roman buildings.

Figure 3.8. The Ad Quadratum, nested squares and sacred cut.



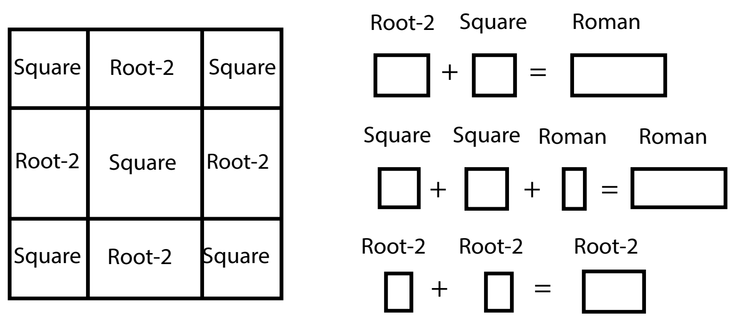
The Rectangle

The golden rectangle has been used for dimensions of artwork. The Birth of Venus has an approximate phi ratio in its dimensions and in the figure of Venus herself. Salvador Dali's *Last Supper* also has these dimensions. Many rectangular pictures in art are created with no particular dimensions in mind, but there are some that appear with regularity. The double-square format, where the rectangle has a width twice its height was used in *The Family of Darius before Alexander*, painted by Veronese in 1565-1570. Giotto's *Saint Francis Undergoing the Test by Fire Before the Sultan* by Giotto utilizes overlapping squares that define the boundaries of the central seated figure. A root rectangle is a rectangle with an irrational number as the ratio of the length to width. One could use √2, √3, or √5. *The Flagellation of Christ* by Piero uses a √2 rectangle. Its width is about √2 multiplied by its height.

The art theorist Jay Hambridge in the twentieth century advocated a type of art based on dynamic proportion. By this he meant based on root rectangles that he thought reflected the dynamism of growth and energy in the natural world. He contrasted this with the static proportion found in regular polygons like equilateral triangles, squares and pentagons. Hambridge favored irrational numbers to rational ones. The so-called dynamic symmetry movement saw some popularity in the early decades of the twentieth century and was applied to industrial design. A number of artists also took it up, including Robert Henri, George Bellows, Mark Rothko, and Maxfield Parish.

Kappraff (1996) describes the resulting shapes inside of a sacred cut square (Figure 3.9). There are five squares, the large central one and four smaller ones in each corner. There are also four √2 rectangles located at the center of each side. A various number of additive properties follow. If we combine a √2 rectangle with a square the result is a Roman rectangle. If we add two squares to a Roman rectangle it produces a larger Roman rectangle. If we add two √2 rectangles we get a larger √2 rectangle. Conversely, halving a √2 rectangle results in two smaller √2 rectangles. These operations produce shapes that can be combined in a variety of ways and that can be used for architectural layout.

Figure 9. Shapes derived from a sacred cut, after Kappraff (1996).



The Garden Houses of Ostia west of Rome date to the second century and were a planned community. Watts and Watts (1986/1992) analyzed these and found them to be full of geometric constructions. The ground floor plans conform to the sacred cut as do many of the other dimensions of the complex. The House of the Tuscan Colonnade in the ancient Roman city of Herculaneum adjacent to Pompeii, is based on the design of a square, as are many of the other houses. The placement of the atrium, peristyle, tablinum and other spaces are realized using a square, sacred cut and quadratum. A more detailed analysis of this is provided in Calter (2008). According to Williams (1997), the Pantheon in Rome has a ground plan based on a $\sqrt{2}$ rectangle.

The Pentagon and the Pentagram

Following Calter (2008), we will provide a brief summary of other pentagonal shapes in art and architecture. The pentagon as a five-sided figure with equal sides and angles has been used occasionally in architecture. The related pentgram is an equal-sided, five-pointed star. They each have five-fold rotational symmetry and have probably been chosen as attractive because of these regularities. The Pentagon in Washington, D.C., the Palazzo Farnese and the papal palace in Caprarola, Italy are pentagonal in shape. The pentagram is used as a symbol for witchcraft and appears in the deck of Tarot cards used in fortune telling. Some fortifications are shaped as pentagons. The shape makes them easy to defend against attackers coming from multiple directions. It is also possible to construct both a golden pentagon and a golden pentagram.

The Hexagon and the Hexagram

A regular hexagon, like the regular pentagon is the one most often encountered in art and design. We note elsewhere the hexagonal structure of snowflakes. Six circles can surround a seventh central circle, all with equal diameter. Connecting alternate points of a hexagon creates a hexagram. The result is a six-pointed star. Hexagonal floor plans have been used in architecture. The hexagram is sometimes known as *Solomon's Seal* or the *Star of David* and is the symbol of the state of Israel. This symbol was a sign for Judaism however dating only from the 17th-century onwards.

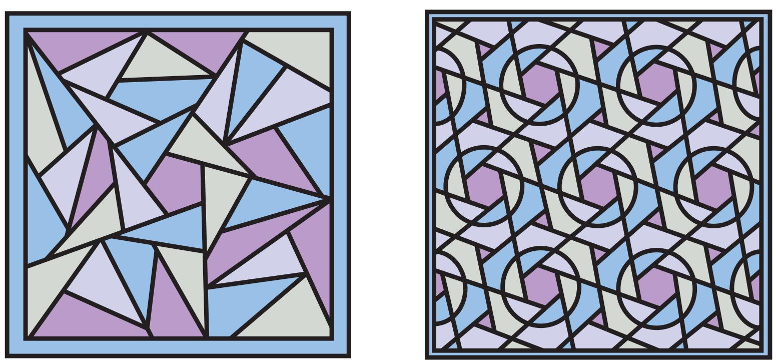
The Cross

The cross can be derived from the square by taking two adjacent sides and inverting them. Many groups and religious faiths have used the cross as a symbol. It is perhaps most obvious as the cruciform layout of many European churches. The psychologist Carl Jung mentions that the Greek cross with equilateral sides was most prevalent up to about 1,000 A.D. but then one of the bars moved upward to form the Latin Cross, perhaps signifying a transition upwards to the spiritual. This shape was then incorporated into the floor plan of many churches and cathedrals. The floor plan for the cathedral at Chartres uses a cross. This architectural style was in vogue during the medieval and Gothic periods. The circle, with its maximal symmetry was also a popular floor plan in European churches during these periods.

Chinese Lattice Designs

Window lattices are decorative grills or screens used to cover windows. Most contain a variety of different polygons in their design. These lattices have been built in China since 1,000 BCE and have been found in many parts of the country. They are constructed in most cases of wood but archeological examples in bronze, brick, stone and porcelain also exist. Dye (1974) collected numerous examples and studied them systematically. He formed a classification of 26 major types in part determined by the type of shapes they contain such as parallelograms, waves, or swastikas. Figure 3.10 shows a few examples. These lattice patterns are a tribute to the creative and geometric genius of their Chinese designers.

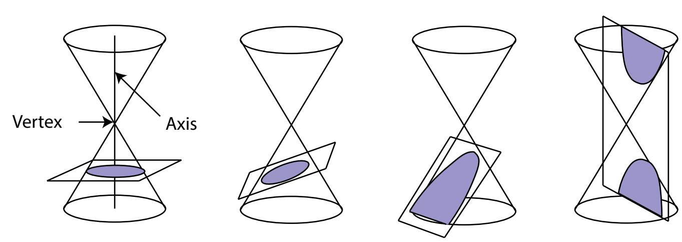
Figure 3.10. Examples of Chinese lattice designs, after Dye (1974).



The Ellipse

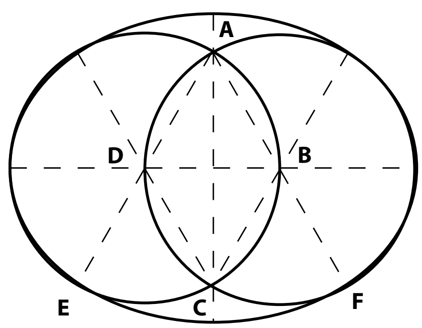
Imagine two cones placed point to point, one resting on its base, the other balanced by its vertex on top of the other (Figure 3.11). If we took a plane and sliced through these in different ways what results are the conic sections. When the cutting plane is perpendicular to the cone's axis, the part that slices through forms a circle. If we tilt the plane a bit, the section formed by the intersection is an ellipse. Tilting it even more so that it is parallel to an element and the result is a parabola. Finally, if we tilt the plane so that it cuts through both cones parallel to their axes what we have is a hyperbola, with two arched sections. Appollonius of Perga (262 BCE – 190 BCE) was one of the most advanced geometers of ancient Greece. He published no less than eight books on conics, seven of which still survive to this day.

Figure 3.11. The conic sections.



Serlio, in *The Five Books on Architecture*, provides a method for drawing ellipses, called an ovato tondo using only a straight edge and a compass. One starts by drawing two circles, each passing through each other's center and intersecting in Figure 3.12 at A and C. Then draw a line AB and extend it outward to F. In a similar manner, draw line ADE. Then from point A swing an arc from E to F. Similarly swing an arc with C as its center from D to G. Serlio then lists examples of ovals in architectural structures, one being an oval amphitheater. Ellipses are used frequently in picture frames, windows and arches. As Calter (2008) notes, an upright ellipse is a good frame to use for portraits. Ovals are also featured in various locations on U.S. paper currency.

Figure 3.12. The Ovato Tondo with lines used in the method of construction.



The Circle in Art

The circle has perfect symmetry. Because so many polygons can be inscribed within, it is a symbol of unity. It is also used as a symbol of infinity because going around one there is no beginning or end and because it can be considered as a polygon with an infinite number of sides. Since all points are equidistant from its center, it has additionally been used to stand for democracy (Calter, 2008). As we describe later in the section on composition a tondo is a circular painting. Examples of tondos are *the Madonna della Sedia* (Seated Madonna) by Raphael in 1516 and *Adam and Eve* in Florence, Italy, painted in the fifteenth century. The circle according to Arnheim seems to strengthen the center and provide the shape with a strength and independence. The roundrel is a circular relief sculpture that was used like the tondo to portray religious figures such as the Madonna. Since the heavens above and the planets are circular, it also was used in celestial themes.

Plaquette is a French word meaning plaque and stands for small low relief sculptures made out of bronze and other metals. They were popular during the Italian renaissance and onwards. Many were made to commemorate important events, but they were made also for purely decorative reasons, especially during the Mannerist period. They most often depict scenes from historical, mythological or religious origins. In a plaquette, only one side is decorated, whereas in a medal both sides are decorated. We mention them here because they were mostly round, although rectangular and other shapes also exist. A representative example of a plaquette is *the Moderno*, depicting the battle of Cannae, dated to 1503-1504.

Circles are also a common motif in mandalas. A mandala is a spiritual symbol representing the universe found in Hindu and Tibetan religions although it has more recently become a generic term for any pattern that depicts the cosmos. The basic structure of a mandala is a square with four gates and a circle about a center point. The gates are shaped like the letter T. Mandalas are used as a way of focusing attention during meditation. Figure 3.13 shows an example of a mandala pattern.

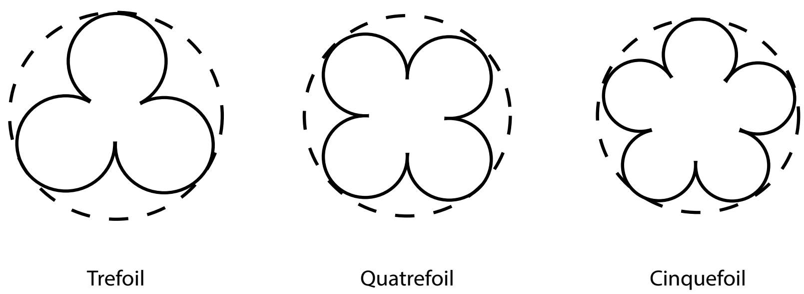
Figure 3.13. A pattern in the style of a Buddhist mandala. Free image sourced from clker.com

The Circle in Architecture

Gothic style developed starting in 1140 A.D. where it was popular around Paris. By about 1250 A.D. the style had spread over most of Europe. It became an International movement but had shrunk in influence by about 1550 A.D. We will focus here on how this style manifested itself in cathedral window design. The Abbey Church of St. Denis and the Chartres cathedral are good instances. The cathedral windows in these and other cathedrals used circles to good effect, producing beautiful and intricate patterning. Prominent in those windows were designs known as the trefoil and quatrefoil.

A trefoil is graphic shape made of three circles. They are constructed by placing three circles so that they touch and such that their centers are connected by an equilateral triangle. This can then serve as a template for further embellishment. A quatrefoil is constructed in a similar manner where four circles are brought together such that the four vertices of a square touch the centers of the circles. There are also alternate versions of the quatrefoil in which the square's vertices touch the points where the outer contours of the circles meet. Examples of these are shown in Figure 3.14. The concept can be extended to the use of five, six, or more circles.

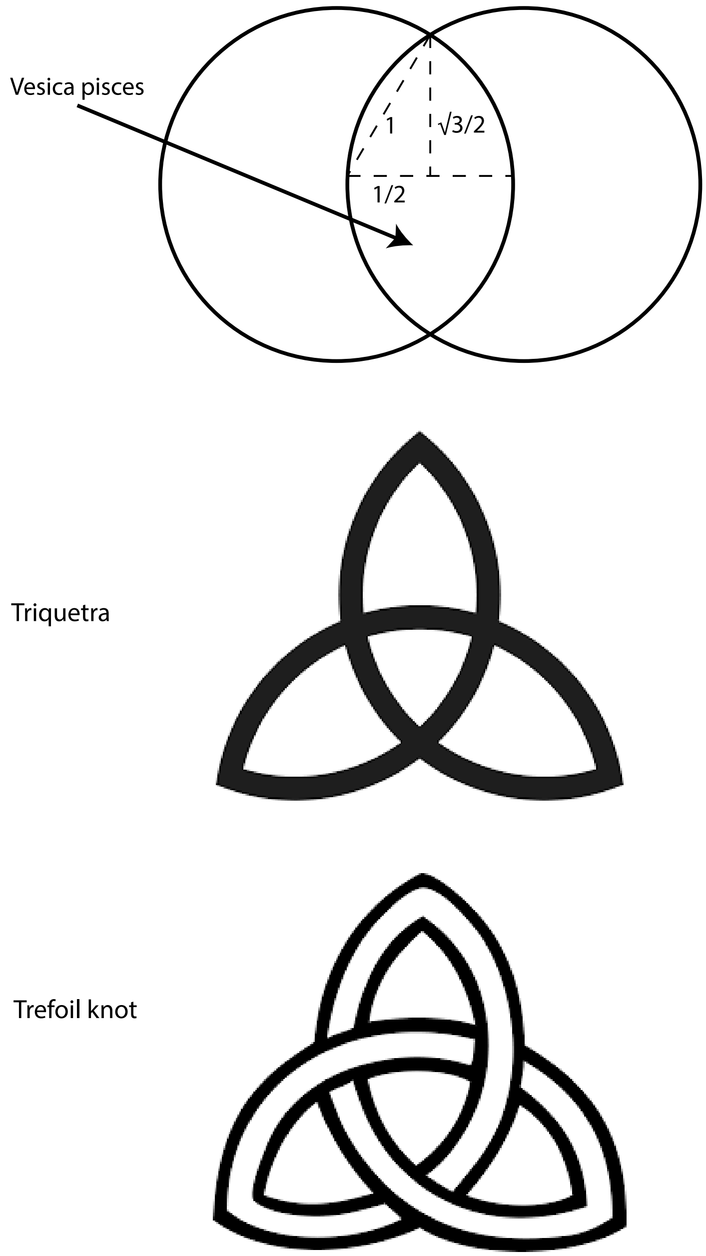
Figure 3.14. The trefoil, quatrefoil and cinquefoil.



The triquetra is a pattern made of three almond shapes shown in Figure 3.15. Another name for this almond shape is the Vesica Piscis, in Latin meaning "fish bladder". These shapes are created by the overlap of two circles such that the center of each lies on the circumference of the other as is depicted in Figure 3.15. If the circles have a radius of 1 then the separation between their centers is also 1. This is the greatest cross-sectional width of the almond shape. To get the height we use the Pythagorean theorem using the right triangle. This gives us a value of ½ for the smallest side of the triangle, 1 for the longest side (the circle's radius) and a value of $\sqrt{3}/2$ for the remaining side. One consequence of this is that the ratio of the height to the width of (this half of) the almond shape is always $\sqrt{3}$, regardless of the sizes of the circles used.

When these almond shapes are formed into a knot with alternating over- and under- crossings it is called a trefoil knot, shown in Figure 3.15. The trefoil knot is prominent in Celtic art. It is in the *Book of Kells* and in works made of thread, wood, stained glass and iron. It was common also in the Holy Roman Empire because it served as a symbol of the Holy Trinity. For that reason it is sometimes also referred to as the Trinity knot. The Vesica Piscis also turns up in the geometry of the flying buttresses of the Chartres Cathedral in France.

Figure 3.15. Vesica Piscis with method of construction, the triquetra and trefoil knot.



Fractals

A fractal is a pattern that repeats the same design over many different spatial scales (i.e., big to small or vice versa). The details in a fractal look the same at different magnifications. Fractals are pervasive throughout the natural world. They can be found in the branching structures of rivers, trees, and blood vessels, in the contours of landscapes and mountains, in the flow patterns of clouds, smoke and mist, and in the shorelines of continents. Fractals can additionally be found in man-made phenomena such as income distribution and fluctuations in stock prices. Many different sorts of fractal geometric patterns can be generated using computer programs that are widely available on the Internet. Fractals and chaos often co-occur. A number of chaotic attractors have been found to have a fractal texture. The patterning of points on these attractors appears the same at different scales. An attractor is a state that a system tends to evolve, described mathematically.

All fractals have four features in common (Williams, 1997). First, they have a statistical geometric regularity so they appear the same at different length scales. This property is called scale invariance. They need not be exactly the same, only approximately so. For example, the branching of blood vessels magnified ten times (10x) under a microscope will appear similar to, but not identical with, the pattern of branching at one hundred times (100x) magnification. It should be mentioned that fractal organization can be temporal as well as spatial. A process unfolding over time can appear the same when measured at one second, one tenth of a second, and so on. Turbulence in fluids and gases reveal similar patterns of variation across different time scales.

Second, a number quantifies the complexity of a fractal over a range of scales. This measure is referred to as the fractal's dimension and is described in greater detail later. Third, fractals are generated by repetitions of an operation. The operation may be natural, such as the crumbling of rock pieces, or it could be deterministic, such as the iteration of a mathematical equation. Figure 2.1 from the philosophy chapter shows an example of computer-generated fractal patterns. It must be mentioned that fractals are always rough or jagged in appearance. They lack the presence of smooth lines or gradual changes.

Fractals and Dimensionality

The *similarity dimension* of a fractal refers to how much space it occupies. Euclidean dimensions are represented as integers: a line is one-dimensional, a square is two-dimensional, and a cube exists in three dimensions. Yet the more pervasive fractals found in the natural world have non-integer values and fall between these standard whole dimensions. The more wiggly a line is, the higher its fractional similarity dimension. A line that bends or deviates just a little bit from being straight will have a dimension just slightly greater than one. A line that wanders all over a two-dimensional page fills up more of the available space and its dimensionality will be closer to two. We next describe how to calculate the similarity dimension of a wiggly line.

It is often not possible to measure the exact length of a line in nature. That is because the length will increase with increasingly more precise measurements. The finer or more exact the measurement, the more detail or small deviations we take into account and the longer the length. For this reason we can only estimate a line length with our estimate being dependent on the level of detail we with to take into account.

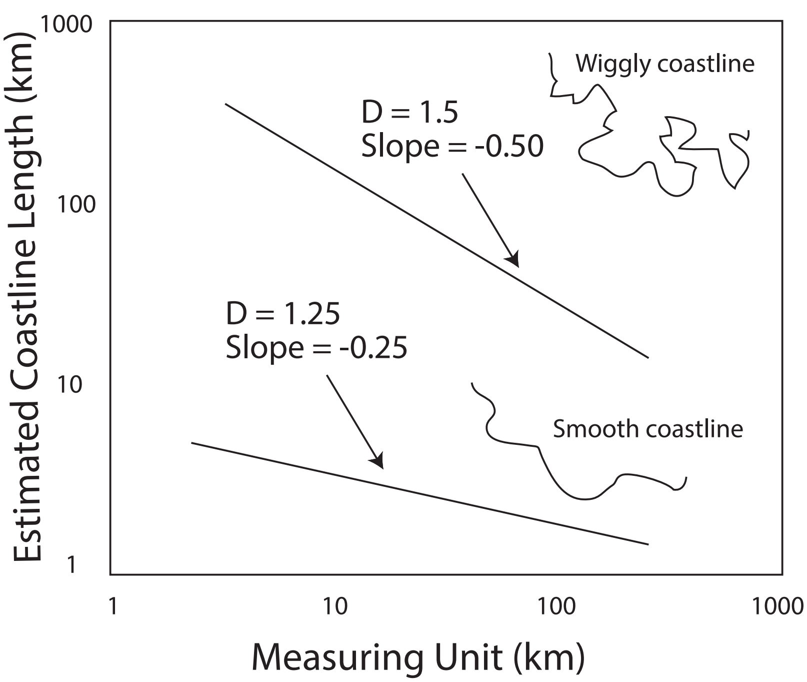
One way to estimate a wiggly line is to use a measuring stick or ruler. We can place one end of the ruler where the line starts and then mark off where the other end of the ruler intersects the line. We record this length, then move the starting end of the ruler up to the intersection point and determine a new intersection, recording this second length. We repeat this process until we reach the end of the line and then add up all our measurements to obtain our estimated length.

By now you may have guessed that our estimated length varies with the length of our ruler. If we used a smaller ruler, we take more of the wiggle and bending of the line into account and our estimated length goes up. If we had used a longer ruler, we would miss more of these details and the estimated length would be less. If we let the Greek symbol epsilon ε stand for the length of our ruler and L_ε stand for estimated length, a plot of the two against one another in log space yields a straight line trending downwards (see Figure 3.16). The similarity dimension D then becomes:

$$D = \log L\varepsilon \;/ \log (1 / \varepsilon)$$

The slope of the straight lines in Figure 3.16 is related to the dimensionality (D = 1 – slope). The steeper the slope, i.e., the more negative it is, the more the line meanders and the greater its dimensionality. The slope of the imaginary coastline depicted by the top line in Figure 3.16 has a slope of –0.5 so it has a fractional similarity dimension of 1.5 (D = 1.5). This could represent a coastline with lots of wiggle. The slope of the coastline depicted by the bottom line in Figure 3.16 is less, at –0.25, so it has a correspondingly lower similarity dimension (D = 1.25). This coast is therefore less wiggly. A perfectly two-dimensional figure has a slope equal to one. Lines with slopes greater than one will have fractional similarity dimensions greater than two.

Figure 3.16. The estimated length of a contour such as a coastline increases as the rule by which we measure it gets shorter. This relationship is expressed by calculating the fractal dimension. A higher fractal dimension indicates the line is more "wiggly" and that more length is gained by measuring with a shorter ruler.



Fractals and Jackson Pollock

Taylor, Micolich, and Jonas (2002) calculated D values for Pollock's abstract drip paintings. These are created by dripping or flinging paint of different colors from a brush onto a canvas laid on the floor (Figure 3.17). His earlier work had a D of 1.12, while his later works had a D of 1.89 (Taylor, Micolich, & Jonas, 2002). This indicates that his images became more detailed and complex over time. This could have been achieved by flicking the paint off the brush more forcefully, allowing smaller drops to fall to the surface of the canvas. These D values are similar to the D values for natural images. The mean fractal dimension for abstract artworks is 2.56, close to the 2.51 for natural scenes. This shows that artists tend to reproduce the regularity and complexity found in the natural world, for both representational and nonrepresentational artworks.

Figure 3.17. Jackson Pollock's drip painting No. 5, 1948. Image entered public domain in 2004.

Why do artists reproduce the statistics of natural images? One explanation is that we are efficient at processing such images and find them beautiful. Our brains evolved looking at these scenes and are good at processing this sort of information, meaning we expend less mental energy to do so. In our discussion of the processing fluency account we said that images that are easy to process are considered more aesthetic. In this explanation, the brain is "lazy" and seeks to conserve energy. Any process that is executed more efficiently by the brain may result in a feeling of beauty. This seems to apply both to natural images and ones created by artists (Graham & Field, 2007; Redies, 2007). Spehar, Clifford, Newell, and Taylor (2003) found in experiments that preference for natural images peaked at a D value of 1.3. In their study they also determined that preference was highest for Pollock paintings with a D value of 1.5. Aks and Sprott (1996) found a preference for computer-generated fractal patterns at a peak D value of 1.26.

The Sphere and the Dome

The sphere is a three-dimensional circle. It is realized architecturally as a dome, since some domes can be half-spheres, or hemispheres. However, some domes also referred to as cupolas, can be flattened, bulbous or elongated. Some also have a polygonal, usually octagonal, cross-section. The famous Pantheon in Rome is a sphere. One can inscribe a sphere that lies along its inner surface and that is tangent to the pavement. In cross section the walls at the bottom are thicker to support greater weight but then get thinner travelling upwards. The Pantheon is still the largest masonry dome in the world. It was built by the Emperor Hadrian and is 142 feet in diameter with an open oculus window at its center. The Hagia Sophia in Istanbul (what was Constantinople) is another example of a very large dome. It is 180 feet tall and 107 feet in diameter. Other famous domes throughout the world include St. Peter's in Rome, the Taj Majal in Agra, India, and Saint Basil's in Moscow (Calter, 2008).

Complete spheres have been used in the form of globes for many centuries. Globes that represent the heavens are celestial and those that show the Earth are terrestrial. Aside from their practical use in navigation and astronomy many globes can be considered works of art in their own right. Some globes were gilded with gold decoration. There is a globe museum in Vienna, Austria that is worth visiting as it contains a wide variety of historical globes. Vincenzo Coronelli created two globes for the Holy Roman Emperor Leopold I. Each globe had an engraved portrait of the Emperor and an inscription. Also in the collection are orreys, three-dimensional models of planets revolving around the sun that could be set in motion. Some of these even contain moons that revolve around the planets while the planets simultaneously revolve around the sun.

The Sphere appears in paintings sometimes accompanying Fortuna, or Lady Luck in which case it represents chance as in *Das kleine Gluck* by Durer, 1495. In art a globe can signify exploration and colonization. When in the presence of royalty it symbolizes power or control over the world. Paintings of astronomy and astronomers frequently show a globe. In *The Astronomer*, dated 1668 Vermeer shows the man reaching out to touch a globe. The Dutch twentieth century artist M. C. Escher (1898-1972) created several works with reflective spheres, one showing what appears to be himself in *Hand with Reflecting Sphere*, 1935. Escher was interested in mathematical phenomena and drew many works showing tilings, infinity, impossible structures and symmetry.

The Solids

Like the two-dimensional regular polygons there are also three-dimensional figures that possess regularity. These are known as the Platonic solids (Figure 3.18). These are solid bodies whose faces are regular polygons that are all identical and that meet in identical fashion at every vertex. Each point or vertex is the same distance from the center. There are a total of five such solids. They are the tetrahedron, octahedron, icosahedron, dodecahedron, and the cube. Here are some brief descriptions for each:

- The tetrahedron has four triangular faces, four vertices, and three faces coming together at each vertex.

- The octahedron has eight triangular faces, six vertices, and four faces coming together at each vertex.

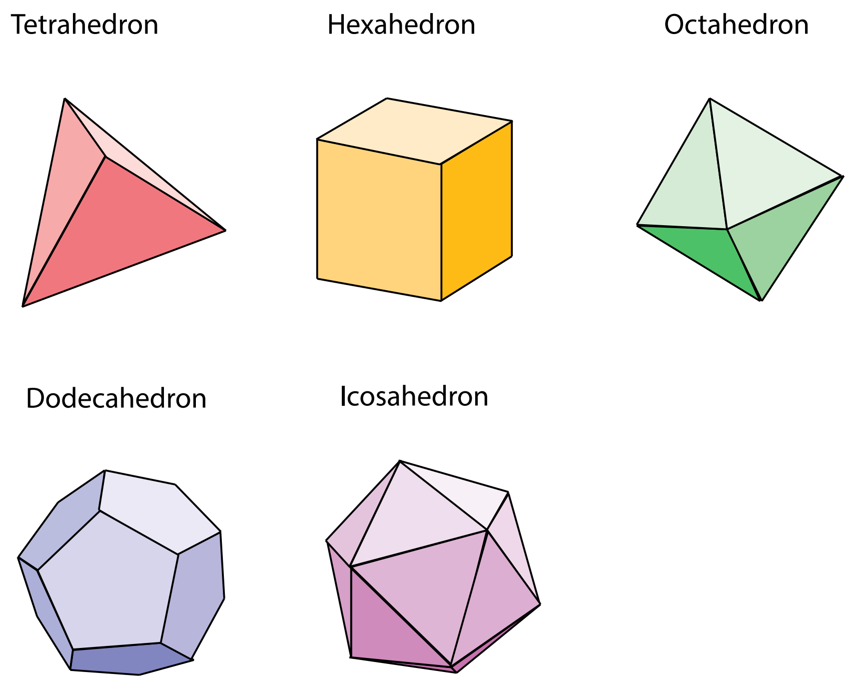
- The icosahedron has twenty triangular faces, twelve vertices, and five faces coming together at each vertex

- The dodecahedron has twelve pentagonal faces, twenty vertices, and three faces coming together at each vertex

- The cube has six square faces, eight vertices, and three faces coming together at each vertex

The relation between the number of edges, faces and vertices can be expressed in the simple formula: number of edges + 2 = number of faces + number of vertices Although described by Plato and named after him, he was far from the first to discover them. They were recognized in the British Isles two thousand years before Plato as a set of carved stone figures. The 4,000 year-old set was unearthed at stone circles in Aberdeenshire, Scotland.

Figure 3.18. The Platonic solids all have faces with regular polygons.

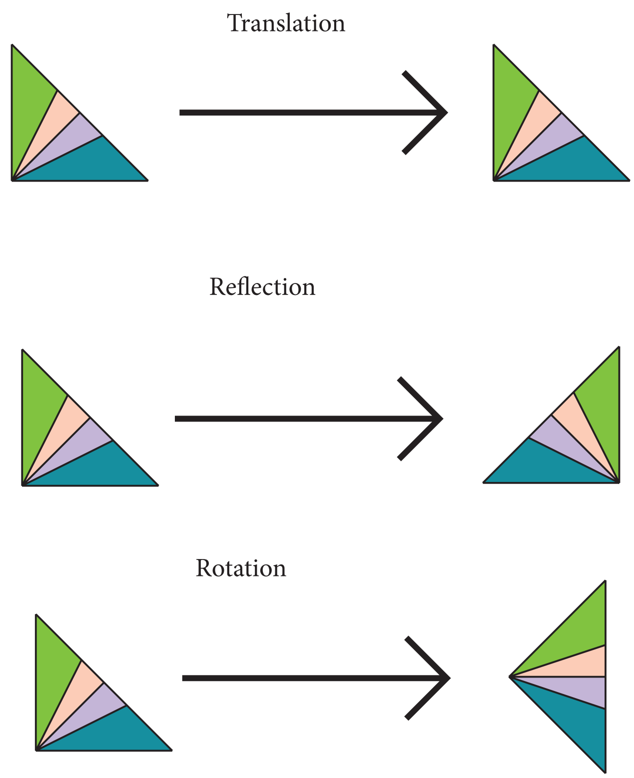


Nature also uses the Platonic solids. Diatoms are marine algae that grow exoskeletons with these shapes. Other microscopic creatures called radiolarians also embody the Platonic solids. They are found as zooplankton throughout the oceans and have existed on Earth since the Cambrian era onwards. Ernst Haeckel in his book *Art Forms in Nature*, portrays these fascinating organisms. Some of them even have names with the Platonic solid that they resemble mentioned. Examples are *Circorrhegma dodecahedra*, *Circogonia icosahedra*, and *Circoporus octahedrus*..

Symmetry

Visual symmetry in general terms is the application of an operation to a shape that leaves it unchanged (Weyl, 1952). There are several types of symmetries. Translational symmetry is probably the simplest as it involves the duplication of a pattern. In reflective symmetry one half or portion of a pattern becomes the mirror image of the other. In rotational symmetries a pattern is rotated by a given degree. Figure 3.19 shows the three symmetry operations applied to a simple motif. Symmetry of all sorts is widespread: we see it everywhere around us in both artificial and natural environments. Our own faces and bodies are symmetric as are many of the things we make such as houses and cars.

Figure 3.19. The three symmetry operations applied to a simple motif.



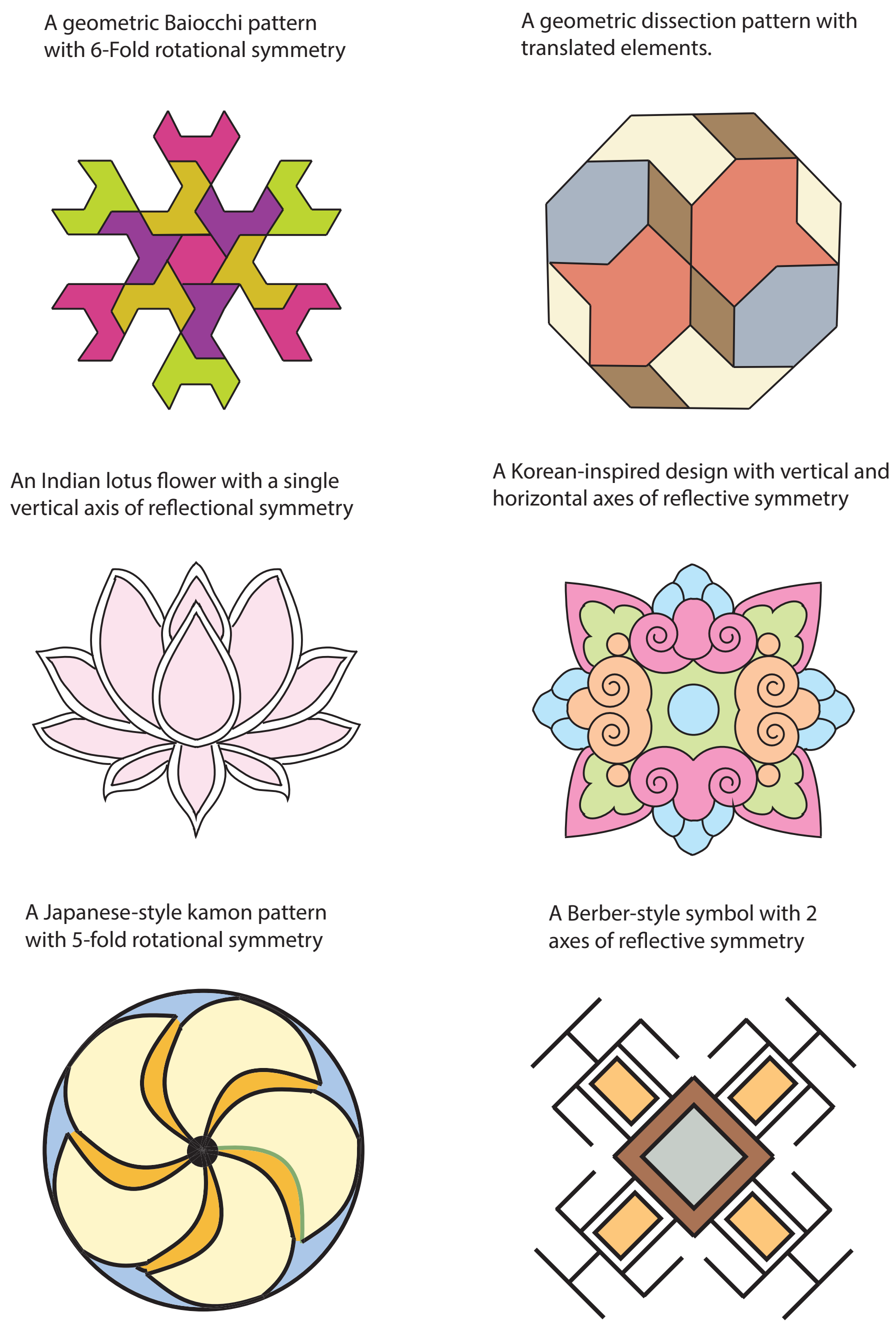
Humans and other species tend to prefer symmetrical patterns to nonsymmetrical ones and this preference may be rooted in mate selection

(Johnstone, 1994). According to one theory, mirror symmetry signals genetic fitness and the ability to ward off infection (Grammer & Thornhill, 1994; Rhodes, 2006). For more on the evolutionary aspects of symmetry, see the sections on faces and bodies in the evolution chapter. But the beauty of symmetry goes beyond the biological we like to build and look at symmetric objects in art and design (Washburn & Crowe, 1988). All three of the symmetry types are present in the art of all known cultures throughout recorded human history (Stevens, 1982).

Point Symmetries – Logos and More

Point symmetries are those that occur in zero spatial dimensions. In other words they are motifs or designs that occupy a single point in space. They do not extend out in a line or into two dimensions in a plane. The design is subject to one or more of the three basic symmetry operations. For translation the motif can be repeated in any direction but in lots of design work it is moved horizontally or vertically. For reflection a point symmetry pattern can have one, two or even more axes of reflection, also usually oriented vertically and horizontally. Point symmetries with rotational patterns have a motif that is rotated, typically by 90° or 180°, although other angles occur as well. Corporate logos are good examples of point symmetries. They also appear in tattoos, jewelry, craftwork, graphic design and other types of art. Stevens (1982) gives many examples of point symmetries that occur in the artwork of countries around the world. Figure 3.20 shows examples of geometric and point symmetry patterns from different cultures around the world. These are described in more detail below.

Figure 3.20. Point symmetry patterns inspired from cultures around the world.



The Japanese kamon or mondokoro patterns were emblems used to identify a person or family. Many of these are point symmetry designs. One categorization scheme has them organized into 241 sections based on appearance (Adachi, 1972). Nearly 7,000 kamon have been compiled. Many resemble familiar objects like animals, flora and tools. The kamon is the equivalent of the European heraldic crest and represented an individual's clan and organization. They were used on flags, tents and uniforms by the military in battles and originally by the aristocratic class but eventually adopted for use by commoners as well. They eventually permeated Japanese society and were used by merchants, shop owners, temples and criminal syndicates. Korean art also uses point symmetries. In particular there are window frame designs, many of them octagonal in shape that resemble Chinese lattice patterns. Most of these are abstract with intersecting lines and grids but some utilize floral and scroll work.

The Berbers are a group of people from North Africa west of Egypt and the Nile region. Most currently live in Libya, Mali, Niger and Tunesia. Originally Caucasian, these people spoke Arabic with the influence of the Islamic culture and then French with that country's colonial invasion. The earliest examples of Berber art are cave paintings that date back to more than 10,000 B.C.E. The design in Figure 3.20 is based on an abstract pattern found in a cave painting in North Africa.

Line Symmetries – The Frieze Groups

Line symmetries also go by the name of border patterns or friezes. The latter name is used when they serve as architectural decoration. In these patterns the motif or design is extended in a single direction in space, usually along the horizontal. These patterns are in widespread use in graphic design, illustration, fashion, knitting, pottery, rugs and textiles, among other applications. Mathematically there are only seven ways one can apply the three symmetry operations to a motif and have it repeat linearly in one spatial dimension. Figure 3.21 shows each of these seven types. Their descriptions are provided below.

Group t patterns consist of a motif that is translated only. The t stands for translation. Here, an object is only duplicated and then moved. The direction of motion can be at any orientation, horizontal, vertical or oblique.

Group tg patterns contain a glide reflection where the motif is translated and then reflected. The reflection axis is parallel to the direction of extension. In these examples the extension is always horizontal.

Group tm patterns contain a translation and a vertical mirror where the reflection axis is perpendicular to the direction of extension.

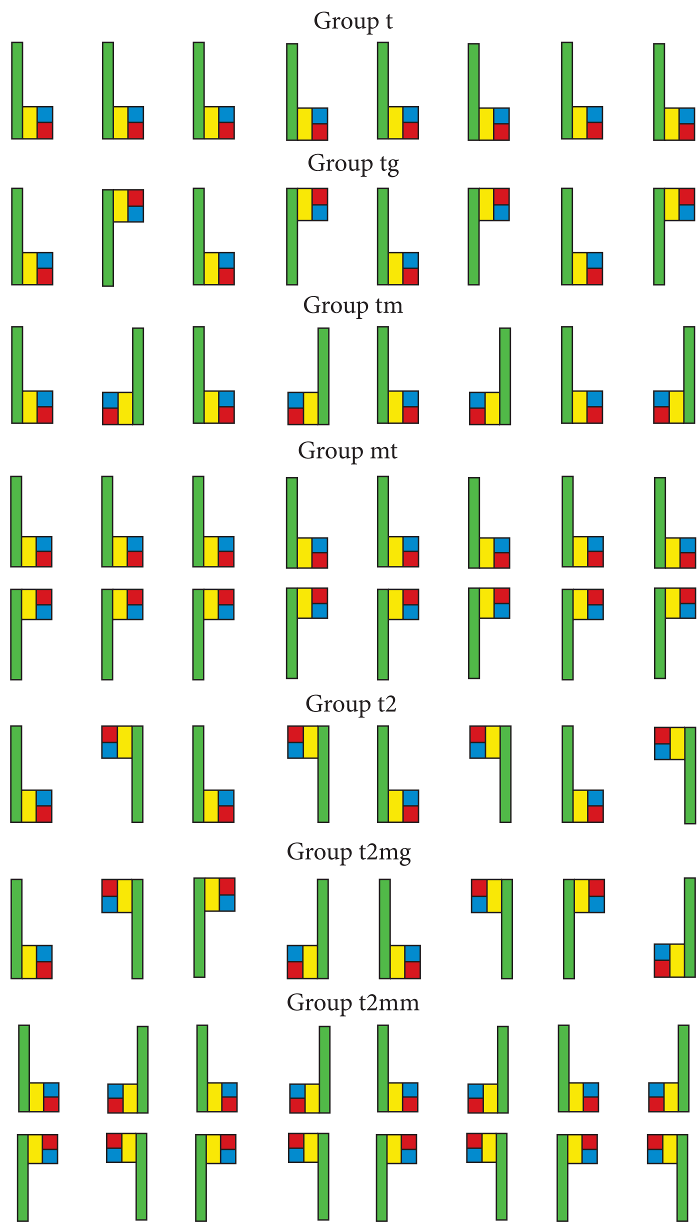
Group mt patterns contain a single transverse or longitudinal mirror in which half of the motifs are mapped onto each other. The mirror is parallel to the direction of extension.

Group t2 patterns have 180° rotations. The center of rotation is in the center of the extension axis.

Group t2mg patterns have 180° rotations alternating with mirrors. The motif is first rotated and then reflected.

Type t2mm patterns contain vertical and horizontal axes of mirror reflection.

Figure 3.21. The seven types of line symmetries or frieze groups illustrated with a simple geometric motif.



Plane Symmetries – The Wallpaper Groups

Any motif can be repeated in the two-dimensional picture plane using conjunctions of the various symmetry operations. It turns out there are exactly seventeen ways in which this can be done to fill the plane in an orderly way. The Russian mathematician and crystallographer Evgraf Fedorov was the first to discover this in 1891.The resulting patterns are referred to as wallpaper patterns. Figure 3.22 shows examples of each type with descriptions given in the wallpaper groups glossary in the appendix. As was the case with friezes, these seventeen plane groups can be found in the art of all human cultures. Islamic artists working during the middle ages and later made extensive use of these symmetries, in part because they were forbidden to portray human figures. The decorative work at the Alhambra in Granada, Spain contains many of these symmetry groups. Some examples of the magnificent patterns created by these artists are shown in Figure 3.23. For those who want to delve deeper into these a good place to start is the book *Symmetries of Islamic Geometrical Patterns*, by Syed Jan Abas and Amer Shaker Salman.

Figure 3.22. The seventeen types of wallpaper patterns.

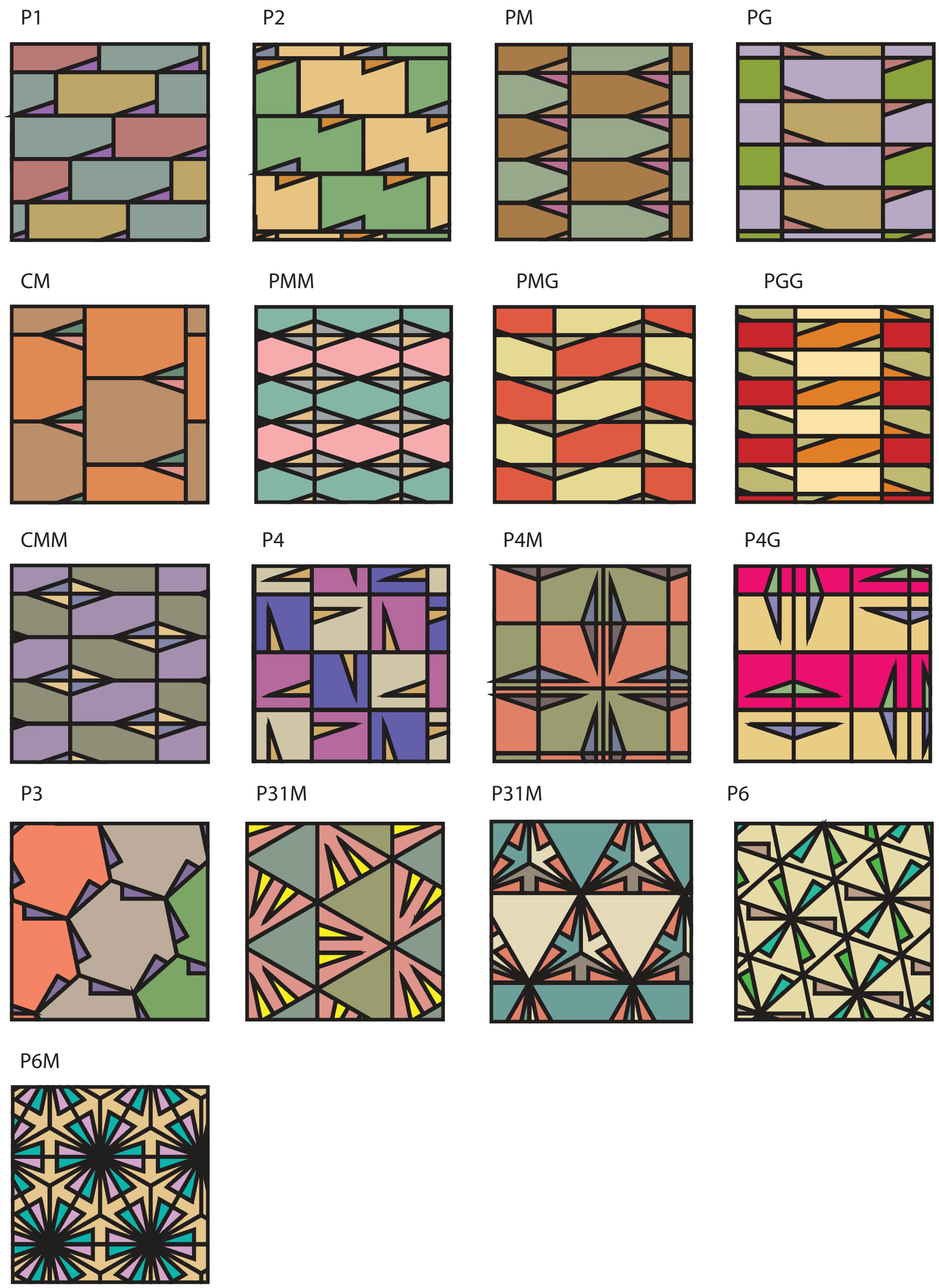
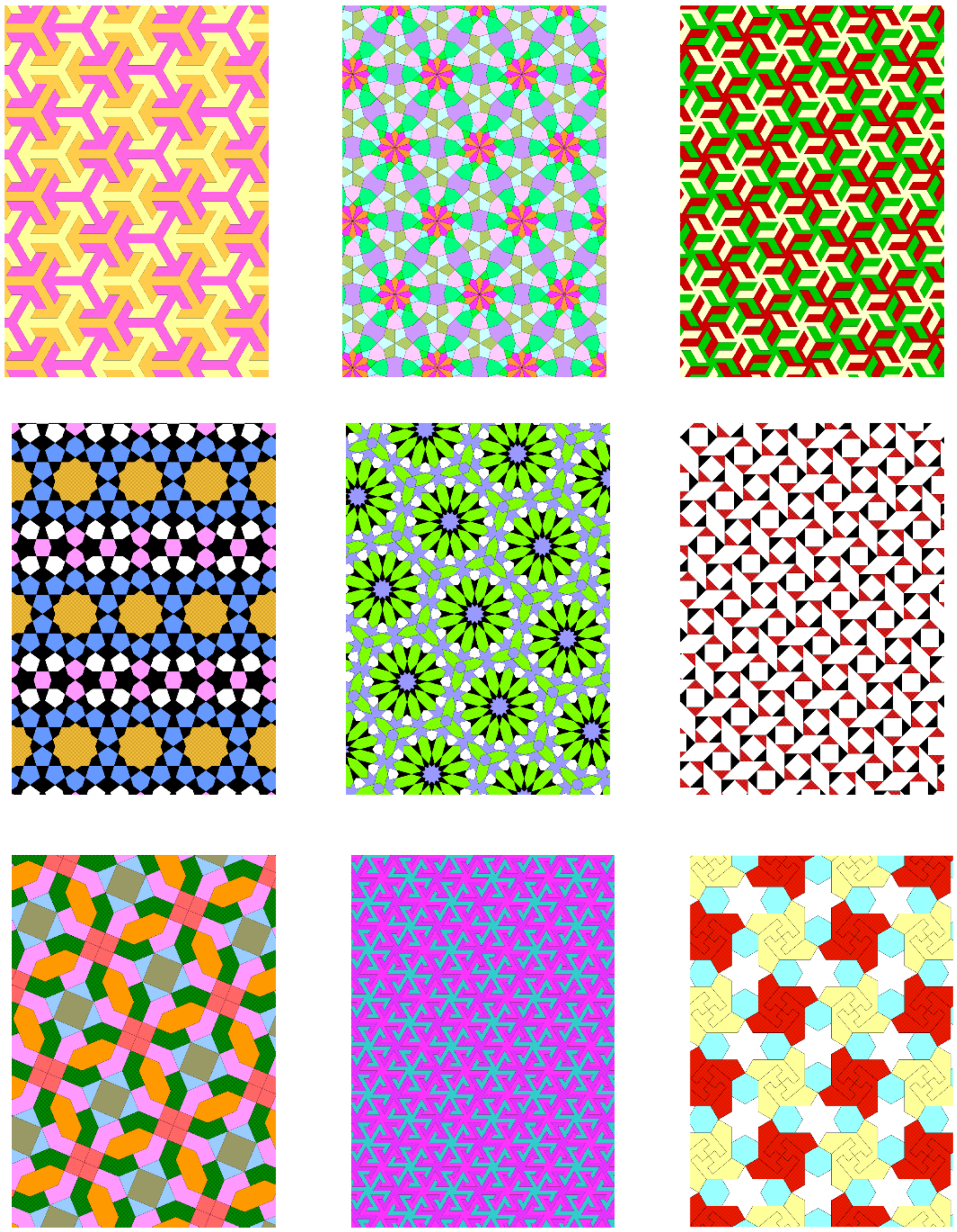


Figure 3.23. Examples of Islamic geometrical patterns.

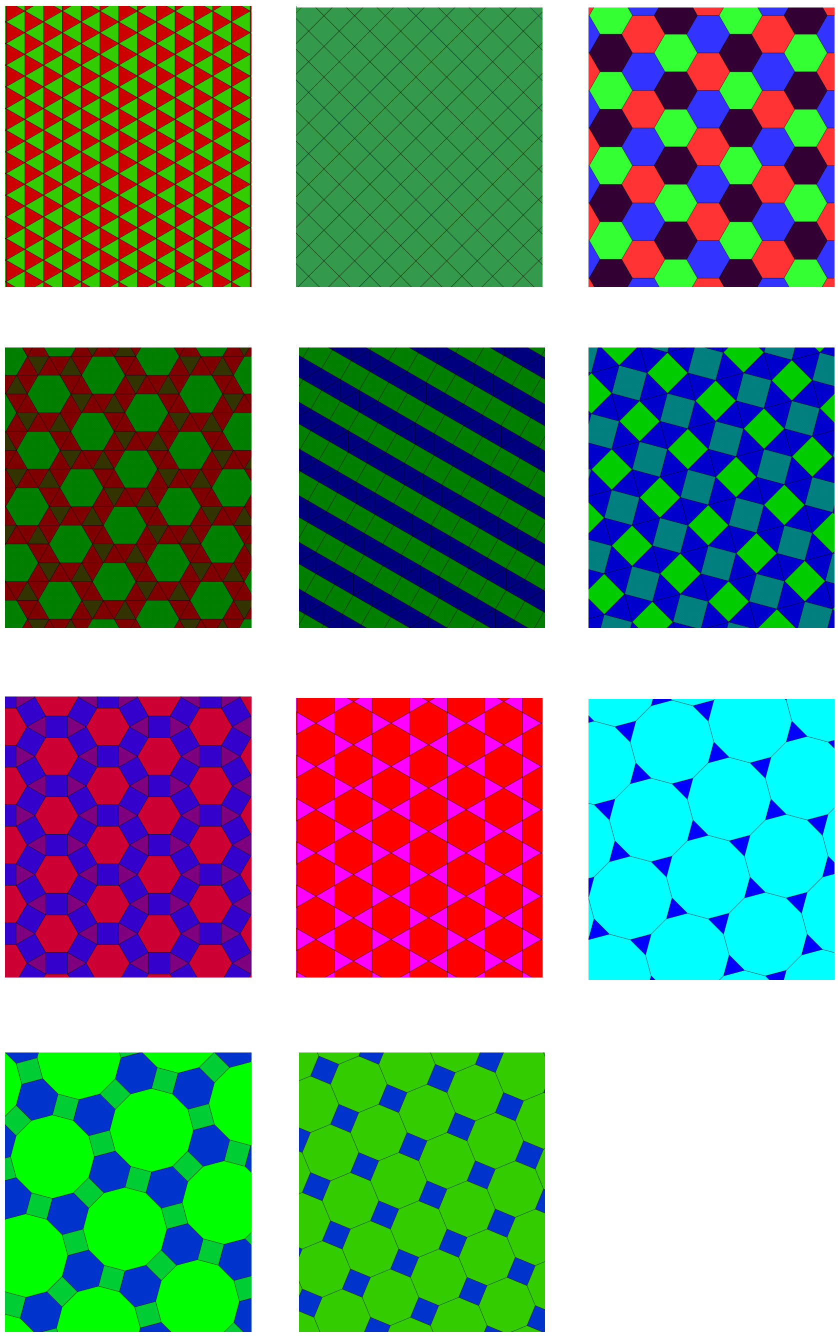


Tessellations and Tilings

Symmetries also manifest themselves in the relationships between elements in other types of patterns that fill up two-dimensional space. A tessellation or tiling of the plane occurs when a polygon is used to completely fill up the plane, leaving no gaps or overlaps. Tessellations continue indefinitely in all directions, meaning they are infinite. Artists and mathematicians have been fascinated with them since early-recorded human history. The Sumerians used geometric mosaics as early as 4,000 BCE. The ancient Greek mathematician Archimedes (287–212 B.C.) studied their properties. The German astronomer Johannes Kepler pictured a number of polygon tessellations in his book *Harmonice Mundi*, published in 1619. Tilings are all around you. You may notice them on parquet or linoleum floors, walls and ceilings. They are used as decorations on pottery, tapestries, carpets, metal work, woodcarvings and stained glass (Seymour & Britton, 1989). They are found throughout Islamic art and more recently in the work of Dutch artist M.C. Escher.

Only three regular polygons tessellate. These are the equilateral triangle, the square and the hexagon. (Figure 3.24). A semi-regular tiling will allow for more than one type of polygon with the condition that each vertex is the same. Similar vertexes are ones where identical polygons meet. For example the second semi-regular tiling shown in Figure 3.24 has two hexagons and two triangles meet at each vertex. There are eight possible semi-regular tilings.

Figure 3.24. The three tessellations in the top row are produced by regular polygons and are made of equilateral triangles, squares and hexagons. The remaining rows show the eight semi-regular tessellations. These have more than one type of polygon where the number and type of polygons at each vertex are the same.



There are also demi-regular tilings. These are ones where two types of vertex situations are allowed. Demi-regular tilings are found in the natural world in the form of crystals and cellular structures. Many of them are also employed in Islamic and Celtic patterns. William Morris, the 19th century English textile designer, used such tilings as the basis for his wallpaper patterns and fabric designs. Another Englishman, Owen Jones, travelled the world collecting examples of mosaics, tiles and textile patterns, publishing them in his 1856 book, *The Ornament of Grammar*.

Any single triangular shape will tessellate the plane by itself. This is true whether they are regular or irregular, acute obtuse, right or isosceles. The same is true for quadrilaterals. One can make tessellations with rhombi, parallelograms and trapezoids as well as with rectangles. However, not all pentagons tessellate. Regular pentagons do not. There are fourteen types of irregular convex pentagons that tile the plane. Although regular hexagons tessellate not all irregular hexagons do.

Order and Complexity

The American mathematician Birkhoff (1932) wanted to quantify aesthetic appreciation. He gathered examples of art from many cultures across fields of art, music and design and analyzed them. He was able to boil all of this down to a simple formula: Aesthetic Measure (M) = Order (O)/Complexity (C). In other words, the beauty of an object is equal to the amount of order it contains divided by its complexity. In his view patterns that are more ordered and less complex should be judged more beautiful.

His first step toward calculating aesthetic measure was to assign numbers to both his numerator and denominator values. He did this for a wide variety of artworks including tiling patterns, friezes and designs. For polygons Birkhoff's order value is determined by adding up scores for the presence or absence of four different symmetries and then subtracting a penalty of one or two for unsatisfactory conditions. Examples of these are when interior angles are too close to 0 or 180 degrees or if the distances between vertices are too small. The result of this was a number that could not be higher than 7. He defined Complexity as the number of straight lines that contain at least one side of the polygon. For a square this number would be 4, while for a Roman Cross it is 8 (4 horizontals and 4 verticals). He published a set of 90 polygons with associated M values.

There are a number of problems with Birkhoff's scheme. First, his choice of what constitutes order and complexity is somewhat arbitrary. These factors may be inherently subjective and vary from person to person. Aesthetic complexity is (no pun intended) too complex to be encompassed in such a simple formula. Also, it assumes that beauty is based on maximizing order and minimizing complexity, when in fact most people prefer moderate amounts of complexity. A mathematician may prize order above all, but some people may like disorder to varying degrees.

Birkoff's proposal failed to hold up against subsequent empirical testing. As a result Eysenck (1941) formulated a different formula to predict aesthetic preference, expressed as M = O x C, with the letters standing for the same values as Birkhoff's formula. This new formula acknowledges that complex aspects of form can also contribute to beauty. Using a set of Birkhoff's polygons he performed a factor analysis and determined those attributes that correlated with preference. These included symmetry, angles close to 90° or 180° and number of non-parallel sides. Additional variables included compactness, repetition and equilibrium.

Berlyne (1974) found observers preferred patterns that had either lots of or moderate amounts of complexity. In several studies and with a multitude of different pattern types he found two types of response functions, either a generally increasing interest and preference with more complex patterns or an inverted-U shaped trend of increased preference up to some moderate level and then a downturn thereafter. He believed that people prefer an optimal level of arousal. Some individuals prefer lower levels of arousal caused by simpler stimuli. These would show an inverted-U shape response function. Others may prefer greater stimulation and more complex patterns. These would produce the continually increasing functions.

It is probably the case that people prefer coherence and understanding generated by simple patterns. At the same time they also want some amount of mystery and obscurity that they could only experience through complex patterns. Optimal patterns will have some mixture of these two components, predicting preference for moderate complexity. A large literature supports this view. Many people for a wide variety of patterns prefer moderate levels of complexity, resulting in the inverted-U shape function relating beauty and complexity.

Algorithmic Information Content and Compression

The concept of algorithmic information content (AIC) can help us understand complexity better. Assume that we start with an idealized computer that has infinite storage capacity. We then present the computer with a message string, representing the system whose complexity we want to describe. The description consists of the shortest program or algorithm that will cause the computer to print out the string. The length of this program is the AIC of the string. It is basically the shortest set of instructions that can be used to generate or reproduce it.

As an example, take the binary string 00001111. The shortest program that would reproduce this would be something like: "print four zeros, then print four ones". This is a short program, so the string would be considered simple. Next take the string 01001110. Our program in this case would be: "print one zero, a single one, two zeros, three ones and one zero". This program is longer so the string is more complex. The first string is redundant, since its elements repeat more often. The second string has fewer repetitions and so is less redundant, making it more complex.

Redundancy in information theory is encompassed by the notion of compression. A highly redundant string is said to be compressible, meaning that we can economically code for it using a short description. In other words, the AIC of compressible strings is low. However, there are many bit or binary strings that are incompressible. These strings have no redundancies and can't be compressed. There is no program shorter than the length of the string itself that will describe it. Random strings, those generated by random processes, have a maximum AIC.

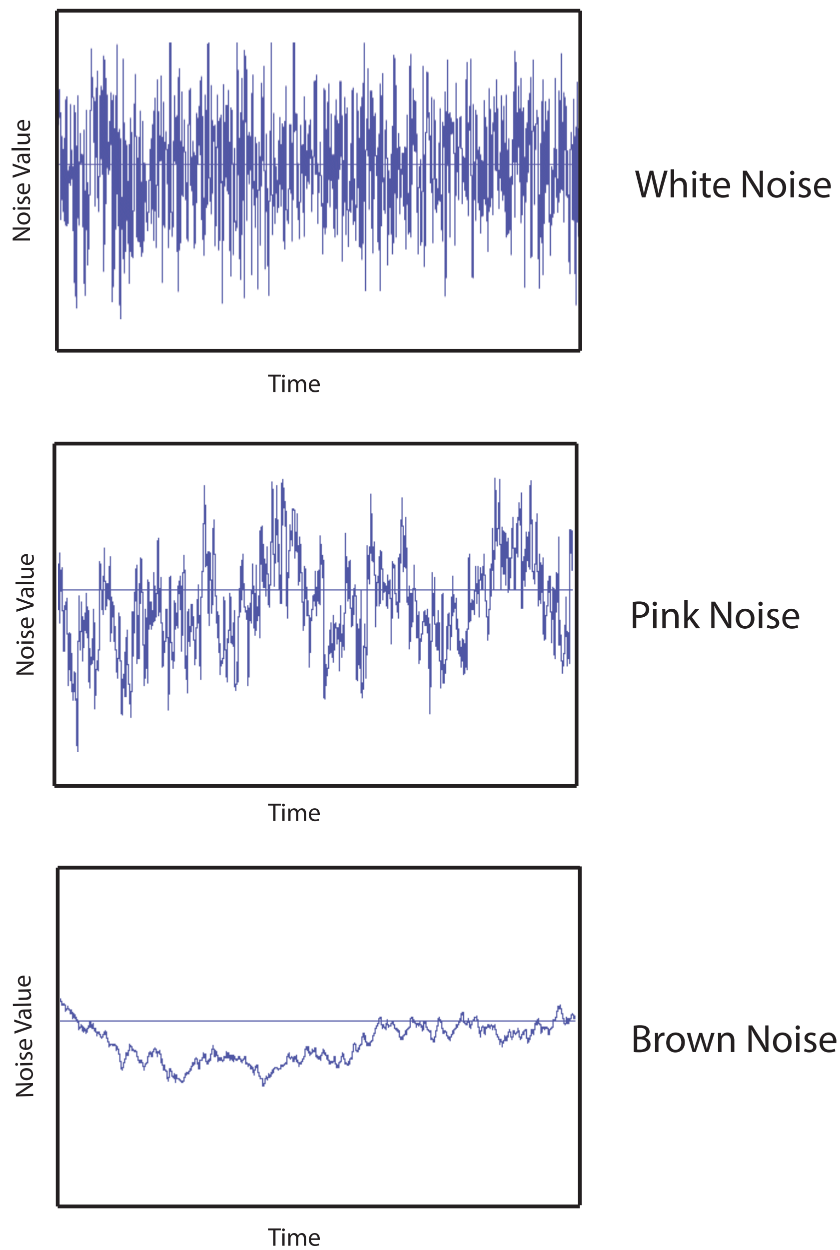
Forsythe et al. (2010) found that GIF compression correlated well with subjective measures of visual complexity. GIF compression is the reduction in file size from a raw or uncompressed bitmap image. The greater the reduction and the lower this value, the simpler the pattern is because it can be described by a minimal code. They had subjects rate the complexity of a sample of representational and abstract art images using a scale from one to five. In a second study they examined the relationship between GIF complexity and mean beauty ratings for abstract, figurative and natural scenes. They again obtained an inverted U-shaped function that peaked near a GIF compression measure of 4 (on a scale of 1-5). These results suggest a peak preference for more complex patterns, at least within the range of values tested.

Friedenberg and Liby (2016) created 10 x 10 and 15 x 15 grids randomly filled with black elements at different densities. Participants were asked to rate how beautiful the patterns were. For both grid sizes ratings were low at low and high densities and peaked near middle densities, those where the grids were close to half full. A GIF compression measure showed that the grids were most complex at this density as well, so for these stimuli the observers were judging the most complex patterns as the most beautiful.

Music and Noise

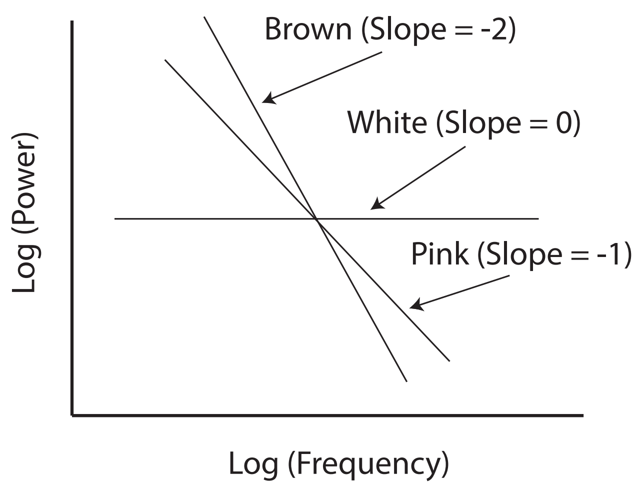
Noise is something that cannot be described in an orderly way and so is the ultimate form of disorder. We can describe noise by plotting it as a time series. A time series is simply a set of observations or measurements that are ordered in time. Let us suppose that we have measured the frequency of static coming out of a radio tuned in-between stations. We then plot our values in the order they were recorded. The time series plot we obtain is depicted in the top of figure 3.25. We can see that there are many different frequency components here. Low frequencies show up as large deviations while higher frequencies appear as smaller deviations.

Figure 3.25. Time series for white, pink, and brown noise.



We can get a better description of the noise's frequency components if we plot the power of each frequency in log-log space. This type of plot is called a power spectrum. Figure 3.26 shows the power spectrum for these data. It is shown as the horizontal line in the figure with every frequency at equal power. This is the signature of white noise. White noise can be found in the natural world. Examples include the sound of wind passing through trees with foliage or of water coursing through a stream.

Figure 3.26. Power spectra for white, pink, and brown noise.



The middle portion of Figure 3.25 shows a time series plot for measurements of another type of noise. Notice that in comparison to white noise there is a distinct low frequency trend in the data. This appears as larger wavelike fluctuations.

However, there are some mid and high frequency trends present as well. The slope of the line in the power spectrum depicted in Figure 3.26 is now very close to negative one (-1). This is the hallmark of pink noise, which is dominated by low frequencies. Pink noise is also present in natural phenomena. It can be found in heartbeats, thunderstorms and earthquakes. The last type of noise we will discuss here is brown noise. The time series and power spectrum for this are also shown in figures 3.25 and 3.26. Low frequency fluctuations are even more dominant in brown noise than they are in pink noise. The slope of the line in the log-log plot is now negative two (-2).

White noise is completely random and therefore unpredictable. The absence of structure makes it continually surprising. Eventually the ear seems to "lose interest" in finding patterns in it, which may explain why at low intensities white noise is soothing. Brown noise is highly correlated and predictable. For example frequencies if rising may continue to rise like a scale, and this is perhaps too "boring" and regular for the ear. This suggests that a noise in-between these two types might be preferred, one that strikes the right balance between unpredictability and predictability that the ear would "like" the most. Pink noise seems to fit this category. Not only does it occur in nature but it has been found in human-generated sources as well. Power spectra with slopes near negative one have been found in Bach's Brandenburg Concerto no. 1 (Voss & Clark, 1975). Other similar results have been obtained for classical music, rock music, and a news-and - talk radio station. The fact that we like to listen to these sorts of things suggests a preference for pink noise.

However the results obtained by Voss and Clark have some methodological limitations. Their samples of radio and music were over long time intervals, on the order of hours. Any audio signal sampled for long intervals becomes pink in nature. Boon and Decroly (1995) sampled over intermediate time intervals and a frequency range that is experienced by human listeners. They found the signals were now closer to brown than to pink noise. So it appears that the type of noise preferred best by people is best characterized as brown rather than pink.

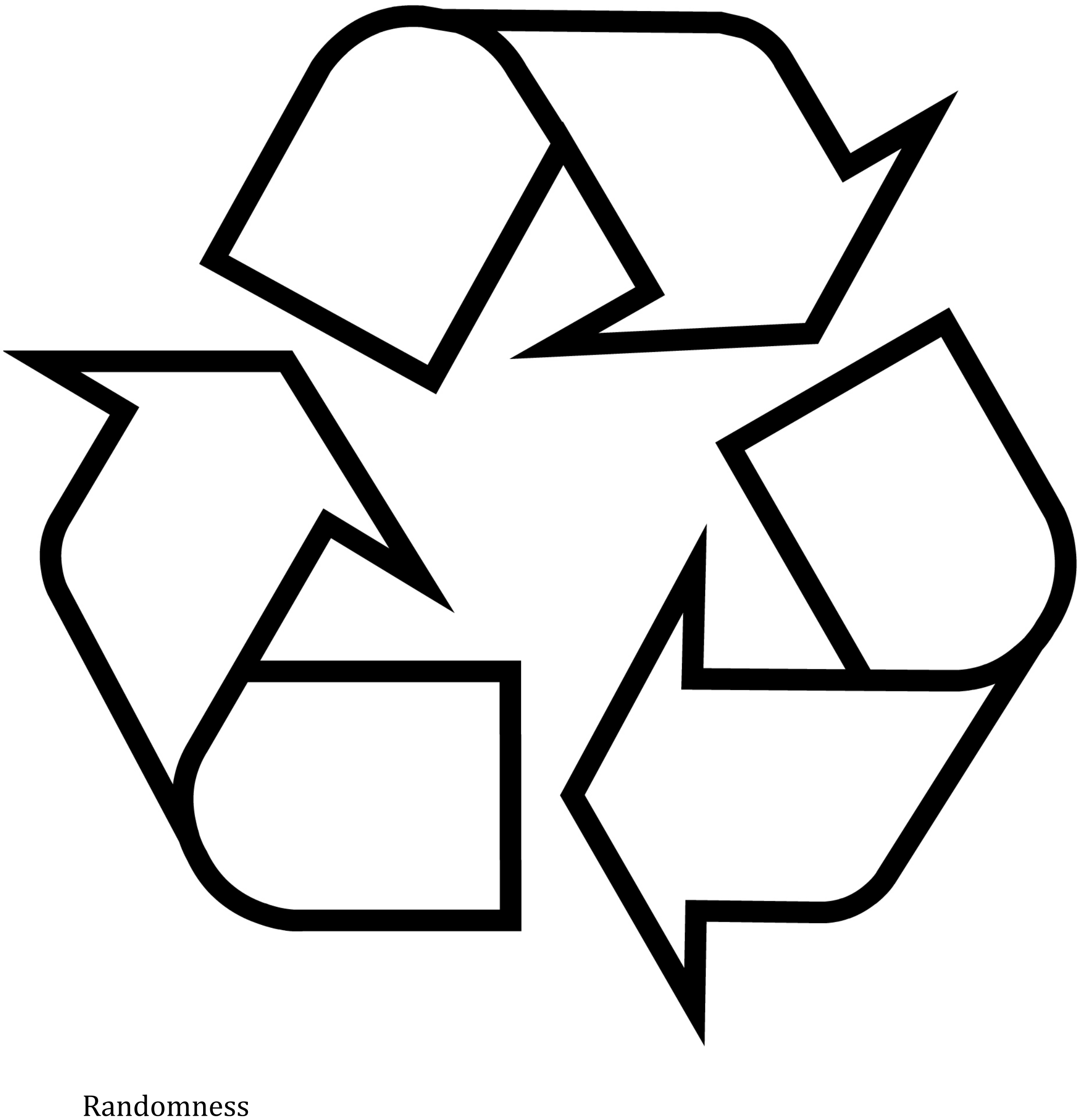
More Math and Visual Art

The Möbius Band

Take a long rectangular strip of paper, twist it and then glue the two ends together. What results is a Möbius band shown in Figure 3.27. This band has some amazing properties. It has no "inside" or "outside", it has only one single surface. If you draw a line with a pen across its entire length, you will eventually come back to where you started. This will be the case for any odd number of twists, but not for an even number of twists. If a Mobius band is used on a conveyer belt it will last twice as long before breaking. The band gets its name after the German mathematician and astronomer August Mobius who published his discovery in 1858.

A number of artists have used the Mobius band in their work. Escher made some drawings of it. The Swiss sculptor Max Bill created a variety of ribbon sculptures in metal and granite using the Mobius band as a theme. The American physicist Robert Wilson also made sculptures of it in stainless steel and bronze during the 1970s. So did the English sculptor John Robinson, who made a trefoil knot with a Mobius band in his work titled *Immortality*. Many other artists and designers have employed the Mobius band in their work, including architects to create interesting buildings and children's playground areas. A version of the Mobius band has perhaps forever attained immortality as the ubiquitous recycling logo (see Figure 3.27).

Figure 3.27. A Mobius band has only one surface, with no inside or outside. The recycling logo uses a version of the Mobius band. The recycling logo is in the public domain



Randomness

Some visual artists such as Gerhard Richter and Ellsworth Kelly have used the principle of randomness in their art. Random patterns lack order or structure. As such they cannot be predicted. They can only be described statistically. One can only say there is a certain probability that an element will occur in a random pattern, not that it will or will not occur with certainty. To illustrate let us look at a series of coin tosses. Below are two sequences of coin tosses with an "H" signifying a heads and a "T" signifying tails. Which of these two do you think is random?

HHTHTTHTHTHHTTHTHTHT

THHHHTTTTHTTHHHHTTHH

Most people will identify the top sequence as being random. This sequence has a lot of alternations between T's and H's but very few runs of any length. This sequence was made up by the author to appear as if it were random. The bottom sequence is actually random, created by a random number generator. As you can see, truly random sequences can have runs of long length. A random outcome on any given trial is equally likely. With two options there is always a 0.5 probability that either a head or tail will turn up. Random patterns have no "memory". The probability of their outcomes remains the same regardless of how long a run has occurred. A failure to understand this principle, known as the "gambler's fallacy" has resulted in a lot of lost fortunes. Just because you have lost the last 10 pulls on the slot machine does not mean that you are any more likely to win on the next: the probability of a loss after a long run of losses is still as equally likely as a win.

Richter in his work has put up to 196 different 5 x 5 or 10 x 10 color panels. Each cell space in these square grids is randomly assigned one of twenty-five different colors. Runs of similar colors will appear. However runs in this case can occur horizontally and also vertically, since runs on adjacent columns can accidently line up. The results are clusters of similar color. When one looks at one of these pieces they might imagine that the artist created them deliberately. This however is just an illusion as the likelihood of a given color being chosen and assigned to each cell is always the same on each trial.

Detecting Counterfeits

Mathematicians have developed a new tool for analyzing patterns adding together different families of waves, or wavelets, together. We won't go into the technical details on how this works here but describe in a more qualitative way. Researchers using this technique start with a very high resolution scan of an image such as a painting. The wavelet description consists of a numerical representation of the fine level detail of a painting. This would include information about what colors and textures there are and how close they are to each other.

The wavelet procedure has been used to test if paintings are originals or copies. In 2005 the Dutch TV program NOVA issued a challenge to members of an image processing conference in Amsterdam. They were asked to distinguish a real Van Gogh painting from five other copies created by an art restorer named Charlotte

Caspers. Three teams at the conference, using wavelet analysis, were all able to successfully identify the copies. The particular strategy they used was based on an assumption that an original would be painted more quickly, using a series of smaller brushstrokes than a copy. This is because the copyist would presumably be more focused on getting the exact pigments, stroke orientation and other details correct.

Caspers later issued another challenge, this time that researchers be able to distinguish her own paintings from copies of her own paintings that she herself made. The brush stroke fluency assumption used earlier was less successful in this case. It didn't work when particular types of brush were used, or when the resolution of the scans was not high enough. But as a result of studying originals and copies made by the same artist, scientists can now develop more powerful means of analysis. Other interesting applications of these techniques are in reconstructing portions of original work that have been damaged and in generating new artistic styles.

The stakes in detecting fake paintings are high since works attributed to original artists can sell for one hundred million dollars or more. To give you an example, the most expensive work sold at auction in 2015 was Pablo Picasso's *Les Femmes d'Alger*, that went for $179 million dollars. Table 3.2 provides some descriptive statistics on the most costly paintings ever sold. Many of the most exorbitant art transactions take place through private deals rather than at auction. In recent years wealthy individuals in the Gulf and China have been purchasing many of these outrageously expensive paintings.

Table 3.2. The top 10 most expensive paintings ever sold. Prices adjusted for inflation, based on telegraph.co.uk

Ranking	Artist	Painting	Price	Buyer Information	Year
1.	Paul Gauguin	*When Will You Marry*	$300 m	Qatar prime minister, Hamad bin Jassim bin Jaber Al Thani	2015
2.	Paul Cezanne	*The Card Players*	$274 m	Hamad bin Jassim bin Jaber Al Thani	2011
3.	Mark Rothko	*No. 6 (Violet, Green and Red)*	$186 m	Russian billionaire Dmitry Rybolovlev	
4.	Pablo Picasso	*Les Femmes d'Alger*	$179.3 m	Hamad bin Jassim bin Jaber Al Thani	2015
5.	Jackson Pollock	*No 5, 1948*	$165.4 m	David Martinez (disputed)	2006
6.	Willem de Kooning	*Woman III*	$162.4 m	Steven Cohen, hedge fund billionaire	2006
7.	Pablo Picasso	*Le Reve*	$158.5 m	Steven Cohen	2013
8.	Gustav Klimt	*Portrait of Adele Block-*	$158.4 m	Ronald Lauder, cosmetics magnate	2006

		Bauer			
9.	Vincent van Gogh	*Portrait of Dr. Gachet*	$152 m	Japanese industrialist Ryoei Saito	1990
10.	Francis Bacon	*Three Studies of Lucian Freud*	$145 m	Elaine Wynn, co-founder of a casino empire	2013

More Math and Musical Art

Pop Music and the Magic Equation

In 2012 a research team at Bristol University in the U. K. came up with an equation that predicts the success of a pop music song. The equation starts by identifying twenty-three different characteristics of pop music like tempo, duration, loudness, and beat variation. It assigns each of these features a different weight and then adds them all up. A weight is usually a decimal fraction that runs between zero and one, with higher fractions indicating greater importance. So the weight 0.87 applied to a feature means that feature contributes more to the overall score than say a weight of 0.24. The weights were determined by analyzing the features of past pop songs to see which ones were associated with their success measured by the song's ranking in the hits list.

Musical tastes change over time, so the analysis had to take this into account, changing the weights slowly over time to account for shifts in taste. For instance danceability as a feature was more predictive of success in the early 1990s than was loudness, but both loudness and danceability were together predictive of success in the 2000 decade. The equation was able to predict with some accuracy how successful many past songs were. For example, the hit "I Gotta Feeling" by the Black Eyed Peas received a score of 8.9 out of 10. Other songs the equation predicted well over the history of pop music were Elvis Presley's "Suspicious Minds" from the 1960s, "Get It On" by T. Rex in the 1970s, and "If You Don't Know Me by Now" by Simply Red in the 1980s.

Bells and Permutations

Church bell ringing has been practiced in England since the twelfth century but starting at around 1600 a new style emerged. The goal originally was to make the bells more audible over longer distances but it turned into an art form unto itself, now called "campanology". Bell ringing serves many functions including telling the time, announcing weddings or other community events and issuing warnings. The bells are run by a group of ringers who traditionally had to commit the sequence to memory. No musical scores are allowed but a conductor leads the group.

If there are four bells then we can number each of them starting with 1 to represent the smallest bell with the highest note called the treble, to 4 with the lowest note, called the tenor. Most performances start off with the sequence or row of 1234, in descending frequency. This starting row is called a “round”. Following this the rules are that each bell is rung once only in a row. Many church bells are heavy and difficult to control, meaning it is difficulty to play complex melodies, especially where the same bell has to be rung twice in a row, so this rule of allowing one bell per row may give each bell time to return to its starting position.

A second rule is that each bell can move only one place in position when the row is next played (so that 1234 -> 2134 is allowed but 1234 -> 2143 is not). Also no row can be repeated except at the end when the round is played a final time. The total number of different sequences that can be played is expressed by a permutation, expressed as 4! that is 4 x 3 x 2 x 1 = 24. Permutations grow quickly in size. The total number of sequences for eight bells is 8! = 40, 320, so an increase in the number of bells means a large increase in the number of possible rounds that can be played. Table 3.3 shows an example of one performance of four bells called “Plain Bob” that runs through all 24 permutations. The study of permutations actually started as part of campanology in the 1600s by Fabian Stedman but was not formally included as a part of mathematics until the 1770s.

Table 3.3 The order of church bells played in “Plain Bob”. 1 is the highest pitched bell and 4 is the lowest. The performance starts off and ends with the round 1234.

1234	2314	3124
1243	2341	3142
1423	2431	3412
4123	4231	4312
4213	4321	4132
2413	3421	1432
2143	3241	1342
2134	3214	3124
		1234

Physics – Its not just Rocket Science

Space and Time

Barrow (2014) discusses the relation between different types of art with space and time. Space can exist in one-, two-, or three-dimensions. Each of these corresponds to a line, plane or volume, respectively. Friezes are an example of one-dimensional art. These are linear patterns that decorate buildings and other surfaces. We discuss these more in the section on symmetry. Paintings are art in two-dimensions, since they have a length and a width on a planar surface. Sculpture is an art form that exists in a three-dimensional space or volume. Sculptures have a length, width, and a height. Fractal dimensions represent the spatial aspect of patterns and can be in fractional values between the whole number integer values.

Time is another aspect of the physical world that must be considered along with space. Space is always combined with time, since the two exist together in any situation. Music is an artwork that has one-dimension in space along with time. Music is temporally linear, one note or chord occurs after another in a sequence. In this sense, it is like a temporal frieze. Film is an artwork that has two-dimensions in space along with time. We have the movie screen in two-dimensions and the sequence of film stills along with the soundtrack as the time. Theater is an instance of art that takes place in three-dimensions of space along with time. In this case the actors are moving around on a three-dimensional stage and speaking the dialog, which is the temporal component.

There are even more complex possibilities. We can have theater that contains film and music. For example, a play could have some of its characters watching a movie on a screen with a movie soundtrack. The characters in the play could be talking to themselves about the movie while they are watching it. This would be taking three-dimensions of space, one of time for theater and within that two-dimensions of space and one of time for the movie. So if we added up all of these it would be seven-dimensional art. Table 3.4 shows in the first two columns spatial dimensions with their representative art forms. In the last two columns it shows examples of art that correspond to the combination of different spatial dimensions with time. In all of this time always has just one dimension.

Table 3.4. The two columns on the left show examples of art for differing numbers of spatial dimensions. The two columns on the right show different examples of art with varying spatial dimensions combined with a single dimension of time. After Barrow (2014).

Space Dimension S^N	**Art Form**	**Space Dimension S^N x T**	**Art Form**
N = 1	Frieze	N = 1	Music
N = 2	Painting	N = 2	Film
N = 3	Sculpture	N = 3	Theater

Physics and Beauty

Frank Wilczek, winner of the Nobel Prize in physics in 2004, asks the interesting question of whether the world is a work of art. If it were then the Creator (God) would be the artist in a religious conception. Most religions ascribe various motivations for the creation of the universe such as goodness, righteousness and benevolence, but artistic ambition is not one of them. As a scientist, Wilczek believes it is possible to uncover the laws that govern the universe. He thinks those laws as well as the forces and products they create are inherently beautiful because they follow elegant principles like economy and symmetry. In his 2015 book, *A Beautiful Question: Finding Nature's Deep Design*, he tours the ancient and modern history of mathematics and physics, showing that people like Galileo Galilei, Johannes Kepler, Isaac newton and James Clerk Maxwell all searched for beauty and it was their quest, not always their results, that were beautiful.

Kepler early in his career thought that the orbit of the planets could be modeled by Platonic solids of different sizes, each encompassed by spheres. This produced circular planetary orbits. This model is simple but ultimately was proven incorrect. Kepler himself later in life modified his ideas and more accurately described the planet's orbits using ellipses. However, in first conceiving of the orbits as spherical, he was in a good position to then determine the differences between the observed data and his theory. This ultimately made it easier for him to later refine the model and get closer to the truth.

This echoes a notion in science that all other things being equal, a simpler theory is more likely to be correct. This has sometimes been embodied in the dictum of Occam's Razor: Among competing hypotheses, the one with the fewest assumptions should be selected. Wilczek himself notes that this is not always the case. The best theory is the one that accounts for the most data. In other words, it is the one capable of generating the most testable hypotheses that are proven true, or more accurately stated, hypotheses that are supported since falsifiability is always a possibility. If this were the case, then the best theory could in fact be quite complex. Einstein seemed to understand this, as he stated that things should be made as simple as possible, but not simpler

In physics there are several fundamental forces. They are the electromagnetic force, gravitation, and the strong and weak nuclear forces. One of the holy grails of physics is to come up with a set of equations that can unify and describe all of these forces in a simple way. The Standard Model does a good job of doing this. In addition it classifies all of the subatomic particles currently known. However it is far from perfect, as it does not incorporated a full theory of gravitation as described by general relativity. Nor does it account for dark matter or dark energy, believed to be behind the accelerating expansion of the universe. Wilczek argues that the Standard Model (a slight variation of which he calls The Core Theory) embodies beautiful ideas. The equations for atoms and light in the model are almost literally the same equations governing musical instruments and sound. It thus accounts for a wide variety of phenomena using a small number of descriptors, displaying the property of economy.

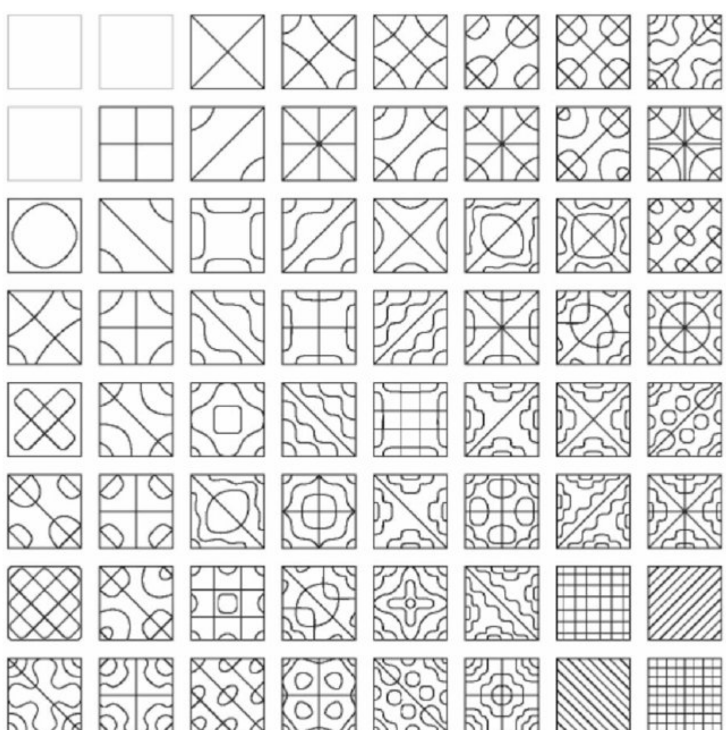
According to Wilczek beauty in nature and theories about nature have two features. The first is symmetry, by which he means harmony, balance and proportion. The second is economy, which is producing an abundance of effects from very limited means. Symmetry abounds in nature and in art. Humans like to look at visual symmetries. Symmetry also manifests itself in the laws of physics. They can very often be described mathematically and exploited to simplify many problems. The speed of light has the same value in all frames of reference, which is the symmetry group of special relativity. Also there is the invariance of the form of physical laws under coordinate transformations in general relativity, another example of symmetry.

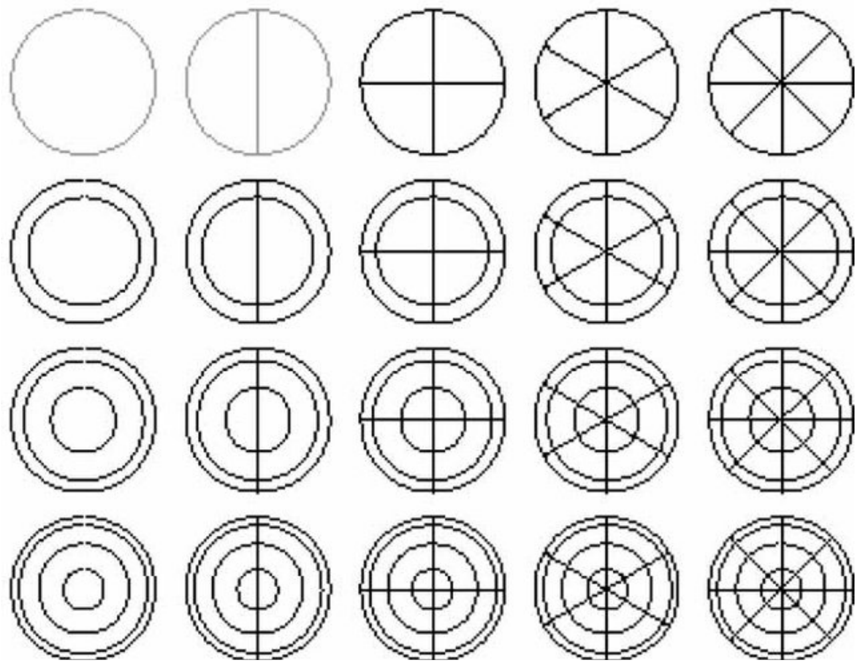
Economy is shown throughout nature as well. Most complex phenomena we see in the world are the product of a fairly small number of elements governed by a few laws. The laws govern the way the particles can combine and interact. For example, there are currently 102 elements in the periodic table. Yet these can combine in many ways to create the vast number of organic and inorganic molecules we know. These molecules in turn give rise to biology and yet more complexity. Another example comes from the brain. The brain is made of neurons whose basic signaling properties are understood. But if we include vast numbers of them and interconnect them in complex ways, the simplicity produces complex phenomena like thought and consciousness. In what follows we will show examples of patterns produced by the laws of physics that exhibit symmetry and economy (simplicity), two of Wilczek's criteria for beauty.

Chladni Patterns

Surfaces vibrate and in so doing can display harmonic and resonant patterns. All sounds are made up of harmonics that are different frequencies in a particular relation to one another. Ernst Chladni in 1787 was able to demonstrate these sound patterns visually by scattering sand onto a square plate and then rubbing the side with a bow from a musical instrument. He was also able to vibrate the plate in ways other than using a bow. Certain notes, some of them harmonics of each other would produce different patterns in the sand on top of the plate. Places where no vibrations occur are called nodal lines and it is along these areas where the sand gathers. He found that different shaped plates produced different patterns. A triangular plate, for instance produced triangular patterns and a circular plate produced circular patterns. Figure 3.28 shows examples of circular and square Chladni patterns.

Figure 3.28. Examples of circular and square Chladni patterns. Adapted from Waller (1961).





Lissajous Figures

The French mathematician Jules Lissajous in the mid nineteenth century created a small experiment. He attached a tiny mirror to the tip of a tuning fork and then aimed a beam of light at the mirror. The reflection was then directed to a dark screen by being bounced off another mirror. Striking the tuning fork now produced a sine wave, depicting the vibration visually. A sine wave shows the up and down motion of an object. It can represent patterns of light or sound. If Lissajous placed another tuning fork with a mirror at right angles to the first he could now show the simultaneous motion of two vibrating objects superimposed on top of one another.

The pattern that results depends on the frequency ratio of the two forks. When they are in a 2:1 ratio as in an octave, the visual pattern is a figure eight. Major and minor thirds as well as other musical ratios can now be viewed visually. What is interesting here is that many of the frequency ratios that sound consonant also look pleasing to the eye. The things that we find beautiful are not always confined to the modality of a single sense. Consonant frequency ratios are thus examples of "deeper" aesthetic principles at work.

Harmonographs and Harmonic Patterns

Professor Hugh Blackburn, a professor of mathematics at the University of Glasgow, is believed to have invented the harmonograph in 1844. In the lateral version of this instrument there are two pendulums suspended from a table. One of the pendulums contains a small platform with a piece of paper attached to it. The other contains an arm with a pen. The combined motion of both pendulums gets transmitted to the pen, which traces out a pattern onto the paper. The frequency of vibration for the arms can be adjusted by sliding a weight up or down their lengths. Different frequency ratios can be created by the relative heights of these weights. A rotary version contains three pendulums, two of which are spinning, i.e., they have a rotatory motion. Different patterns can result when these are spinning in the same or opposite directions. These patterns are both simple and beautiful. They were very popular in the late 1800s. A portable version of the harmonograph could even be folded up into a container and brought to a party!

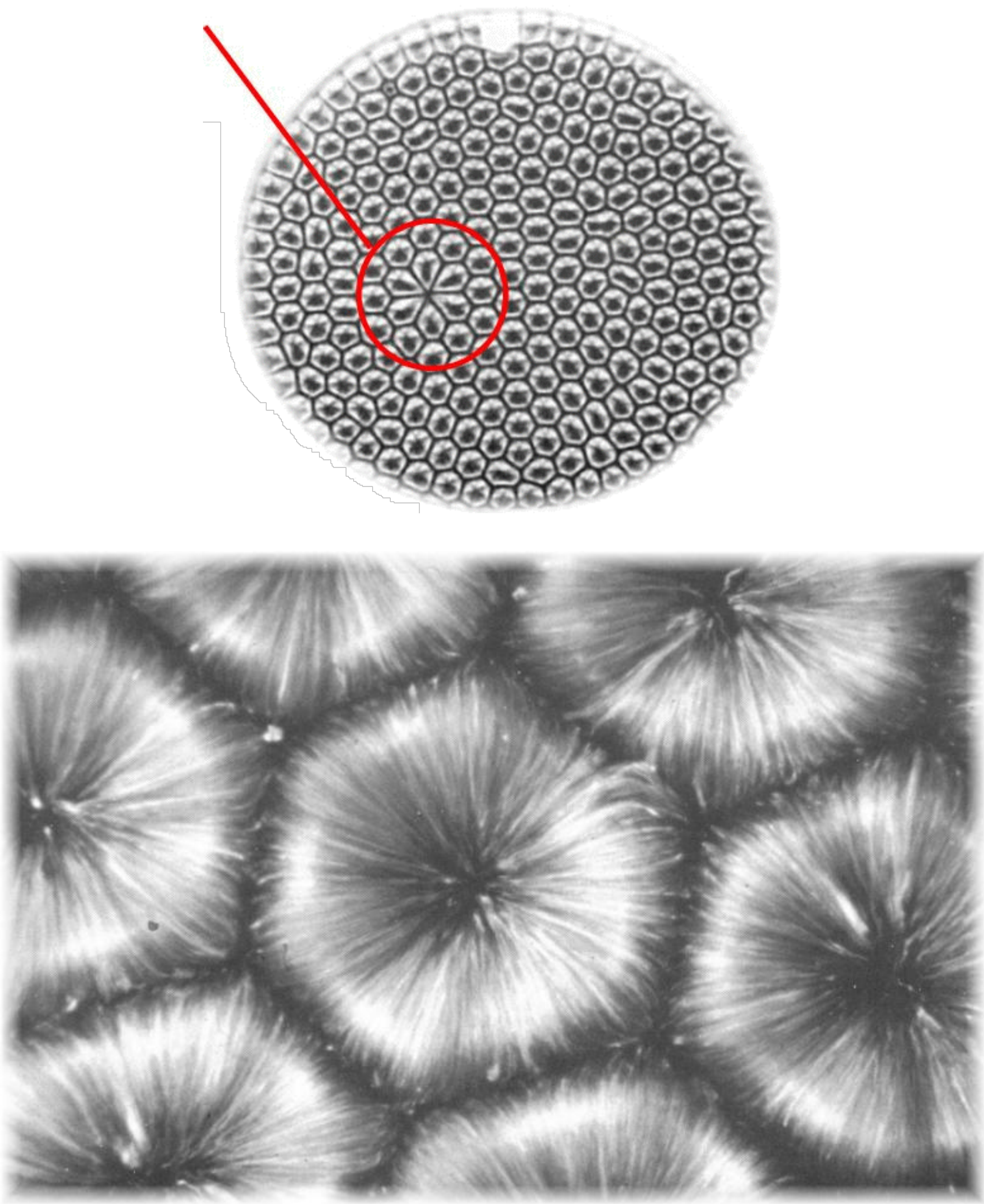
Rayleigh-Benard Cells and Thermodynamics

According to thermodynamics, energy in any system always “seeks” to flow as fast as possible (Odum, 1988). It turns out that structured energy flow moves more quickly than that which is less structured. For example, energy flow is faster in a chimpanzee than it is in an amoeba because the chimpanzee is more structured and ordered. We can therefore see the creation of order and organization in the universe as driven by energy flow. This property of dissipative efficiency then could cause systems to become more ordered with time. If we plot energy flow over the time course of the evolution of life we see a dramatic increase. Energy flow, measured as metabolic rate, gets faster as organisms evolved over several billion years on earth (Swenson, 1989).

Energy flow can also explain why reorganization occurs within a given system (Goerner, 1995). If the pressure to flow builds up, energy cycles faster and faster within the system. The energy eventually reaches a limit on how fast it can flow. If this limit is reached and the resistance to flow is still less than the pressure driving the flow, a reorganization takes place. A bifurcation occurs and the pattern restructures itself into a more efficient configuration that can dissipate energy better.

A good example of this are Rayleigh-Bénard cells. If a thin layer of silicon oil is heated in a pan, the oil particles at first move randomly. As the temperature is increased, this pattern no longer dissipates heat well. There is a sudden reorganization into hexagonal-shaped cells where particles rise in the center of each cell and fall near its edges. This new arrangement is better at dissipating heat. If the temperature is increased further even more complex arrangements, such as rotating spiral patterns develop. Figure 3.29 shows some examples of these cellular patterns.

Figure 3.29. Some examples of Rayleigh-Benard cell patterns. Image sourced from NOAA Physical Sciences Lab. psl.noaa.gov



Li Symmetries, Self-organizing Systems and Emergence

Li symmetries are all around us. The forces of nature create these by acting on material surfaces over time. Examples of Li symmetries include ripples in sand caused by the flow of water, dried cracks in mud, the stripes on a zebra and the texture of bark on a tree. Alan Turing, the British mathematician was the first person to develop their mathematical properties in the 1950s. The Chinese though, have been studying them for thousands of years. Li symmetries are examples of self-organizing systems. Self-organization is a process by which the internal organization of a system increases in complexity without being guided or managed by an outside source. In self-organization, the pattern at the global level emerges solely from interactions among the lower-level components. The rules specifying the interactions are executed using only local information, without reference to the entire pattern (Camazine & Deneuburg, J. L. 2001). There are numerous examples of self-organization in the physical, biological, and human realms. These include crystal growth, chemical autocatalytic sets, bird flocking, cellular automata and various phenomena in economics.

Self-organizing systems typically display emergent properties. The concept of emergence is that the features of a whole or complex are not completely independent of the parts that make them up. They are said to go beyond the features of those parts or emerge from them. Many phenomenon in the natural world seem to be emergent. In fact, emergence has been used to explain almost everything from the big bang to the human mind. Holland (1998) describes several features of emergence. Emergent systems are made up of interacting parts. The function of these systems is rule governed. These rules are invariant even though the parts or components of which they are made do change over time. In fact, the states or processes of these systems are in constant flux; we say they are dynamic. Their dynamic and constantly changing nature gives rise to novelty; a non-stop parade of new patterns or behaviors that are difficult if not impossible to predict.

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There is another sense in which things change but stay the same in emergent systems. Holland (1998) calls this persistence. This is where patterns of interaction persist despite a continual turnover of their constituent parts. He cites as an example the standing wave in front of a rock in a white-water river. The water molecules making up the wave are constantly changing, but the global wave pattern remains. So we can say that although the rules and particular patterns of emergence are invariant, their parts are always on the move. Perhaps the reason we find Li symmetries and other self-organized patterns beautiful is because they reflect fundamental properties of the natural world and of ourselves. We are the product of self-organizing forces and mental phenomena like consciousness could be the result of emergent processes in the brain.

Art History and Physics

Leonard Shlain, in his book *Art & Physics: Parallel Visions in Space, Time, and Light*, shows that artists throughout history have often portrayed or anticipated new insights in physics. In this section we will summarize some of these comparisons. In his introduction Shlain notes that art and physics are both concerned with organizing perceptions and that they often deal with the same concepts like “volume”, “space”, “mass”, “force”, “light”, “color” and “density”. The two disciplines also sometimes strive for the same outcomes, these corresponding to the concepts “elegance”, “symmetry”, “beauty”, and “aesthetics”. While physicists try to *explain* the world in thoughts and imagery, artists try to *portray* this very same world, also using thoughts and imagery. In the coming paragraphs we will take a relatively quick walk through the history of art looking at parallels in how physicists and artists understand space, time, light, mass and energy.

Linearity, Proportion, and Ancient Greece

The ancient Greek mathematician Euclid was the first person to systematically describe the nature of space. In Euclidean geometry the shortest distance between two points is a line, meaning that space is uniform and homogenous. It can be cut into lengths and is measured using units as we do with a ruler. In the Euclidean concept of space objects can be placed in it and moved around without either the object or space being affected. The ancient Greek philosopher Aristotle also fashioned our traditional concept of time. He characterized it as being linear with a past, present and future. Events occur in time and can be ordered sequentially. Light also had a linear element. Plato thought that light shot out of our eyes to illuminate objects while Aristotle (correctly) believed that light rays shot out of the sun and bounced off of objects into our eyes, enabling us to see them.

This emphasis on linearity can be seen in ancient Greek art. Friezes ran in a straight line across the top of buildings. Ancient Greek artists often positioned their figures in a linear orientation that depended on the horizon line. These architects even made the outer columns of temples more thick than the inner ones because they believed light rays would actually dissolve them more quickly.

Ratios play an important part in Greek art. A ratio is the proportion of the length of two lines to one another. They believed that the golden ratio was especially beautiful in part because many of the features of the human face are in this proportion to one another. The proportions of the Parthenon were also constructed using phi. The ancient Greek artis Polyclitus wrote a book called *Kanon* (Rule), in which he outlined the measured proportions between the different parts of the human body. He formed a theory of aesthetics based on these measures. His sculpture *Doryphoros*, the *Spear Bearer*, was designed to illustrate these ideas..

Discontinuous Space and the Middle Ages

Shlain argues that space during the medieval period became fragmented. The Christian church dominated Europe during this time. Heaven and hell in their belief formed two spaces that were different than the space of the living on Earth. Time also seems to have fragmented. In history according to St. Augustine, nothing occurred before Genesis. Time began the creation of the universe and would end on Judgment Day. The future would then disappear and be replaced by eternity during which nothing ever "happens", i.e., there would be no history at least in the human sense after then.

This fragmentation of space is reflected in the Christian art of the mosaic. A mosaic is a picture made up of small pieces of colored glass and tile laid adjacent to one another (Figure 3.30). Discontinuous space of this sort is seen in Christian frescoes, paintings and stained-glass windows. Time is also fragmented in some early medieval paintings where a figure is represented multiple times in different locations and postures. Light during this time was nonlinear and did not travel from one source through a given space and time. Instead it emanated from the spiritual world and manifested in the physical world in the form of halos around the heads of religious figures like Christ, angels and saints. Light was believed to come from the soul that lay in another world. Books during this period were "illuminated" so that light could come *through* the page rather than bounce off of it.

Figure 3.30. Mosaic of Christ from a church in Cambridge. Image from PublicDomainPictures.net.

Perspective, Shadows and the Renaissance

In the Renaissance era artists began to think of the third dimension of space, not just left and right and up-down, but also near and far. The correct way to portray objects in space pictorially is called perspective. It assumes that there is a single observer of a scene and that objects converge toward the horizon. Also implicit in depth is that objects that are closer to the observer will cover or obscure those that are farther away. The medieval painter Giotto di Bondone uses the rules of perspective but also violates them. In his painting *The Pentecost* (1305) the halos of the figures facing the viewer are behind their heads as usually depicted in a religious interpretation. However the halos of those facing Christ are shown as in front, otherwise they would obscure the heads of those figures, producing an absurd paradox (Figure 3.31).

Figure 3.31. *The Pentecost* by Giotto di Bondone, 1305. Image in public domain. Sourced from wikiaart.org.

The Renaissance also saw the use of the shadow, first introduced by the Florentine artist Piero della Francesca. Shadows assume that light travels in a straight line and that it cannot pass through an object. Artists of this time have reverted back to the Aristotelian conception of light as coming from the sun and not from a spiritual source. Painters of this era also noted that shadows have crisp edges in bright sunlight where there is a sharp transition from dark to light, called chiaroscuro, translated as “clear-dark”. More distant shadows are softer and fuzzier. This effect was deemed “sfumato”, meaning “turned to vapor” and was noted by Leonardo da Vinci. Objects in landscape paintings that are far away will have softer edges and are lighter and bluer in color. This is because there is more air between the viewer and these objects due to atmospheric haze. The painter Francesco Grimaldi in 1665 described interference fringes around shadows and said these were caused by the flow of light around an object. He believed that light acted more like a wave than a stream of particles, predating the first wave theory of light in physics that was proposed by Christiaan Huygens in 1678.

Determinism and the Romantic Movement

The Romantic period of art started in the late 18th century and peaked between 1800 and 1850. During this time period painters, writers, poets and intellectuals emphasized emotion and intuition over science, logic and reason, reacting against these Enlightenment values. Scientific determinism postulates that we can predict the future based on the past if we know all of the relevant forces. Determinism operates within the framework of causality in which one or more events occur before others in time and cause them to happen. Causality and determinism allow us to predict even what a person might do if we knew all of the physical forces involved. This takes away from the notion of free will, which is that we ourselves ultimately determine our own actions.

Many Romantic era writers expressed dismay over determinism believing it made the world seem sterile and humans powerless. The poet and painter William Blake was one of these. He not surprisingly omitted perspective from his paintings. He additionally believed that time and space were shaped by our subjective experience as is evident in this line of poetry from his *Auguries of Innocence*:

> To see a World in a Grain of Sand
> And a Heaven in a Wild Flower,
> Hold Infinity in the palm of your hand
> And Eternity in an hour

Blake was an avowed anti-rationalist. He believed his fellow artists in the academy were slavishly adhering to science and the conventional ways of doing art. His belief was that these methods were squelching individuality and true expression.

The Art and Science of Photography

It is difficult to say when the art of photography first arrived as there have been many devices for capturing images created over the centuries. The first of these was the camera obscura, created by the Arab physicist Ibn al-Haytham in 1021 AD. A camera obscura is a box with a pinhole at one end. The image comes through the hole and is projected upside down onto a viewing surface at the other end. A person can then trace this image on a piece of paper. There is some debate now whether the Italian artist Canaletto used one to create his magnificently detailed paintings of Venice in the 18th century. Cameras are interesting because they allow us to stop the flow of time, to freeze a two-dimensional spatial record of a moment and study it in detail.

A camera is both an artistic and scientific instrument. In 1544 the Dutch mathematician Reiners Gemma Frisius used one to observe and record a solar eclipse. In 1872 Eadweard Muybridge used a series of cameras triggered by tripwires to record the way in which a horse gallops, discovering that all four of a horse's hooves are off the ground at one point in the gait cycle. Photography as an art and science cannot really have begun until there was some method of preserving the image other than tracing it by hand. This occurred in 1816 and evolved into practical photography with the invention of the daguerreotype in 1837. The daguerreotype was the first camera small enough to be carried around and which could reliably capture an optical image on film.

Curved Space and Manet

The German mathematician Georg Riemann in 1854 proposed that there may be non-Euclidean spaces in which the shortest distance between two points is an arc rather than a straight line. In a Riemann space, two straight lines are not parallel and do eventually meet. A traveller existing in such a space and travelling in a straight line would eventually end up where he started, as is the case if one were inside a giant donut or the outside of a sphere. Objects inside a Riemann space do not maintain absolute form and change shape depending upon their location.

Some of these ideas of curved space came up a few decades after this in Einstein's views on space and mass. According to Newtonian physics, space was everywhere the same and objects did not change based on where they were located. Einstein however, showed that mass can bend space. Imagine a trampoline with nothing on it. This is how Newton conceived of space. Now imagine throwing a cannon ball onto the trampoline. The cannon ball will cause the trampoline to sag downwards. This is what a large mass will do to space. The cannon ball in this example is like a planet that warps space around it. Objects close to the planet will travel down this space toward it just as a smaller ball placed on the trampoline will spiral in toward the cannon ball.

Edouard Manet shocked the French art world with his paintings and in so doing mirrored these ideas of altered space coming from math and physics. He deviated from classical traditions in painting with willful violations of the laws of perspective, alterations to the ordering of foreground and background, and with multiple lighting sources. But most interesting was how he bent space in his paintings. His 1862 work *Music in the Tuileries* demonstrates this (Figure 3.32). It shows a party in the forest where there is no vanishing point, where all of the tree trunks arc, all of the men's hats are tilted and the horizon line curves. In other paintings he eliminated the horizon line altogether by portraying very close in scenes. Many of these techniques had never been done before in Western art and they predated the concepts of curved space-time that Einstein would introduce 50 years later.

Figure 3.32. *Music in the Tuileries* by Edouard Manet, 1862. Image in the public domain. Sourced from Wikimedia commons.

Time, Impressionism and Futurism

The impressionists also stunned the art world in the late 19th century by deviating from classical norms. They used intense saturated colors, omitted details and painted what they thought a scene looked like rather than portraying it objectively. Claude Monet, perhaps the best-known impressionist, also experimented with time. He thought that painting an object at one point in time was insufficient to capture what its nature. To convey the essence of an object he instead painted what it looked like at multiple points in time. A good example of this is his Rouen cathedral series begun in 1891 where he painted the front of this French cathedral from the same position but at different times of day. In all, he created 40 separate such works. Monet thus represents visually the idea in physics of space-time, that objects have three spatial dimensions and one temporal dimension.

The impressionist artist Paul Cezanne represented time and light in a different way. He showed scenes in which time seems to have disappeared altogether. The light is diffuse rather than coming from a specific direction, so there is no sense of whether the painting was done in the morning, noon or afternoon. As a result his landscapes and other scenes have a quality of timelessness to them. Cezanne also experimented with perspective. In his *Still Life with Fruit Basket* (1888-1890) he shows different objects on a table each viewed from a different perspective, with a basket viewed from below and a vase viewed from above (Figure

3.33). The result is a bit disturbing, as if the viewer exists in multiple places simultaneously or that the objects in the scene have jumped around.

Figure 3.33. *Still Life with Fruit Basket* by Paul Cezanne, 1888-1890. Image in the public domain. Sourced from Wikiart.org.

Futurism was an artistic and social movement the originated in Italy early in the 20th century. It emphasized speed and technology among other things and included all types of art like painting, sculpture, graphic, industrial and interior design, film, literature, music and architecture. Some of its proponents include Filippo Marinetti, Umberto Boccioni and Carlo Carra. Marinetti argued that one should erase the past in order to live fully in the present. Speed is a constant emphasis by futurist artists who showed fast moving bicycles, cars and trains.

Visually the futurist artists attempted to portray the future by incorporating motion into a stationary image. They did this by superimposing a series of still shots into a single photograph or canvas, allowing the viewer to see the past, present, and future all at once. Perhaps the best example of this is the 1912 *Dynamism of a Dog on a Leash* by Giacomo Balla (Figure 3.34). It shows a little dog being taking for a walk by its owner. One can see the movements of the dog's legs and tail as they swing back and forth tracing arcs through space.

Figure 3.34. *Dynamism of a Dog on a Leash* by Giacomo Balla, 1912. Image in the public domain. Sourced from Wikiart.org.

According to of Einstein's relativity theory, the precise sequencing of events in frames of reference becomes muddled. However at the speed of light these frames come together and time effectively comes to a stop, meaning there is no movement. In effect, at light speed in space-time, all events are simultaneous. This situation is exactly what the futurists were showing: movement of the past, the now and the future all happening at once. Whereas the impressionists were showing time across several different paintings the futurists were showing it in a single image.

Color and the Fauves

Shlain continues with a discussion of relation between color in art and physics. Color in physics is the joint property of an object and the light that shines on it. An apple is red for example because it reflects red wavelengths of light and absorbs the remaining wavelengths. Likewise the leaves of a tree are green because they reflect or bounce back green wavelengths and absorb the others. Photoreceptors in our retina pick up these wavelengths and interpret them to be the designated color. We thus think of color as an object property, red being a characteristic of the apple and green being the characteristic of the leaf. However, when objects are traveling, their color characteristics change based both on the speed of the object and the location of the observer.

The Doppler effect, named after the Austrian physicist Christian Doppler, is the change in the frequency of a wave for an observer moving relative to its source. A classic example of this is when an ambulance drives past. The pitch of the siren sounds higher as the ambulance approaches a stationary observer and lower as it recedes. This is because the waves "bunch together": as the emitting source gets closer, the distance between the waves gets smaller and the frequency increases. Conversely, the waves "spread out" as the emitting source moves farther away. The distance between the waves now gets greater and the frequency decreases. This effect also holds for light. An object moving away from an observer shifts into the red end of the spectrum while one approaching shifts to the blue. So color, rather than being an inherent characteristic of an object, can actually be observer-relative.

The fauvist movement in art that started in 1905 was characterized by the "inappropriate" use of color. Artists like Andre Derain and Maurice de Vlaminck painted landscapes where green leaves could be blue, blue water could be green and a brown mountain could be red. The art world had never witnessed this application of color. One reviewer mentioned that the paintings were like wild beasts (fauves, in French) and the name stuck. The fauves arbitrary use of color parallels the relativistic notion of color that we see in physics. However while color changes in physics are understood and occur under specific conditions only, the fauves were far freer to interpret and assign color in whatever way they wished.

Emptiness and Asian Art

Traditional Western art rarely features large parts of the canvas as being empty. Art in this tradition is about "something". For example in a still life this would be fruit, in a portrait a face and in a landscape a tree. It wouldn't have made sense in most 18th century European paintings to portray a large empty sky devoid of any features because in the Euclidean sense, space is "nothing". The use of pared down design elements did eventually emerge in Western visual arts and music but not until the 1960's and 1970's where it was known as minimalism. Eastern philosophy views space differently. In Zen teachings empty space has the possibility of generating substance and of giving rise to things. Space in this view is not the absence of anything, but the place where things begin.

Discoveries in physics now seem to support this notion as quantum fluctuations can produce particles of matter out of what seems to be an empty field. For some years it was believed that the neutron and proton were the smallest possible particles and that they could not be broken down any further. We now know that this is not the case. Results from colliders in which particles are shot at each other at great speed show ever smaller and smaller particles like quarks and the Higg's boson.

The universe as a whole instead of collapsing into the "Big Crunch" is actually expanding at an accelerating rate. The accepted explanation for this is the presence of dark energy, an unknown form of energy hypothesized to permeate all of space. Dark energy is estimated to be 68% of the total energy in the observable universe. Dark matter, an invisible form of matter, is so dense and small that it cannot be detected but it is believed to make up 27% of the universe. So-called "ordinary" matter only makes up about 5% of the universe.

Empty space and absence play a prominent role in Asian art. Many Chinese landscape paintings show blank areas of a scene that are filled in by the observer to become mist, fog, or waterfalls (Figure 3.35). The Japanese concept of Ma means "gap", "space", or "pause" between two structural parts. It is not created by the painting or artwork but instead is intended to take place within the imagination. An example of Ma in architecture could be a sliding door that allows outside space to be joined with inside space. Wabi-sabi is another Japanese concept that takes on many meanings, including imperfection, impermanence and incompleteness (Koren, 1994). Absence is a part of the wabi-sabi aesthetic and is demonstrated in Zen gardens where there are large spaces of raked gravel between rocks.

Figure 3.35. A Chinese landscape painting showing the use of empty space. Released by Peter Griffon. Image sourced from publicdomainpictures.net.

There are many other examples of empty space in Asian art. In origami, folding a flat piece of paper in a set sequence produces objects like birds. These more complex objects seem to come out of the nothingness of the blank paper sheet. In the practice of bonsai miniature trees in pots are trimmed into aesthetically pleasing shape. It is the removal of substance from the tree that makes it beautiful. Although bonsai is a Japanese practice, the art form actually began in China where it is known as penjing. In haiku, very few words are used to convey an image, which must be completed in the reader's mind. For example in the following haiku (by the author) the details of the scene and what is actually said or not said isn't specified:

the words we say
and the words we don't
winter fog

This poem could refer to a couple taking a walk on a foggy winter day, but who are the couple? Is it a husband and wife? Two friends? Are they having a problem with their relationship? Haiku has more appeal because of what it *doesn't* state. The Japanese term yugen, translated as "deep" or "mysterious" can be used to describe aspects of this quality.

Cubism and Relativity

According to relativity when moving at the speed of light the space outside the traveller's frame of reference in front and behind unify so that the space seen is infinitely thin. The front, back and sides can be imagined to be all in the same current location. In effect each of the locations group together to exist simultaneously. This phenomenon is portrayed in the style of art known as Cubism, where objects, rather than painted as seen from a single viewpoint, are painted as seen from multiple viewpoints. The Cubists would paint an object such as a women's face as seen from the front, the sides and the back, all next to one another. So instead of just one face, there might be three or four different versions of the same face all coexisting alongside or part of one another (Figure 3.36).

Figure 3.36. A portrait of a face in the style of Picasso. Image sourced from PublicDomainPictures.net.

Cubism originated in the early 20th century and refers mostly to art produced near Paris during the 1910s and into the 1920s. It was started by Pablo Picasso and George Braque and joined by several other artists. The movement gets its name from an art critic who commented on Picasso and Braque's work, saying the paintings looked like little cubes. Cubism was influenced by Cezanne's work that depicted 3-D form in an abstracted way. The movement went on to influence many other art movements like futurism and dadaism.

At the speed of light only four colors can exist. These are black, white, gray and brown. All other chromatic hues are absent. Surprisingly, the Cubists also used primarily these four tones. According to Shlain, Braque's portrayal of shadows additionally represents the way shadows would appear at speeds approaching the speed of light.

An observer aboard an imaginary train traveling at light speed looking forward or to the rear would see a compression of depth. To the side the length of objects would contract, creating the illusion that height elongates. A wide variety of artists starting in the 1880s began to experiment with elongated figures. Cezanne did this, as did Seurat with his hieratic figures and Amedeo Modigliani with his paintings of women. The German expressionists also painted tall thin figures. But the artist that experimented the most with elongation was the Swiss sculptor

Alberto Giacometti. He consistently portrayed tall, drawn out figures, in some cases in groups walking around together. Shlain writes that Giacometti's figures could be used in any physics class to demonstrate how people would look to an observer travelling past near the speed of light.

The Field and Abstract Expressionism

We have discussed the notion of emptiness and nothing in the section on Asian Art. Western artists also picked up on aspects of these ideas during the American post-World War II movement called abstract expressionism. This was developed in New York in the 1940s. Forms of expressionist art existed in Germany earlier in the 1900s and the term has been used to describe the work of Wassily Kandinsky. The abstract expressionists turned their attention away from "things" and focused instead on fields and spaces filled with textures and shapes that seemed to lack a proper sense of what it means to be an object. In this movement the forces behind the creation of things rather than the things themselves was at the forefront. The artist who perhaps best represents this is Jackson Pollock who created his paintings by dripping and flicking paint onto the canvas with a brush. In Pollock's works what one sees is the creative process itself more than the product. Other examples of abstract expressionist artists are Mark Rothko, Agnes Martin and Barnett Newman.

In physics particles and objects exist inside fields of force. For example the electromagnetic field or a gravitational field can act on particles causing them to move. Fields are typically invisible to the eye and fill up space. They cannot be seen under usual conditions but the effects of their actions on things can be noticed. Pollock's works can be seen as representative examples of fields. There are no "things" in his paintings, but the energy behind their creation is visible. His canvases are also filled completely in the same way that a field is spread out over space. Likewise, the works of Barnett Newman cover large surfaces with a single homogenous color that was uniform in texture.

Music and Physics

Following Shlain's history of the visual arts we will now summarize his history of music. Whereas the visual arts occur in space, music occurs in time. Notes follow one another in a temporal progression and the listener must integrate this information as it unfolds. Records suggest that musical instruments existed at least 35,000 years ago and were likely used as part of ritual or religious ceremonies. Early musicians determined that the length of a string relates to its frequency. Longer strings vibrate more slowly and produce lower pitches when plucked. Shorter strings vibrate more quickly to produce higher pitches. Pythagoras was the first to study this in a systematic way.

Music in ancient Greece was monadic. This refers to a solo vocal with a single melodic line and instrumental accompaniment. Not surprisingly, music during the middle ages existed solely for the church. Gregorian chant was developed during this time and consists of multiple singers chanting simultaneously without musical accompaniment. Polyphony was developed in the medieval period and became popular starting in the fourteenth century. In polyphonic music two or more melodies are played at the same time. This dramatically increases the complexity of music and allows composers to play melodies against each other in various ways.

The Renaissance gave music yet another dimension. Chords were now introduced. A chord is a set of three or more notes played simultaneously. Chords can be likened to perspective in the visual arts: they give the work a third dimension. In Western music the most used type of chord consists of a root note, a second note that is a third above the root and a third note that is a fifth above the root. By the fifteenth century musical notation was standardized, allowing for greater ease of composition and for it to be recorded and archived. Notation also spurred the development of pure instrumental music without voice. By the 16^{th}-century and up until the 20^{th}- century music was composed mostly for instruments alone, with the exceptions being operas, masses and song cycles.

Around 1600 the basso continuo was created. This is a bass line that runs through a musical piece, providing it with continuity. Shlain likens the bass line to the horizon line in the visual arts. It serves as a reference frame against which other parts of the song can relate. Also around this time was the development of the musical home key. A key additionally provides a unifying framework for a song. It is a group of pitches or scale upon which a composition is created. Music with a key is considered tonal and predominates in the Western musical tradition. A key grounds a musical piece with a specific triadic chord. It is the root note of this chord that is considered to be the key. Keys can be major or minor, with minor keys generally sounding darker and sadder than major ones. Shlain writes that a home key is like the viewpoint in perspective visual arts. It provides the overall approach a listener takes to the piece.

Atonality is music without a home key. In atonal music each note has the same relative importance as the others. The Austrian-American composer Arnold Schoenberg developed atonality and his 1909 *Opus 11, No. 1* is a good example. Schoenberg also created the twelve-tone technique also called dodecaphony. In this form, no tone in the scale can be repeated until all twelve have already been played. Here, not a single note is favored since all are played an equal number of times. The composer Richard Strauss also deviated from a single key. In his music he combined many different keys together at once. This form of music is known as polytonality.

Shlain compares polytonality to cubism in the visual arts, with each tone corresponding to a different perspective of a visual object. Dixieland jazz can also be compared to cubism because in this style many musicians play different melodies together at the same time. Atonal musicians experimented with time as well as pitch. Anton Webern, a student of Schoenberg, composed an entire piece of compressed music only 19 seconds in duration. The Russian composer Igor Stravinsky varied the tempo within some of his songs. Traditionally tempo, the rate at which music is played, stays constant within a piece.

There is an analogy to physics here. Newtonian physics is absolute in the sense that phenomenon occur the same throughout space and time independent of an observer. This is very much like the use of a key in tonal music that unifies a piece and specifies how all the notes relate to a single reference point. Einstein's relativity says there is no privileged observer and that phenomenon are always in relation to a frame of reference. This is more like atonal music in which the individual notes each assume importance relative to one another. There simply isn't enough space here to discuss all of the parallels between art, math and physics. For a wonderful and more extensive treatment of this topic we recommend *Mathematics + Art. A Cultural History* by Lyn Gamwell.

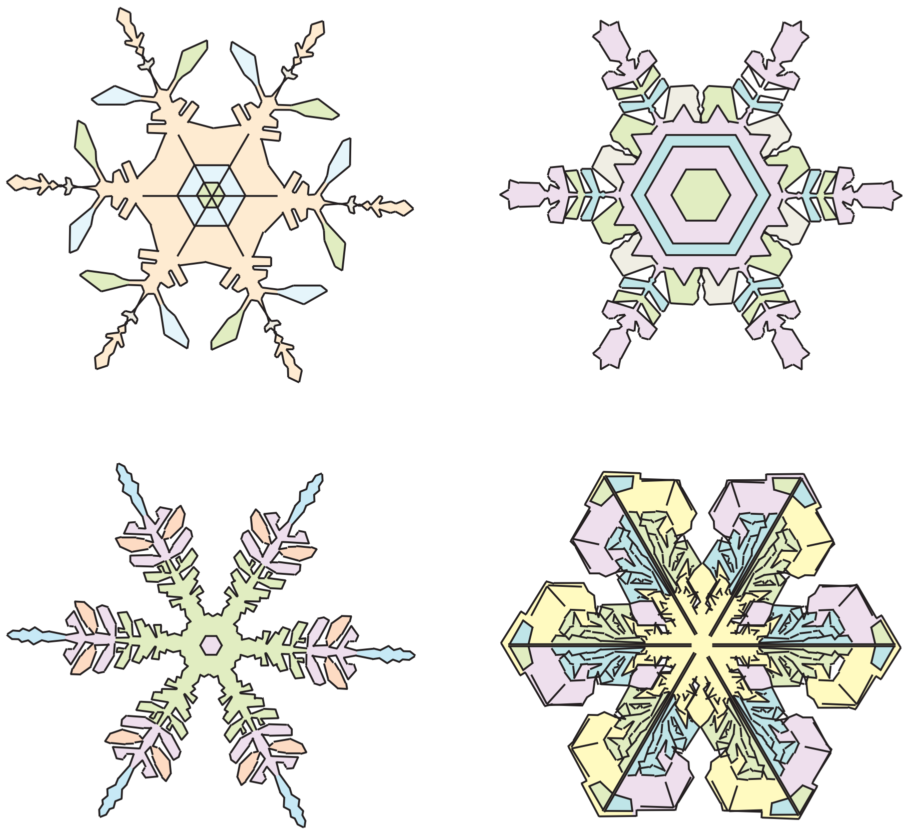
Physics Odds and Ends

Physics and the Weather - Snowflakes

Snowflakes are formed when water freezes around specks of dust falling through the atmosphere. They have six arms because water molecules have a hexagonal symmetry. That is to say that water molecules arrange themselves into a lattice like a stack of six-sided tiles. The exact pattern that any snowflake has depends on the conditions it encounters on its way to the ground. These conditions include changes in temperature, pressure and moisture. These factors change from one place to another and over time, so it is indeed unlikely that any two snowflakes will be exactly identical. The chances of this happening are more than one thousand billion to one.

If one takes a close look at actual snowflakes, you will see that they are not perfectly regular. The arms are slightly different and not perfectly symmetrical, unlike the way they are portrayed graphically on Christmas cards and decorations. Figure 3.37 shows some real life examples. The longer a snowflake falls, the longer its arms will grow and the greater the diversity of smaller patterning along the arms. Although there are so few exactly alike, snowflakes do fall into about thirty-five different categories based on more gross similarities in their shapes.

Figure 3.37. Snowflake patterns more similar to those found in nature rather than in artistic representations.



Physics and Song - Shattering Glass

You may have seen on TV the scene where an opera singer holds a note and shatters a glass. Is this true? Could a singer ever do such a thing? Believe it or not, yes it is possible. The laws of physics do allow this to happen. If the rim of a wineglass is tapped with a spoon, it oscillates, meaning some parts of the rim move inwards while others move outwards. In between these two points is an area that does not move. These oscillations move the air, causing a sound wave, which is why one hears a ring. A thick glass is resistant to such movement, but a thin glass or one with a crack in it will break if a strong enough motion is imparted.

The rim of the glass has a natural frequency that it wants to vibrate at, called its resonant frequency. If a singer can produce a note at this frequency the oscillations are amplified that will pull on the glass enough so that it breaks. However, the singer must generate a fairly high volume and hold the note for two or three seconds to keep up the resonance. A professional singer could tune their voice to this resonant frequency by tapping on the glass and using it as a "tuning fork". Something on the order of 100 dB is required to break a piece of fine crystal. Opera singers that are extensively trained could generate and sustain this level of loudness, about twice what our normal speaking voice us. If a microphone and amplifier are used then a singer could induce the effect without hitting the exact resonant frequency. The American voice coach Jamie Vendera did a demonstration of this on the Mythbusters TV show in 2005. He was able to successfully break a glass but only after twelve tries.

Physics and Drawing - Doodles

Many of us may remember back to classes in high school or college where we doodled in our notebook to pass the time. Barrow (2014) wondered whether there was a favorite type of doodle, one that most of us would draw. He believed there was, so long as someone is not trying to draw a particular object. Free-form doodles of this sort are not usually circles because they require too much concentration and effort. However, legend has it that the German artist Albrecht Durer could draw a perfect circle over and over again. Instead, most of us seem to draw teardrop-shaped open loops. These shapes resemble roller coasters or the loops for an off-ramp that crosses back over a highway.

These curves also resemble "clothoid" curves in physics and engineering. They are the smoothest transition curve that you can take around a bend such that you feel a steady centrifugal force. In other words, the curvature is proportional to the distance along the curve. This is also the path a car moving at a constant speed would follow if the driver turned the steering wheel at a constant angular speed. This is in fact why highway exits are designed this way. If they were circles you would need to constantly adjust your speed to maintain a constant pull on the wheel. This would make for a jerky and uneven ride.

It may be that a similar principle is at work with doodles. We like to pull the pencil or pen around a constant speed as it arcs across the paper. This is the type of curve that it may feel best to draw, as it requires less conscious effort to keep on course and a minimum change of force in our fingers. There is more than just one type of clothoid spiral: they look different based on how fast we want to move the pen. Take a minute now to try and draw a perfect circle and then a doodle to feel the difference between the two!

Physics and Dance - The Grand Jete

Ballerinas can jump and seem to "hang" in the air during the mid-portion of their leap. This is especially prominent in the jump called the grande jete. In so doing they seem to defy gravity. How do they do this? Normally when a projectile is fired into the air it follows a parabolic trajectory with a curved peak at the top. This traces the object's center of mass as it travels through the air. If one looked only at this center of the body, the object would appear to go up and then down, with no "hang time".

In the grande jete the ballerina as she jumps raises her legs into a horizontal position and raises her arms up over her shoulders. This elevates the center of mass relative to her head so that if one looked at her head it would appear to travel horizontally at the top of her jump, not peaked (up and then down) as is normally the case. In fact her head can remain travelling horizontally for almost one half second. Physicists have placed sensors on dancers and plotted how they change over time. The result is a trajectory with a flat top.

This demonstrates that performers can "defy" the laws of physics in the service of artistic aims. It is not clear whether the grande jete was introduced intentionally or subconsciously and whether it was originated by a dancer or by a choreographer. A dancer performing this move might proprioreceptively feel as if they were spending more time at the top of the arc, whereas a choreographer seeing the move as an external observer would experience the effect visually. The difference between these two possibilities is whether artistic forms are user or audience generated.

Bringing it All Together – Math and Physics Chapter Summary

Whole number ratios like 2:1 and 2:3 in music are considered consonant. In the visual domain, the golden ratio, or 1.618 is considered beautiful and has been applied in the study and construction of buildings, paintings, faces, and other objects. The visual expression of the Fibonacci sequence is also considered beautiful. Some flower petals fan out in this sequence to get the most sunlight. Seeds on some flower heads also spiral outwards from the center to fill every possible space according to the Fibonacci rule. The reason for why these patterns look beautiful seems to be tied to growth patterns in which objects attempt to arrange themselves in a way that maximizes the use of some resource like space or energy.

Vertical and horizontal lines are preferred to obliques by human observers, probably because we are exposed to these in the form of horizon lines, trees, and engineered environments. Artists in paintings also use more vertical and horizontal lines. Curves have been utilized extensively by all cultures as decorative art. This is especially true for the arabesque foliage patterns in the Baroque and Roccoco periods. Their popularity is probably due to the imitation of vegetative patterns in nature. The Celts applied curves in the form of spirals to many of their designs. These patterns are also seen in nature. Key patterns mimic the folding of material into confined spaces as is found in the gyri of the brain and corals. A principle of efficiency seems to be at work here, where a maximum amount of material must be packed into a small space.

Regular polygons may be preferred because they are simpler, having equal sides and angles. They show up in graphic and architectural designs. Ellipses and circles are also pervasive in design, art and architecture. A circle can be considered as a polygon with an infinite number of sides.

Fractals are patterns that are self-similar at different scales. They are found everywhere in the natural world in the form of rivers, trees, mountains and clouds. The drip paintings of the artist Jackson Pollock are also fractal. Many artists reproduce the statistical properties of natural images, probably because we have evolved to process them efficiently. This principle of processing fluency is discussed in greater detail in the psychology chapter.

Translation, reflection, and rotation are three symmetric operations that when applied to patterns are considered beautiful. They have been used in the decorative arts of all cultures throughout recorded history. They are manifested in point, frieze, and wallpaper groups as well as in tessellations and tilings.

Complexity is another factor that has been studied with regard to aesthetics. Most research shows that people prefer a moderate amount of complexity. If patterns are too ordered they are boring. If they are too complex they are confusing. When aesthetic ratings are plotted against increasing complexity, there is an inverted U-shaped function. The number of spatial and temporal dimensions art forms occupy can also characterize their complexity. Music is considered simple according to this scheme, while theater is more complex.

Visual or auditory noise can be characterized by the amount of power present at different frequencies. There are three different types of noise in natural and artificial phenomena. These are white, pink, and brown noise. The latest research suggests that brown noise may be the most preferred.

From a religious perspective, if nature is a work of art then God is the artist. Many scientists have used beauty as a way of generating hypotheses and of understanding and explaining data. Simplicity, symmetry, and economy are found everywhere in nature, in physical, chemical, and biological systems and can be useful ways to understand how nature works.

A system is self-organizing if it increases in complexity without external guidance. Self-organizing processes produce Li symmetries. Examples include ripples in the sand caused by water movement and the texture on tree bark. Many complicated processes in nature can be reduced to the operation of a few simple rules. Simplicity in nature gives rise to complexity in many cases. Self-organizing systems produce emergent properties where the whole is greater than the sum of the parts.

Surprisingly, art history can be analyzed using concepts from physics. Many artists seem to have anticipated developments in physics. For example, the ancient Greeks used linearity and ratios in their art, while discontinuous space was a hallmark of art like stained glass windows during the middle ages. The Renaissance saw the use of perspective, while the impressionists used time in nontraditional ways. Art and physics also deal with similar concepts like frequencies, volumes, mass, and color.

Many of the studies described in this chapter come to similar conclusions. They find that a small set of organizing principles can explain beauty and preference for all kinds of art forms. These principles are 1) generally mimicking the patterns seen in nature, 2) a preference for moderate complexity of form, 3) a preference for symmetry, and 4) a preference for patterns that follow the principles of economy and efficiency.

Chapter 4 - Evolution

Evolution – It's in our Nature

All human abilities, including our attachment to beauty and proclivity to create art, start with evolution. In this chapter we will examine the natural and sexual selection forces that drive these traits. We begin by looking at ourselves. What makes for a beautiful person? For faces the answer turns out to be factors like symmetry, averageness, and sexual dimorphism. We look also at bodies, describing some of the latest research on different factors. These include height, waist-to-hip ratio, body mass index, breast size, muscularity, ring-to-index-finger ratio, skin, cosmetics, tattoos, hair, clothes and fashion. Even the way we smell and walk can affect our perceived attractiveness. Following this we summarize research on the social aspects of beauty: how it influences the way we treat each other. Turning to art, we see that it too can be explained using evolutionary theory. Art seems to have been with us even before we were *Homo sapiens*, judging from a brief tour through prehistoric art history. Our preference for certain types of landscape, natural images and music all have evolutionary origins, as does the human capacity for mathematics.

Natural and Sexual Selection

There are two types of selection acting in evolution. Natural selection is a change in the environment that results in the survival of particular traits. Sexual selection is the determination of traits based on mate choice. Traits get selected for in either way, whether it is the environment or mates who are doing the selection. These two forces often trade off against one another. In one species of beetle, having large horns is attractive to females, but it also makes it harder to move around and escape from predators like birds. Another often-used example is the male peacock's tail. It is attractive to females of the species but also makes the male stand out to predators more.

Sexual traits can either be physical or behavioral. Mating dances and courtship rituals are examples of the latter. Since these actions require energy and skill they serve as indicators of reproductive fitness. The animal that can sing the loudest or dance the longest ostensibly is the one with the greatest amount of agility, stamina or skill and so ought also to be the best parent. Usually a trait that evolved first in response to natural selection can then be utilized for sexual selective purposes. For example feathers evolved to solve the problem of flying, but then can be colored or shaped in various ways to display for mating.

In human societies women do the selection. In evolutionary theory this is because they undergo the greatest reproductive costs. They generate only four hundred eggs during a lifetime prior to menopause, must go through nine months of pregnancy and then produce milk during an extensive lactation period. Men on the other hand can produce twelve million sperm per hour, can inseminate a large number of women, then potentially abandon them with little or no reproductive costs. Minimization of reproductive costs in sociobiological theory has been used to explain why women are more likely to fall in love and men are more focused on sex. Love helps to promote long term bonding while sex can be a "shoot and scoot" affair.

What we Seek in the Opposite Sex

We will discuss what both sexes prefer in greater detail elsewhere and so provide only a summary introduction here. Men tend to prefer women who have a waist-to-hip ratio of about 0.70 as this has been associated with greater fertility. Women find men attractive who have wide shoulders and a muscular upper body, including chest (pectorals) and arm muscles (biceps). This has been quantified as a waist-to-shoulder ratio, the most attractive being a value of 0.60. The least attractive male body type is pear-shaped with a fat abdomen and hips and a small upper body with narrow shoulders. A downward pointing triangle representing the upper body in men would be considered good while an upward pointing one would not.

There are two inequalities in sexual preference where tastes go in opposite directions. The first is male preference for younger women and female preference for older men. In the U.S. and in Canada the difference is about two years. Men want on average women who are two years younger and women want men who are on average two to three years older. The second inequality is for body height. Women want men who are taller than they are while there is a weaker male preference for shorter women. Both sexes though, agree on symmetry as an attractive feature both in faces and bodies. Symmetry has been linked to health and therefore reproductive fitness.

There are also differences in regard to "internal" traits. Men and women each seek in one another some traits that are the same and some that differ. Both men and women look for kindness (highest on the list) and intelligence secondarily. Following this men seek out physical attractiveness and other features like clear, smooth skin and bright eyes while women want wealth and resources in a partner. After these both sexes desire the same personality traits. These include an exciting personality, adaptability, generosity, dependability, industriousness, creativity and a sense of humor. Many of these correspond to the basic moral qualities espoused by world religions.

If intelligence is desired by both sexes, then how does one demonstrate it? Language is one way. Darwin himself said that language is used as a fitness signal. It turns out that in the English language there are about 60,000 or so different words. However 98% of speech today utilizes only about 4,000 of these. This excess vocabulary may be there as a means to demonstrate to the opposite sex how smart we are. Vocabulary size and use is actually correlated with intelligence and is still used as a component in I.Q. testing.

Beauty and Mating Strategies

Theory from evolutionary psychology and its antecedent sociobiology, discuss mating behavior in terms of reproductive success (Wilson, 1975). Men and women are expected to act in ways that maximize reproductive success. Men do so by “sleeping around”. In this fashion if only one or a few babies are born, the man has passed on his genes with virtually no effort, a low cost-to-benefit ratio. So men in this view should be motivated to value sex and physical appearance over love and long-term bonding. Women on the other hand must bear the brunt of childcare costs. To maximize their success they need to gain help and resources from their partner. To do this means ensuring a long-term bond and faithfulness. This theory helps to explain the different values that men and women hold in the mating game and the differential emphasis placed upon looks by men. Following Etcoff (1999), we outline next the variety of different evidence that support this theory.

Men tend to value looks in their partners more than women, while women value the ability to provide resources and social status more in their partners than men. A 1990 study by David Buss found that men valued physical attractiveness and good looks in a partner more than women did in 34 out of 37 cultures surveyed. In none of those cultures did women care more about looks than men did. Men are also the major consumers of the porn industry. Images of naked men are consumed more by homosexual men than by straight men.

These differences also show up in sexual fantasies. Men are more likely to fantasize about women they do not know and to substitute different partners during the same fantasy. Alternatively, women are much more likely to fantasize about people they know (Ellis & Symons, 1990). Studies also show that men find the potential of having sex with a stranger more appealing than women do. These differences appear in personal ads. Advertisements by women seeking men more often mention beauty as their primary selling point. Advertisements by women seeking men are more likely to mention friendship, sincerity and financial success (Deaux & Hanna, 1984). For short-term relationships however, both sexes consider looks more important.

These differences in mating strategies are evident in statistics about marriage. The best-looking girls in high school are more than ten times more likely to get married as the least attractive (Taylor & Glenn, 1976). Beautiful girls tend to “marry up”, meaning they marry men who usually have higher incomes and education than they do. In contrast a man’s looks in high school do not predict his likelihood of marrying or the socioeconomic status of his potential bride. Having an attractive girlfriend or wife however conveys prestige and social status. In one study participants were shown pictures of a man with an attractive woman. In a first condition they are told the woman is his girlfriend. In a second condition they are told she is a stranger. Participants report the man in the girlfriend condition to be more likable, intelligent and confident. A woman with an attractive man in contrast is not seen as any smarter or more likable.

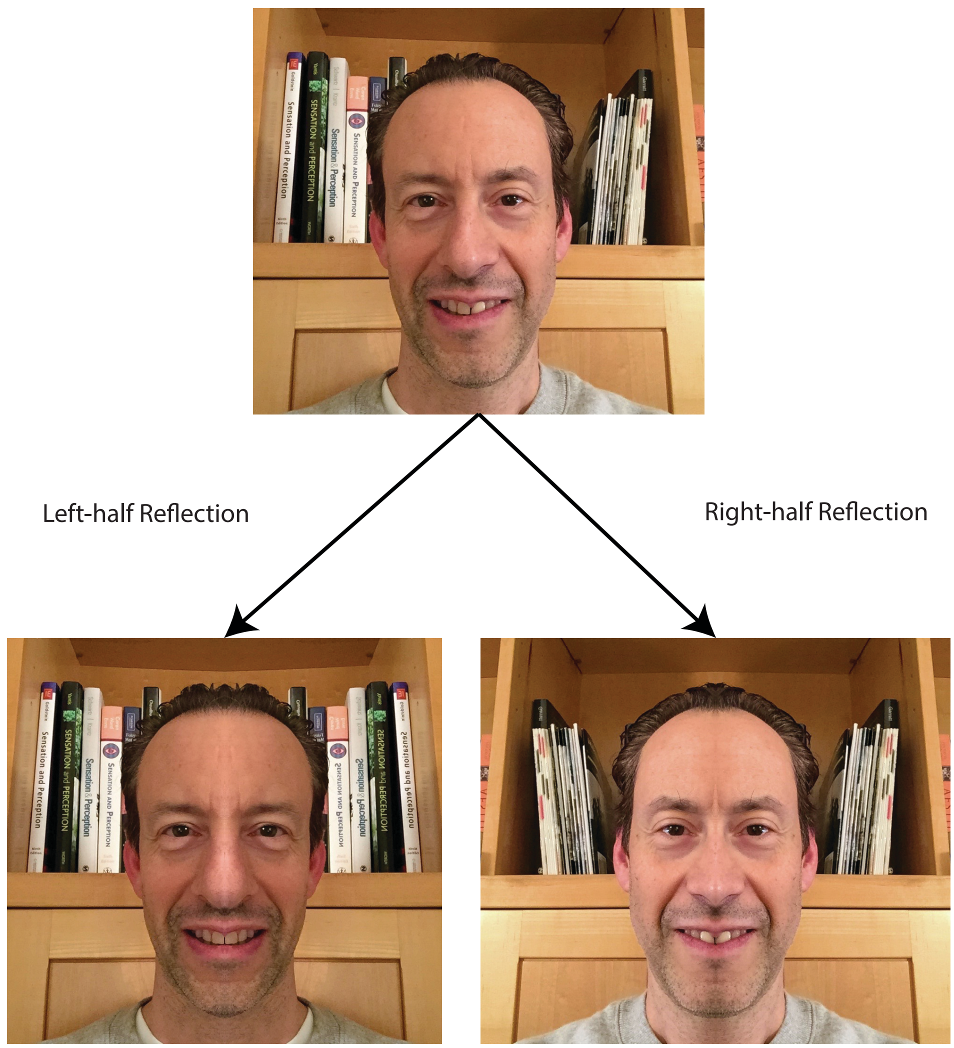
In a study by anthropologist John Marshall Townsend people were shown pictures of men and women with a variety of looks (low, medium or high attractivenesss) and with several professions varying in prestige (waiter, teacher, doctor). They asked the participants whether they would like to have a date, have sex, or marry the person portrayed by the image and description. Men never chose unattractive women regardless of how high their status. Women, however were willing to choose an average or even unattractive looking man if he had a high prestige job (Townsend & Levy, 1990).

Faces

Facial Symmetry – Where One Half Meets the Other

Facial and body symmetry are cues that signal fitness. The body tends to grow developmentally in a symmetric fashion but parasitic infections can offset this process. Thus, the degree of symmetry broadcasts what is called immunocompetence, how much one can resist such infections. Symmetric faces in particular are considered attractive because mating with someone who has these features ensures a greater survivability for offspring (Thornhill, 1993). A face is symmetric if the features on either side of the face's midline are at equal but opposite locations. One way to make symmetric faces is to take one half of a face, duplicate it, mirror image the duplicate and then place the two halves back together again. One can create two hemi-faces this way corresponding to left-left and right-right half composites. Examples are shown in Figure 4.1. Grammer and Thornhill (1994) were the first to find that faces with greater symmetry were considered more attractive than those with less.

Figure 4.1. Left-half and right-half reflected versions of an original face. The degree to which these two differ is an indication of how asymmetric the original face is. Note these have not been adjusted for aberrations about the midline.



Rhodes et al. (2001) created symmetric faces by taking original face photographs and blending them with their reflected versions. They did this with Chinese and Japanese faces and found a preference for symmetry, thus extending this finding to an Asian population. Rhodes et al. (1998) additionally discovered that symmetric face blends were rated as being high as a potential life partner in comparison to normal face controls. In a separate study, Rhodes et al. (2001) presented symmetric faces to college students who rated them as healthier looking, thus providing support for the parasite resistance theory. Further support comes from a study where symmetry and health in faces were dissociated from one another (Rhodes et al., 2007).

Little, Jones, Burt, and Perrett (2007) showed that women prefer more symmetric faces at the peak fertility phase of their menstrual cycle. This effect occurred only for judgments concerning short-term relationships and when the women had a partner. The results suggest a strategy of obtaining higher quality genes during this period by "cheating" outside of a normal relationship. There is also a documented preference for more male-looking faces during this period that is chronicled below.

Fink, Neave, Manning, and Grammer (2006) presented college students with 20 female faces varying in facial symmetry and found that faces high in symmetry were rated not only higher in attractiveness and health but also in other positive personality characteristics like sociability, intelligence, liveliness, and self-confidence. Faces low in symmetry were rated as being more anxious. Asymmetrical faces are also rated as more neurotic, less agreeable and less conscientious than normal versions (Noor & Evans, 2003). We apparently generalize beyond pure perceptual attractiveness and relate beauty to other positive traits. See the social behavior section for more examples of how attractive people are judged.

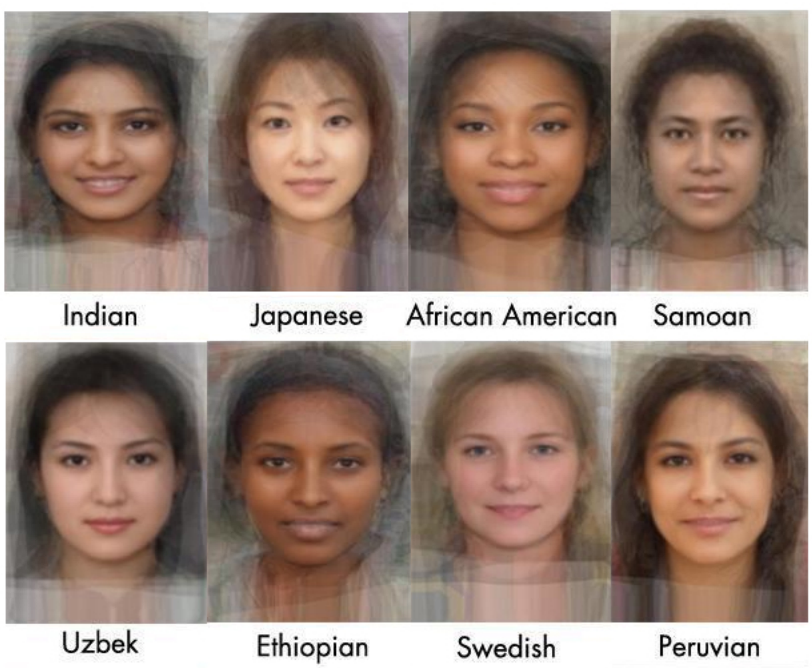
Samuels et al. (2013) presented normal and symmetric faces to babies. The babies preferred to look at faces that were more attractive but not because of vertical midline symmetry. Vingilis-Jaremko and Maurer (2013) presented three different age groups faces with exaggerated symmetry or asymmetry. Adults and 9-year olds, but not 5-year olds rated the symmetric faces more attractive than the asymmetric ones. The effect was strong for the adult participants and for male faces. It was also stronger for adult faces than for children's faces. The results imply that sensitivity to symmetry emerges at around 5 years, matures around 9 years and solidifies in adults who have fully developed visual systems and greater experience looking at faces. Adults who are post pubescent should also be more sensitive as they are motivated at this stage in life to seek out mating partners.

In one interesting experiment Zaidel (2005) created left-left and right-right symmetric composites from faces that were already considered very attractive, as they had been selected from professional modeling agencies. There was no difference between the left- or right-side composites but participants were able to detect asymmetries in these faces. The results show that a face can be very attractive and still not be perfectly symmetric. This means that symmetry is just one of several properties that make up an attractive face. An example of another such property is skin color and texture that has been found to change along with symmetry in male faces (Jones et al., 2004).

Facial Averageness – When Average is More than Just Average

When we talk about an average face in the everyday sense we mean a face that is plain and not very attractive. However average in the evolutionary sense refers to a face that has features that fall in the middle of a population's distribution. For instance, a nose that is not too big or small, eyes that are not too far apart or too close together, etc. To create a face like this requires that we take a set of faces drawn more or less at random from a large population of people. Those faces are then superimposed on top of each other and combined together. The resulting face is quite attractive. This type of averaged face represents stable genetic traits, those well adapted to current environmental conditions. Mating with someone like this will ensure offspring with high fitness values (Rhodes, et al., 2002). Figure 4.2 shows an example of a composite averaged face.

Figure 4.2. Averaged faces of women from different countries. These are rated as more attractive than the individual faces from which they are made. Images available by open access. DeBruine & Benedict, 2017).



Langlois (1990) presented averaged male and female faces to 300 undergraduates. These were judged more attractive than the individual faces that were used to construct them. There was a linear trend relating the number of individual faces that made up the composites and student ratings. One potential confound in these studies is that averaged faces are also symmetric and that observers may be responding to the symmetry in the faces and not their averageness. Rhodes (1999) held symmetry constant and varied averageness, finding that ratings still varied along with it. This shows that averageness does indeed affect attraction independently of symmetry. Jones, DeBruine, and Little (2007) also found that averageness contributes to attraction independently of symmetry. There has been some debate about the validity of this effect but most studies bear it out (DeBruine et al., 2007; Langlois, Roggman, & Musselman, 1994; Pollard, Shepherd, & Shepherd, 2001).

When does sensitivity to average faces develop? Is it present from birth? De Haan, Johnson, Maurer, and Perrett. (2001) showed one- and three-month old infants four individual faces and then an average composite made from them. The one-month olds could recognize the individual faces but not the average, whereas the three-month olds could recognize both types of face, showing they had the ability to perceive the average. The ability to form face prototypes is probably necessary in order to respond to their attractiveness. Rhodes et al. (2002) showed adults and 5-8 month old infants pairs of faces differing in averageness and symmetry. The adults judged faces greater in averageness and symmetry more attractive. The infants did not although they were sensitive to the differences, i.e., they could tell the face pairs were different from each other. So although the ability to detect facial averageness in infants is apparent, this by itself is not sufficient for them to respond to their attractiveness.

Halberstadt and Rhodes (2003) tested whether the averageness attractive effect is specific to faces or general across all types of objects. They presented averaged pictures of birds, fish and automobiles and found that participants all found the more averaged versions more attractive. Familiarity could explain why these participants liked all three of the categories but only averageness could explain preferences for birds and fish. The results suggest sensitivity to averageness is true only for living organisms and not constructed artifacts like automobiles.

Facial Dimorphism - Masculine and Feminine Faces

Facial features for both men and women change during puberty. In men, testosterone release widens the jaw, cheekbone and brow. The actor George Clooney is a good example of a masculine face. In women estrogen release results in a feminine face, characterized by a narrow chin and jaw, high cheekbones, full lips and larger eyes. Men consider women with accentuated female features to be more attractive than average. Some women prefer a masculinized male face but others like a more feminine-appearing male face as exemplified by the actor Johnny Depp (Johnston et al., 2001). Testosterone produces masculine features. It also suppresses immune system function. So theoretically, men with masculine features are advertising their ability to fight off infection, which is a signal of genetic fitness. Images of masculinized and feminized faces can be found on

Women's preferences for masculinized faces are quite variable and affected by multiple factors. Culture may shape these preferences because women from Japan and the United Kingdom prefer more feminine faces while women from the U.S. prefer more masculine ones. Male facial preference also varies based on menstrual cycle phase. Women during the follicular phase (the phase of greatest likelihood of pregnancy) of their menstrual cycle prefer more masculine faces. Outside of this phase preferences are for more feminized male faces. This may reflect a "dual mating strategy" where women desire more aggressive men's genes but prefer a more docile and cooperative partner to raise children (Little et al., 2002; Penton-Voak et al., 1999).

Little, DeBruine, and Jones (2013) presented women with images of male-male competition, violence or wealth. The women showed a preference for more masculinized faces after seeing pictures of direct physical competition among males, images of weapons, or images showing items of high monetary value. These types of cues produce a shift in visual preference for mates with greater physical strength and dominance. These traits signal the ability to acquire resources and become a leader and so could indicate better care for future offspring. Preference for masculinity however is a tradeoff. Men that are too aggressive and violent can abuse their wives and fail to provide child-care.

Welling et al. (2008) found that women's preferences for masculine faces increases after they view images of highly desirable men. This may reflect a desire for greater genetic fitness under conditions of heightened sexual motivation. Interestingly, the women in this study also showed decreased preferences for more feminine female faces after viewing the attractive male faces. This could reflect derogation of same-sex competitors. So women who are surrounded by highly attractive individuals of both sexes (for example, at a fashion show) are going to feel more positive toward the masculine men and more negative toward the feminine women.

The hormone oxytocin has sometimes been called the "cuddle chemical" as it promotes feelings of nurturance and warmth toward others. It is released in many female mammals during nursing to promote bonding with offspring. Theodoridou, Rowe, Rogers, and Penton-Voak (2011) administered oxytocin to men and women and had them adjust faces along a masculine-feminine continuum to a point of optimal attractiveness. Both sexes showed a preference for more masculine faces after receiving the hormone. The oxytocin did not produce any preference for feminine features in women's faces. The authors speculate that oxytocin suppresses the negative attributes (fear) that go along with masculine faces, making them more appealing than usual.

We can next ask what factors affect men's preference for more feminized and hence more attractive female faces. Little, DeBruine, and Jones (2013) found that men prefer more feminine female faces when rating for a short-term relationship and when they have a partner. Men who considered themselves attractive also liked more feminized faces for short-term relationships. Presumably, better looking men feel they can more effectively compete and gain a more attractive partner. The cost of being discovered "cheating" may be worth it under such circumstances. Men not in a relationship may be better at acquiring a partner by relaxing their standards.

Neonatal Faces – The Cuteness Factor

Neonatal or baby faces are characterized by large eyes, a round face, curved forehead, small jawbone, and lower positioning of the eyes, nose and mouth. In research these cute faces are referred to as a “baby schema”. Most people perceive these features as “cute” and evolutionarily they probably elicit caregiving behavior in parents. Doll and teddy bear faces are often designed along these lines. Adults with neonatal features are treated differently. In courts adults with cute faces are perceived as more honest but also as more naïve. As a result they are blamed less often for crimes committed intentionally but punished more for negligent offences (Zebrowitz & McDonald, 1991). The animated character Mickey Mouse started off with a more adult-like face and in his early versions looked more like a rat. Over the decades however, his face changed and took on a more babyish appearance. Interestingly, his behavior also evolved over this time period with his personality becoming less aggressive. In this case we have cultural evolution at work, with consumers shaping the product based on viewing habits over time.

Glocker et al., (2009) performed the first study to show preference for and desire to take care of infants with cute features using photographic stimuli. They created cute (round face and high forehead) and less-cute (narrow face and low forehead) versions of infant faces. Undergraduates rated these for cuteness and the desire for caretaking. The high baby schema infant faces were rated as cuter. They also elicited greater motivation for caretaking. These data demonstrate that baby schema features directly elicit nurturing and caretaking feelings. In another study men and women to make judgments between pairs of baby faces. Women would choose the cuter infant, while men had more difficulty in doing so. However there was no sex difference when it came to choosing the younger or happier baby. Women have apparently evolved to become more sensitive to cute features given that they nurse and provide a greatest amount of early childcare.

Luo, Kendrick, Li, and Lee (2015) presented faces of babies and children to two groups of adults, those with and those without siblings. Both groups liked infant faces that were less than seven months old. But the no sibling group showed reduced liking for faces as they got older, from seven months up to six and a half years. In contrast the sibling group found faces of all ages equally likeable. For adults with siblings, the closer in age they were to them the more they liked the young children’s faces. These results show that growing up with brothers or sisters extends the perception of cuteness for infantile features, upwards in age from infant and baby faces to younger children.

Humans, including younger children, find many animals cute as evidenced by dolls and stuffed toys like teddy bears. But preference for cute faces has only recently been extended to non-human animals. Borgi et al. (2014) created cute and less cute versions of adult, dog and cat facial images (Figure 4.3). They then had three to six year old children as well as adults rate them in terms of their cuteness. In addition they used eye-tracking technology to record where they looked. The results showed higher ratings and increased looking times for the cute versions of all the faces, including the animals. These data show that we develop preference for a baby schema very early in development.

Figure 4.3. Cute animals with neonatal features elicit caregiving and nurturance. Copyright free image courtesy of Unsplash.com

Bodies

Which is Better, Faces or Bodies?

It is an interesting question, which drives sexual attraction more, faces or bodies? We attend to faces more during conversation and it is difficult to judge bodies given that they are covered most of the time in clothing. Generally, people direct their attention to faces more than bodies. However mating goals affect the choice of what men look at first. In one study younger men were shown pictures of women in which the body or face were at first covered. If the goal was a short-term relationship or "fling", they looked at the body more than the face. If the goal was to select a long-term mating partner they looked at the face more than the body (Confer, Perilloux, & Buss, 2010). Female bodies signal fertility better than faces and it is fertility that supposedly drives male desire for flings. In this same study, women did not spend more time looking at male faces or bodies because male bodies do not signal fertility in the same way.

Wagstaff, Sulikowski, and Burke (2015) had 266 undergraduates complete an online survey in which they measured preference for information from the face or body in short- or long-term mating contexts. Information from the body was more important for men in short-term contexts, replicating the study mentioned above. Both sexes overestimated the opposite-sex's preference for looking at the body. Women did accurately perceive men's differential interest.

Body Symmetry

In addition to facial symmetry, certain symmetric body parts are also considered attractive. Men with symmetrical hands, wrists, elbows, ankles, feet and ears are judged more beautiful than their asymmetrical counterparts (Thornhill & Gangestad, 1994). Men with symmetric bodies have sex a few years earlier and have two or three times as many sexual partners as those with asymmetric bodies. Their partners also consider them to be better sexual performers. Body symmetry can also predict likelihood of a female partner's having an orgasm better than how often they make love, how much he invests in the relationship or how much money he makes (Thornhill, Gangestad, & Comer, 1995). Heterosexual men consider women with more symmetrical bodies more attractive. Women who have large and symmetrical breasts are more fertile. Surprisingly, women also become more symmetrical during ovulation. Specifically, this occurs for their fingers and for their ears, by up to 30% (Scutt & Manning, 1996).

Brown, van der Zwan, and Brooks (2012) presented symmetrical and asymmetrical figures to 22 adult participants both as static figures and as dynamic point-light walkers. Symmetry in the static displays was easily determined, but the observers were not able to discriminate symmetry in the dynamic displays. The symmetric static figures were additionally judged healthier and more attractive than the asymmetrical ones. This study shows that more information other than pure motion is needed to detect body symmetry.

Height

Testosterone affects height and as such it is a sexually dimorphic body trait. Men are higher than women because they produce more of this hormone. Most people in general say they like like tall men (Jackson & Ervine, 1992). The tallest presidential candidate usually wins presidential elections in the U. S. and CEOs of successful corporations tend to be taller than average. Height can also predict starting salary. Taller leaders are judged more charismatic (Hamstra, 2014). Increases in perceived height, masculinity, and age (up to 35 years) all increase perception of facial dominance (Batres, Re, and Perrett, 2015). These authors found that all three of these variables affect one another, so they should not be considered in isolation. Women report that taller men are more attractive (Pierce, 1996). Tall men receive more responses in personal advertisements. In fertility clinics, women also tend to select the sperm of tall men (Zeifman & Ma, 2012).

In a review of the literature Stulp, Pollet, Verhulst, and Buunk (2012) report a curvilinear association between height and number of children, with men of average height attaining higher reproductive success. Men of average height also married at a younger age than shorter or taller men. These conclusions were based on a very large sample of 3,578 people aged over 64 years. They conclude that greater reproductive success in this sample is the result of marrying earlier and not necessarily due to greater sexual attraction to men of average height.

Waist-to-Hip-Ratio

Waist-to-hip ratio (WHR) is calculated by taking the ratio of the circumference of the waist to that of the hips. For example if one's waist was 25 inches and their hips were 38 inches, they would have a WHR of around 0.66. Lower values in general and a value of 0.70 more specifically are considered to signal optimal fertility. As such it is predicted that males are sensitive to these features and will be attracted to women with figures near these values (Singh, 1993). This prediction has been borne out in most studies although there can be considerable individual and cultural variation (Furnham, Swami, & Shah, 2006; Singh, 1994). Values considered good for men range between 0.85 and 0.90. Low WHR values are typically associated with women and higher values are associated with men (Pazhoohi & Little, 2012). Figure 4.4 shows examples of women with different WHR values.

Figure 4.4. Waist to hip ratio helps signal fertility and is a cue for sexual attractiveness. Copyright free image courtesy of Unsplash.com.

Svvami, Antonakopoulos, Tovee and Furnham (2006) pitted BMI and WHR against one another to see which would best predict ratings of physical attractiveness (BMI is described below). They presented images of real women to participants in the U.K. and in Greece. BMI was the primary determinant of judged physical attractiveness, while WHR was a significant predictor for the Greek observers but not the British group. So cultural differences do shape people's preferences for these measures. Furnham, McClelland, and Omer (2003) presented two-dimensional line drawings of females varying in weight, waist size and hip size. Participants from the U.K. and Kenya evaluated them in terms of attractiveness, sexiness, likelihood of bearing children, and health. A WHR of 0.7 was considered most attractive. However there were cultural differences. The British considered light figures better looking than heavy figures. Kenyan participants thought light figures were more fecund, while the opposite was true for the British. If Kenyans weigh less than the British, then this could account for the difference.

In a related cross-cultural study, Furnham, Moutafi, and Baguma (2002) found an overall preference for the 0.70 WHR and lighter weights, but Ugandans had a preference for a 0.50 WHR and a heavier weight category. Small waist and hip size was preferred over large weight and hip size. Attractiveness was correlated with all of the attributes measured including attractiveness, fertility, youthfulness and willingness to engage in short-term and long-term relationships. Singh (1995) tested Indonesian and Afro-Americans and found that neither group considered overweight figures attractive or healthy regardless of the size of the WHR. There was similar consensus in this study on what the different cultural groups considered to be an ideal women's shape. Freedman, Carter, Sbrocco, and Gray (2004) found that African-American men chose heavier figures as ideal compared to White American men, but both groups chose figures with a low WHR value. They determined weight to be a more important cue than WHR inn the mate-selection process.

Researchers have also studied women's preference for male figures varying in weight, WHR and other criteria. Asthana (2000) investigated women's perception of male attractiveness. The men in this study ranked 12 line drawings of male figures varying in WHR and personality traits. The results indicated that females prefered males with normal weight and a WHR close to 1.0, along with traits like intelligence, faithfulness, attractiveness and youthfulness. Male figures with a WHR near 1.0 were not judged to be highly attractive or healthy, only those with normal weights and a typical male WHR were considered attractive. Singh (1995) also looked at female judgments of male figures. These women regardless of age, income or education, rated normal weight males with normal WHRs and higher financial status more favorably.

Body Mass Index

Body Mass Index (BMI) is a measurement of body fat based on weight and height. It applies to both men and women 18-65 years of age. It can be used to indicate if a person is normal, under or over weight, or obese. The formula is as follows:

BMI = weight in pounds * 703 / height in inches^2

A healthy BMI is a score between 20 and 25. A score below 20 indicates being underweight. A value above 25 is overweight. Any score 30 or higher is considered obese. Men consider the ideal BMI for a woman to be 19.4. This fits a woman who weighs 112 lbs and is 5' 4" tall. Since the average American woman at this height weighs 140 lbs the preferred BMI is significantly lower than average. However this is culturally biased because in societies where food is scarce, men prefer women who are overweight, presumably because underweight women may be suffering from malnutrition or other health problems.

Koscinski (2013) utilized high-resolution graphic images of women seen from behind to exclude effects of breast size. The images varied independently in BMI and WHR. Participants had to chose between paired female images that appeared the most attractive. Both men and women preferred underweight women with a BMI of 17.3, a value that is considered unhealthy. BMI proved twice as important for attractiveness as WHR, contrary to what is reported in the literature. Pokrywka, Cabric, and Krakowiak (2006) compared finalists of the 2004 Miss Poland beauty contest with students of a Polish medical school (who were supposedly less attractive). They performed a discriminant analysis to find out what measures separated the two. The results showed that the thigh girth – height index, the waist to chest ratio, height and BMI did the best at distinguishing the two.

Wilson, Tripp, and Boland (2005) investigated perception of female attractiveness using line drawings of women at underweight (17.0), average weight (22.6), and overweight (28.2) BMI levels as well as three levels of WHR. College students judged thinner models to be consistently higher in attractiveness. BMI was found to play a greater role in perception of attractiveness than WHR, consistent with theories of attractiveness in western culture. In another investigation Richmond, Austin, Wallis, and Subramanian (2012) had interviewers rate adolescents and found that they were more likely to consider those with higher BMIs as unattractive. The finding was similar across gender and racial/ethnic groups and also stable across time.

Adolescent boys are more likely to label themselves as underweight and adolescent girls with normal weight are more likely to perceive themselves as overweight. McCreary and Sadava (2001) wanted to see if this and other self-perceptions were also true of adults. They used data from a pre-existing study of several hundred men and women ranging from 19-39 years of age. They discovered that although men were more likely to be overweight, many thought they were less heavy than they were. Conversely, although women were more likely to be under or of normal weight, many thought they were heavier than they actually were. Heavier men thought they were more attractive and healthier then heavier women. Lighter women thought themselves more attractive and healthier compared to lighter men. These body weight misperceptions may be rooted in cultural norms of what is considered acceptable weight.

Breast Size

Research in psychology and other fields has shown a preference for medium and large size breasts and a tendency to associate more positive personality attributes with larger breasts. Tantleff-Dunn (2002) presented videos of a female actor with four different cup sizes (A, B, C, D) giving a speech. 318 participants of a wide variety of ages viewed one of the four videos and rated the actor on various characteristics. Males perceived the actor more favorably on both social and professional traits when she had medium size breasts while female viewers were not influenced by size of her breast. Zelazniewicz and Pawlowski (2011) found male ratings of breasts were higher for those viewed at oblique rather than side angles. Oblique orientations are those in-between a full frontal and side perspective.

Swami and Tovee (2013) had British white men from London view figures of women rotated in 360° with five levels of breast size. These men also filled out a questionnaire assessing their attitudes toward women. Medium breasts were rated as most frequent (32.7% of the time), followed by large (24.4%) and then very large (19.1%). Preference for larger breasts was associated with a tendency to be benevolently sexist, to be hostile toward women and to objectify women. Objectification of women means to treat them as objects without feelings or minds. These authors discuss the influence of beauty ideals and practices and how those may help to maintain the domination of one sex over another.

Generally speaking women are dissatisfied with their breasts (Frederick, Peplau, and Lever, 2008). These researchers surveyed male and female views of breasts in a very large sample of 52, 227 adults ranging in age from 18-65. Although most women (70%) are dissatisfied, the majority of men (56%) were satisfied with their partner's breasts. Women who were younger and thinner worried their breasts were too small while older women were worried about their breasts drooping. Those women who were unhappy with their breasts were also unhappy with their bodies and concerned about wearing a bathing suit in public. They were also more likely to hide their breasts during intercourse from their partner.

Gray and Frederick (2012) were interested in finding cultural differences in preferred breast size, body fat and muscularity. They showed computer-generated images of bodies varying in these features to a mixed gender sample from St. Kitts (an island in the Caribbean), the U. S. and an Internet sample. Relatively high levels of body fat are common in people from St. Kitts. The St. Kitts sample were somewhat more likely to prefer heavier women and smaller breasts than participants from the U.S. Attitudes concerning muscularity were equivalent across the two samples.

Another study looking at cultural differences examined perceived breast size (PBS), breast size satisfaction (BSS) and body image satisfaction as well as other measures of psychological well being (Koff & Benavage, 1998). There were two samples, one of 94 Caucasian women, the other of 72 Asian American women. Women from both samples with larger and smaller breasts reported lower BSS. Smaller breast size was associated with lower BSS but a more positive body image when preoccupation with weight was taken into consideration. In contrast larger PBS was associated with higher BSS but more negative body image. Those with lower BSS but not lower PBS reported lower levels of self-esteem.

Dixson, Grimshaw, Linklater, and Dixson (2011a) used eye-tracking technology to investigate where men looked at women with different WHRs and breast sizes (small, medium and large). Initial fixation, where looks first occur, was at either the waist or the breasts. These areas received more fixations than the face or lower body areas like the pubic region or legs. Men looked more often and longer at the breasts. Dixson, Grimshaw, Linklater, and Dixson (2011b) in another eye-tracking study were interested in where men look at women with various breast sizes and areolar pigmentation. The areolae are the colored regions around the nipples. Men rated images with medium and large breasts as more attractive. They also rated breasts with medium and dark areolar pigmentation as more attractive. Lighter areolae are indicative of youth and and were predicted to be rated higher, so these results did not confirm this hypothesis. There were no differences in number of fixations or dwell times across different breast sizes from the eye tracking data.

Muscularity

Whereas women desire to be thinner, the male standard for attractiveness is on being bulkier and more muscular. In one study over 90% of U. S. undergraduate males wanted to be more muscular. This was also the case with Ukranian (69%) and Ghanian (49%) men. Many of these men reported their desire for muscularity was related to increased dominance and attractiveness to women. These reasons support the two evolutionary theories of muscularity. According to the recalibration theory of anger, ancestral humans used anger to convince others to treat them better (Sell, Tooby, & Cosmides, 2009). The greater their ability to harm and/or benefit others the more convincing they would have been. The actor's formidability would have been a symbol of their ability to enforce good treatment. In men physical formidability is represented in the form of musculature. More muscular men are perceived as stronger and better able to impose costs on those who challenge or mistreat them. Therefore men should have a drive to become muscular. A secondary reason for explaining the desire for muscularity is that women prefer muscular men and should be more likely to mate with them. In this view, men become muscular in order to increase their appeal to women.

Based on the media culture perspective, body views are influenced by exposure to idealized images. For men these are a typically a muscular physique. Exposure to these images would then make men desire to become more muscular. There is abundant evidence to support this. Williams (2007) found that men who accept societal views of attractiveness may desire to have a more muscular physique. Taylor and Fortaleza (2016) exposed men to violent or nonviolent narratives accompanied by muscular-ideal or non-muscular images of men. Those exposed to the violent narratives had lower self-perceived attractiveness, greater body anxiety and greater endorsement of body modification methods. Hargreaves and Tiggemann (2009) showed 15 television commercials with or without images of ideal muscular men. Those in the ideal exposure condition reported lower muscle satisfaction and physical appearance. Wack and Tantleff-Dunn (2008) found that in males, appearance satisfaction and valuation of muscularity was related to the extent to which they compared their looks to that of characters in electronic games that they played.

Views of the body ideal apply not just to ourselves, but in the way we see others. Grossbard, Neighbors, and Larimer (2011) administered an online survey to 842 undergraduates. Females perceived other females as significantly thinner and less muscular than actual norms. Males perceived other males as significantly heavier than themselves. Yanover and Thompson (2010) used schematic figures varying in muscularity and other physical traits. Although overweight figures were rated negatively, overweight figures with high levels of muscularity were rated highly on health and attractiveness.

Some of the research on muscularity and body weight has looked at perceptions of homosexual and lesbian populations. Varangis et al. (2012) showed line drawings of men that varied in muscularity to a sample of 190 gay adult men. They found a significant non-linear relationship between muscularity and attractiveness ratings. Swami and Tovee (2008) found a preference for a more developed upper-body build in a gay male sample group. Lucas et al. (2011) had lesbian women rate computer-generated images of women varying in body fat, WHR and breast size. A second group of heterosexual women rated computer images of men varying in muscularity and body fat. Both groups showed a shift in preference toward more physically attractive partners for short-term relationships. These results show that some mating strategies are shared in common regardless of sexual orientation.

Another aspect of muscularity is the V-shaped torso, characterized by a wide shoulders and narrow hips, as can be expressed by a shoulder-to-hip ratio, SHR (Horvath, 1979). One study with 60 male undergraduate students, aged 18-44 years, found that males with a high SHR reported sexual intercourse at an earlier age, more sexual partners, more extra-pair copulations (EPC), and having engaged in more instances of intercourse with people who were involved in another relationship (having themselves been EPC partners). These indicators were also true for women with favorable WHR values (Hughes & Gallup, 2003). Males portrayed in advertisements place an emphasis this V-shaped physique. Male models typically have chest sizes of 40-42 inches and waists 30-32 inches. The chests of male body builders can be almost twice as large as their waists. Both women and men dislike a pair-shaped body in which these proportions are reversed, with narrow shoulders and a wide waist.

Ring-to-Index-Finger-Ratio

Another sexual dimorphic cue is the length of the ring finger to the index finger. The index finger is the “pointer” finger and is between the thumb and middle finger. Greater prenatal testosterone exposure produces a longer ring finger in proportion to the length of the index finger. Men with these larger such ratios are stronger and better at sports like skiing, soccer and running. They also seem to dance better than men who have lower ratios. In one experiment, women were shown video clips of male dancers. Those men considered more dominant, masculine and attractive had longer ring-to-index-finger ratio.

Saino, Romano, and Innocenti (2006) created two versions of hands, one in which the length of the fourth (ring) finger was elongated by one standard deviation relative to a control hand and one in which the second (index) finger was shortened, thus manipulating the ring-to-index-finger-ratio. Women preferred opposite-sex hands that had been masculinized by elongating the fourth digit while men avoided masculinized opposite-sex hands with a shortened second digit. Finger length may thus signal desirable hormone-dependent traits or genetic quality. They note that the genetic mechanisms that link finger development to sex hormones are mediated by a type of gene that is present in vertebrates, so these results may extend to other vertebrate animal species.

Skin – Beauty *is* Skin Deep

Eating fruits and vegetables is not only good for you, but also makes you look better! The skin pigment melanin that is dark and yellow in color is known to enhance protection from harmful ultraviolet rays from the sun. Carotenoids that are yellow in color signal health in bird and fish species and are associated with improved immune defense, protection from the sun and reproductive health in humans. Thus, yellowish skin color advertises health and serves as a cue to fitness. As such people with this coloration ought be judged as more attractive and the research bears this out. Stephen, Coetzee and Perrett (2011) found a perceptual preference in UK-based Caucasian and black South African populations for faces with increase yellowishness. Whitehead, Ozakinci, and Perrett (2012) determined that dietary change of increased fruit and vegetable consumption benefits perceived health and can do so in just a matter of weeks. They find that this cue effect is more pronounced in light skinned Asians and Caucasians and is more the case for carotenoid than melanin pigmentation.

Lefevre and Perrett (2015) further examined the difference between these two pigments. In three studies using controlled facial stimuli they discovered that both carotenoid and melanin coloration are both found more attractive compared to skin with lowered levels of these pigments. In addition they showed that carotenoid coloration was preferred over melanin coloration when they were both matched. Carotenoid preferences were stronger for female faces for both male and female observers whereas melanin colorization was found to be relatively more desirable in men. The hypothesized reason for this is that men have darker faces than women (Frost, 1988). Melanin makes faces darker. Increased darkness in male faces enhances this sexual dimorphic trait, making men look masculine and appealing (Carrito, et al., 2015).

One consistent finding among dark-skinned people is a preference for whiter skin (Crivens, 2000; Lewis, 2011). Bond and Cash (1992) surveyed 66 Black college females with varying degrees of dark-colored skin. The participants were satisfied with their skin tone, but those who desired a different skin tone preferred one that was lighter. The majority of those questioned believed that Black men found light skin more beautiful. A 2002 survey by Mark Hill using data from the National Survey of Black Americans confirms these results. They found an increasing preference for female African Americans, the lighter their skin. The effect for men was significantly weaker, consistent with the idea that African Americans perceive fair or lighter skin tone as more feminine. This preference for lighter skin is found also in Jamaica where Africans traditionally bleached their skin to imitate the British (Charles, 2011). In Jamaica white was considered "sexy" and "superior" and is still common throughout the culture as evidenced in newspaper ads, dancehall songs, and massage parlors. These studies show a pervasive Eurocentric standard of beauty for those with darker skin.

In U.S. culture, there is a seeming preference for tan skin. Tanned individuals are generally portrayed as attractive and healthy in popular media like movies and advertisements. Gillen and Bernstein (2015) sought to test this idea experimentally. Using an online data collection system they presented adults with two photos. One showed a job applicant that was not tanned. The other photo showed the same person with digitally manipulated tanned skin. Observers consistently rated the tanned applicant as more qualified than the non-tanned applicant. In a second study they determined that these positive evaluations were the result of perceived attractiveness. A tanned skin is darker and is the product of increased melanin, so this result is in agreement with other research showing a melanin preference.

One of the downsides of tanning aside from skin cancer is wrinkling. Martin (2000) was among the first to show that faces with wrinkled skin are considered less attractive, even if they are tan. In this study female participants rated tan, non-wrinkled faces as healthier than tan, wrinkled faces although the effect was not found among male participants. People in this study who tanned more were more concerned about their appearance but these same individuals also believed that having a tan improved their appearance. Fink, Grammer and Thornhill (2001) used computer software to change the smoothness and tone of female faces. Male observers preferred faces that were smoother, with a less wrinkled texture. They also liked darker over lighter faces. In a related study Fink, Grammer and Matts (2006) created computerized 3-D faces varying in skin color distribution to simulate changes that would occur with age and cumulative sun damage. Even, homogenous distribution in faces (associated with less damage) was preferred and rated as younger in appearance. Aznar, Torro-Alves and Fukusima (2010) simulated wrinkling in faces using computer techniques. Faces with a greater number of wrinkles and depth of furrows were rated as older in appearance.

Cosmetics

Presumably cosmetics do improve physical attractiveness as they have been used since at least the ancient Egyptian era. But is there actual experimental evidence to document this? Cash et al. (1989) found that male peers judged a photo with facial cosmetics to be more attractive than one without them. Female peers were equally favorable to female photos with or without cosmetics. Workman (1991) had 85 undergraduate females view colored photos of a professional female model wearing varying degrees of facial cosmetics. The model in the heavy and moderate conditions was rated as more attractive and more feminine than the model in the no cosmetics condition. The model in the no cosmetics condition was rated highest on morality. Ratings of personality traits and temperament were unaffected by the manipulation. Other studies like that by Jones and Kramer (2015) found that cosmetics increased attractiveness but that it was a modest effect.

Gueguen (2008) had female confederates with and without makeup sit at a popular bar in France. The number and latency of men's solicitations was measured for one-hour intervals. The makeup condition was associated with a greater number of solicitations and shorter latency between the confederate's arrival in the bar and time of first male courtship. However in this study it is unclear whether it is the makeup or the male's interpretation that makeup on a woman signals increased desire for courtship. There are also other factors like body posture cues that need to be controlled for. Gueguen conducted a similar field study in 2013 in which he compared young female confederates with and without makeup who were hitchhiking. There was an increase in the number of male (but not female) drivers who stopped to offer a ride for those wearing the makeup.

The "lipstick effect" is the phenomenon that during economic recessions, women spend more on beauty products and cosmetics and less on most other consumer products like household items and electronics. This has been documented using both historical spending data and experimental studies. Sacco, Bermond and Young (2016) had two groups of women read stories about either an economic recession or a neutral topic on architecture. The women who read the story about the recession demonstrated a stronger automatic visual attention bias for beauty products compared to the control group. According to Hill et al., (2012) this effect is driven by women's increased desire to attract mates with resources when resources become scarce. In the evolutionary psychology perspective, women seek out high status men with resources as a means of providing for potential or existing offspring. See the chapter on the evolutionary approach for more on this view.

But specifically why do women wear cosmetics? One answer from a perceptual perspective has to do with contrast. Contrast is a difference in lightness between two areas, with one side being lighter and the other darker. Russell (2009) discovered that female faces have greater contrast between the eyes, lips and surrounding skin compared to male faces. A face that is androgynous, or neutral with regard to sex, can be made to appear more female by increasing the contrast in these areas or more male by decreasing it. Application of cosmetics increases contrast thereby feminizing the face and may be the explanation for why women apply makeup like eyeliner, mascara and lipstick. Like amount of hair, contrast is another example of a sexual dimorphic feature, a naturally existing difference between the sexes. Exaggeration of these differences leads to greater perceived attractiveness. Figure 4.5 shows an example of an androgynous face.

Figure 4.5. An androgynous face with both male and female characteristics. Copyright free image courtesy of Unsplash.com.

Tattoos

Tattoos in recent years have become much more common, especially in younger aged populations. They are no longer found only on sailors. Horne et al., (2007) surveyed 400 undergraduates at a large university and found 27% of them reported having a tattoo, women more than men. Women reported getting tattoos for personal body decoration, men for group identity (for example, being a member of the Marines). Women more than men were likely to view a tattoo on a member of the opposite sex as attractive. Drews, Allison and Probst (2000) surveyed 235 college students and asked them to rate themselves on their attitudes towards tattooing. Twenty-nine tattooed students viewed themselves as more artistic, creative, individualistic and risky. The 98 tattooed male students judged themselves to be more attractive. The tattooed men reported having more sexual partners.

Tattoos stereotypically have negative connotations and experimental work confirms this. Resenhoeft, Villa and Wiseman (2008) had 158 community college students view a photograph of a female model with and without a visible tattoo. They were instructed to rate her on 13 personal characteristics. Ratings were more negative for the tattoo condition. In a second experiment using a different model, participants, and tattoo (a dolphin instead of a dragon), there were also more negative ratings.

Swami and Furnham (2007) had a group of male and female undergraduates rate a series of sixteen female line drawings with two levels of hair color and eight levels of tattooing. Tattooed women were rated as less physically attractive, more sexually promiscuous and to be heavier drinkers than women without tattoos, with negative ratings increasing with greater number of tattoos. Gueguen (2013) predicted that men would be more likely to approach women with tattoos. They used confederates (experimental actors) who had temporary tattoos applied to their lower backs. The confederates laid flat on their stomachs reading a book on a popular beach. They found that more men approached the tattooed confederates than the ones without tattoos and did so more quickly. The assigned level of physical attractiveness however did not differ between the two groups.

Figure 3.6. A woman displaying tattoos. Would you judge her differently if she did not have this skin decoration? Copyright image from Unsplash.com.

Why would people wear tattoos? According to Koziel, Kretschmer, and Pawlowski (2009) there are two hypotheses, both related to advertising one's genetic fitness. Tattoos and piercings both pose health risks due to blood-borne transmission of disease. Those who decide to get tattooed or pierced may have higher biological quality, such as greater resistance to infection. By having these procedures done they are therefore signaling their fitness. Alternatively one could use tattooing to hide some less than desirable aspect of themselves like a skin blemish or low body symmetry The researchers measured fluctuating asymmetry, which is a measure of developmental disease resistance in two groups, one who had tattoos or piercing and another that did not. There was greater symmetry (lower fluctuation) in the tattooed group, supporting the first hypothesis. The effect was true mostly for men.

Hair

Facial and body hair are among the most obvious of traits we see in others. They are also the most sexually dimorphic, meaning they are expressed differently in the two sexes. Men typically have more body hair than women not only on the faces in the form of beards but also across all parts of their body. These sorts of differences are usually exploited in the service of looking good. Women in many cultures remove excess body hair by the use of such techniques as waxing. In western culture bodybuilding men are the ones who remove hair from their bodies, ostensibly to better show off their muscles. When male skin below the belly button is exposed, it is not usually shaved, nor is arm or leg hair (Etcoff, 1999).

Dixson and Rantala (2016) showed photographs of men with varying amounts of facial and body hair to women who were categorized as low fertile, high fertile or using contraceptives. As described in the section on faces women prefer men who are more masculine in appearance when they are in the fertile stage of their menstrual cycle. The results were that the women preferred facial hair that was more evenly and continuously distributed than when it was patchy. Patchy hair is thicker or more concentrated in certain areas than others. Men with body hair though were judged less attractive than those that were clean-shaven. The exceptions to this were areas around the areolae (dark area around the nipple), pectoral region (chest) and sternum (breast bone). There was no effect of fertility on women's preferences. In a similar study Dixson and Brooks (2013) had men and women judge images of male facial hair only. Women found heavy stubble to be the most attractive. Men rated full beards and heavy stubble as most attractive. Both sexes rated full beards highest for parenting ability and healthiness. Apparently full-bearded men are perceived as better fathers who could protect and invest in offspring. Figure 4.7shows an example of a male face varying in amount of facial hair.

Figure 4.7. A man with a beard. Clean-shaven, stubble, and beards elicit different judgments regarding fatherhood and sexual attraction. Copyright free image courtesy of Unsplash.com.

Swami, Furnham and Joshi (2008) had men and women rate a series of line drawings of female faces with different levels of skin tone, hair color and hair length. There were significant interactions among the three variables but several main effects. Light skin tones were preferred and contrary to previous research brunettes were rated more highly than blondes. Hair length had little to no effect on ratings. Swami et al. (2008) had a large cross-cultural sample of people judge female line drawings varying in skin tone, two levels of hair color and three levels of body weight. They found that ratings of health were not consistent with ratings of attractiveness. Drawings rated as high in health were not also always rated as better looking. Neave and Shields (2008) presented male faces varying in degree of facial hair to 60 females and had them rate the faces on several attributes. Males with a full beard were considered more aggressive, masculine, mature and older. Faces with light stubble were considered the most attractive and this was the hairstyle preferred by women for both short- and long-term relationships.

Bereczkei and Mesko (2006) presented young female faces with neotenous (baby-like) and mature facial features and with different lengths of hair. Men rated neotenous features such as large eyes and a small nose and sexually mature features like long hair in the periphery as the most beautiful. The male raters judged faces with long hair as more intelligent, determined and healthy. Short hair was associated with being more caring, emotional and honest. Surprisingly, short hair length was also associated with greater femininity.

What about hair color? In western culture there is the stereotype that "blondes have more fun". Is this true? Research by social and evolutionary psychologists shows it is (Rich & Cash, 1993). The reason for this preference has not been fully explicated. Sorokowski (2006) found that blonde hair color was a "rejuvenation" factor improving the perceived attractiveness of female faces above the age of 25 years old. He found no relationship between how old a man is and preference for hair color. Clayson and Klassen (1989), in a study with 318 Caucasian college students found that redheaded men were seen as less attractive than those with other hair colors.

Figure 3.8. Do blondes have more fun? Copyright free image courtesy of Unsplash.com

Clothes and Fashion

Clothes serve two functions, as does everything in evolution. First, they are functional, keeping us warm or dry to keep us alive. Secondly they are signals to members of the opposite sex advertising our genetic qualities. The first function is natural selection and is about life or death. The second function is sexual selection and is about reproduction. Just as the male peacock flashes his beautiful tail, we humans also put on our shirts and jackets to put on a show. The sexual function of clothes can cover up our weaknesses or display our strengths. Black can supposedly make us look slimmer if we are too overweight or a short dress can emphasize nice legs. In fact clothes may be more erotic by only revealing part of the body and inviting the imagination to do the rest. According to at least one anthropological theory, clothes evolved to call attention to the erotic zones of the body.

Clothes for men are about displaying income-earning power. Think of the polo shirt or other garb that reflect high-status activities like golfing, polo or yachting. These clothes show that men can afford to have leisure time and the capacity to practice at expensive sports. The tuxedo and the business power suit never seem to go out of style and of course indicate the wearer is capable of making lots of money. For women clothes are more about “displaying the goods” and will accentuate or reveal breasts, hips and legs.

The elite create fashions and to wear what is in fashion is to show that one is a member of the elite. The high cost of fashion shows also that the wearer can afford it. As soon as any new fashion comes out, it is imitated for the masses at lower cost. This means that fashion must constantly change if they are to differentiate the classes. This of course requires attention to what is fashionable and the constant purchase of new fashion items, which of itself again demonstrates elite status and wealth. Let’s look next at psychological studies of clothes.

Figure 4.9. Fashion clothes are often purchased as a symbol to display one's social status. Copyright free image courtesy of Unsplash.com.

Satrapa, et al. (1992) had women from three colleges rate photographs of male students, also from these colleges. The men's faces were removed from the photos. The first male model was dressed in a socially formal manner, the second was dressed in an informal way and the third dressed sportively. All of the models were rated comparably on intelligence and culture. The formally dressed model though was rated as being more extroverted, charming, sympathetic and attractive than the other two models. These data support the idea that expensive clothes serve to advertise male mating suitability.

Williamson and Hewitt (1986) showed male and female undergraduates images of female models wearing normal or sexually alluring attire. Men found miniskirts and short shorts more attractive. Women found that blatant forms of alluring attire such a miniskirt, unbuttoned shirt or bra-less wet T-shirt were less attractive than normal clothes. The female response may be interpreted in terms of sexual competition. Edmonds and Cahoon (1984) had college students rate 40 pictures of women's apparel in terms of how sexually arousing it would be to men. There was a strong correlation (0.85) between ratings for males and females indicating that women have a good understanding of what kinds of clothes are arousing to men. In a second part of the study women who perceived themselves as sexually attractive had a marked preference for those clothes judged to be the most sexually exciting to men.

Females of many primate species (other than humans) advertise their fertility with the ovulatory cycle. Human females may do so using other means. Haselton et al. (2007) tracked 30 women throughout their cycles, photographing them during their high and low fertility periods. They found higher self-grooming and attractive choice of dress during the fertile phase. This finding may explain the previous research finding of men's greater retentive efforts as their partners approach ovulation.

The color red seems to have a special sexual status. Several studies have shown that men perceive red-colored clothes on women as attractive. Gueguen and Jacob (2014) wanted to see if this extended to a tipping context. They instructed 11 waitresses in five restaurants to wear the same T-shirt with different colors (white, black, red, yellow, green, or blue). The waitresses who wore red received more tips, but only from male patrons. There was no effect of color on female tipping. Pazda, Prokop and Elliot (2014) were interested in women's perception of red. In one experiment they demonstrated that female observers perceive a woman in a red dress as being more sexually receptive than a woman wearing a white dress. In a second experiment women were found more likely to derogate (put down) the sexual fidelity of a woman in red compared to a woman wearing white. In a final experiment, women were more likely to guard their romantic partner from a woman wearing a red compared to a green shirt.

Odors

Can we be attracted to odors? Are there certain odors that are "sexy" or "beautiful"? There is a multi-billion dollar industry devoted to this question, with companies manufacturing perfumes, colognes and various deodorants. The field of environmental fragrancing also creates candles, incense, sprays and devices that release chemicals into the air that are supposed to be pleasing. These include scents like apple, vanilla, and sandalwood among hundreds of others. In fact it is hard to find a soap, shampoo, conditioner, dishwashing liquid, detergent or other cleaning product that doesn't have a fragrance added to it (Gilbert & Firestein, 2002).

Many species release odors into the air that attract members of the opposite sex or induce some other type of social response. These are called pheromones. For example, the female silk moth can attract males from many miles away by releasing a tiny amount of the chemical bombykol into the air. It is not clear whether humans release or respond to pheromones. The research so far seems inconclusive. Humans can respond to odors related to reproduction. In the phenomenon of menstrual synchrony, women who live together for an extended period begin to synchronize their cycles. This is due to an odorant molecule released from under their armpits (McClintock, 1971). Men who smell T-shirts that women have worn for three nights during the ovulatory phase of their cycle judge them to be more pleasant (Singh & Bronstad, 2001). Also, men who prefer the smell of T-shirts worn by women who are near ovulation have been found to have higher testosterone levels.

There has been research on an androgen steroid called androstadienone. This work has shown that it influences mood, attention and physiological states (Bensafi, et al., 2004; Jacob & McClintock, 2000; Lundstrom, Goncalves, Esteves, and

Olsson, 2003). Ferdenzi, Delplanque, Atanassova, and Sander (2016) exposed men and women to androstadienone in clove oil and found that it enhanced the perceived attractiveness of opposite sex stimuli (facial and vocal) in men and fertile women. There were also differential response times to it by the two sexes. They however conclude that these effects are general and not sex-specific. Administration of androstadienone in small quantities to women results in a reduction of nervousness, tension and other negative feelings (Grosser, Monti-Bloch, Jennings-White, and Berliner, 2000). Jacob, Hayreh and McClintock (2001) found an increase in women's positive mood in response to androstadienone but only in the presence of a male tester and when the majority of the women were in the late follicular stage of their menstrual cycle. Men were rated more attractive when assessed by women who had been exposed to androstadienone in a speed-dating event (Saxton, Lyndon, Little, and Roberts, 2008). Women exposed to androstadienone spend more time looking at female faces, so this chemosignal may increase intrasexual completion during certain ovulatory phases (Parma, et al., 2012). Other work on androstadienone shows that it can modulate pain perception and make women more generous (Perrotta, Graffeo, Bonini, & Gottfried, 2016; Villemure & Bushnell, 2007).

Copulins are the name for five volatile fatty acids secreted vaginally by human females. They increase during the follicular phase (higher fertility) and decrease during the luteal phase (lower fertility). Men exposed to copulins were more likely to rate themselves as sexually desirable to women. They also rated women's faces as more attractive (Williams & Jacobson, 2016). So copulins seem like a new chemosignal that may affect sexual attractiveness but the research on this topic has just begun and there isn't much more information available.

Gait

Gait refers to the way in which one walks. Men and women walk differently and these differences can be detected even under conditions of minimal information, as in point-light walker displays (Kozlowski & Cutting, 1977). In these displays lights are attached to joints and movement is filmed in a dark room so that only the movement of the lights is visible. Certain body movement combinations have been found to signal the walking style of males (tubular body motion with shoulder swagger) and females (hourglass body movement with hip sway). Homosexual orientation can additionally be determined from gait style as deviations from these heterosexual-typical movements (Johnson, Gill, Reichman, & Tassinary, 2007).

The two sexes also walk differently when displaying sexually to members of the opposite sex. In one study men and women were placed on a treadmill and asked to walk as if someone attractive of the opposite sex were looking at them. Men swung their shoulders more and produced movements emphasizing their chest. Women swung and emphasized their hips more. Members of both sexes are able to detect these differences.

Sakaguchi and Hasegawa (2006) used point-light and full-view video clips of female walkers that were shown to male students. The men were asked to rate the likelihood of approaching the walker for a sexual advance. In the point-light condition raters selected slow walkers with a short stride length as implying vulnerability. This walking style could invite unwanted sexual advances from men such as inappropriate touching or rape. In the full-view video condition raters choose well-groomed or physically attractive walkers as sexual advance targets. These characteristics correlated with the subject's reported occurrence of advances. Also, awkward movements were a quality that invited sexual advances.

Women walk differently depending upon what menstrual cycle phase they are in. Fink, Hugill and Lange (2012) employed digital videos of dances and gaits of 48 heterosexual women between the ages of 19 and 33 years. These were recorded during the late follicular stage (increased likelihood of conception) and the mid-luteal phase (decreased likelihood of conception). The videos were judged by a group of 200 men. The movements recorded during the follicular stage were rated as more sexually attractive. The results show that women walk differently at different phases of their cycle and that men can detect these differences.

In modern culture there is an implied connection between high heels and female sexuality. Morris, White, Morrison, and Fisher (2013) had participants view point-light videos of women walking in flat shoes and high heels. The observers judged the females in the heels videos as significantly more attractive. An analysis revealed that the heels condition led to increased femininity of gait through reduced stride length and increased rotation and tilt of the hips. The authors conclude that high heels exaggerate existing feminine aspects of gait and that these serve as cues to attraction.

Social Aspects of Beauty

Nancy Etcoff, in her 1999 book *Survival of the Prettiest*, outlines the many ways we treat beautiful people differently. In this section we summarize some of the studies she presents and then update this work with more current research. We also show that beautiful people have different expectations and thus act in ways that differ from those judged less attractive.

Early Development

The psychologist Langlois in several studies presented a diverse set of faces to infants three and six months old. They were faces of men, women, babies, Caucasians, African-Americans and Asian Americans. The infants spent more time looking at the faces that were rated by adults as being the most attractive. These results suggest that face preferences are innate as they occur too early for environmental influences. They also suggest that there are attractive features in faces that are universal, i.e., that are found in every face no matter the gender or race (Langlois, et al., 1987; Langlois, Ritter, Roggman, and Vaughn, 1991). Other work shows consistent infant preferences. They like to touch soft as opposed to rough surfaces, prefer to look at patterns that are symmetrical and even seem to enjoy listening to music that is consonant.

But how do adults react to babies? Evolution would dictate that babies be appealing, otherwise they might be neglected and die. This type of beauty, cuteness, elicits nurturing and care behaviors from parents. What does it mean to be cute? Cute features in infants include soft skin and hair, a high forehead, large eyes and pupils, chubby cheeks and a small nose. Infant heads are also much larger in proportion to their bodies compared to adults, with smaller limbs. In one set of studies mothers were observed interacting with their infants. Moms with the cutest infants spent more time vocalizing with their baby, holding their baby close and staring into their baby's eyes. It was also more difficult for these moms to turn their attention away from their newborn. In contrast, those with less attractive infants spent more time attending to their baby's needs. They spent more time burping, wiping, and checking on them. Their attention was also more easily drawn away (Langlois, Ritter, Casey, & Sawin, 1995; Ritter, Casey, & Langlois, 1991).

One of the tragic consequences of being an "ugly" baby is that their caretakers may mistreat them. In one study, it was found that a larger percentage of abused children under court protection in Massachusetts and California were considered unattractive (McCabe, 1988). These children had faces judged less cute and child-like. Their faces were considered to be older looking in appearance. This may cause their caretakers to be less protective of them and to have unrealistic expectations. These same findings are unfortunately the case for infants as well. Mann (1992) found that mothers of high-risk, low-birth-weight twins spent more time vocalizing, soothing, playing and holding the more healthier appearing of the pair. This could also be an evolutionary strategy. Moms that spend more time caring for a healthier child help to ensure the survival of that child, sometimes at the expense of other offspring.

Figure 4.10. How "cute" a baby is can directly affect how they are treated by their caregivers. Copyright free image courtesy of Unsplash.com

The advantages of good looks follow us into school. In one study, schoolteachers from Missouri were given hypothetical descriptions of fifth grade students. These descriptions included a report card and an evaluation of the student's academic performance. The only difference was that one group of teachers received a photo showing an attractive child and the other group received a photo showing a less attractive child. As you might guess, the teachers shown the attractive photo rated the student as being more popular, sociable, and intelligent (Clifford & Walster, 1973). Subjective judgments do seem to explain why beautiful students get better grades because when students are given standardized exams without such bias, the difference goes away (Jackson, Hunter, & Hodge, 1995). Dion (1972) provided adults with hypothetical descriptions of children's bad behavior such as throwing snowballs or stepping on a dog's tail. The behavior of the good-looking children was excused, they were assumed to be having a "bad day". The behavior of the "ugly" children was viewed suspiciously. They were considered in some cases to be possible juvenile delinquents.

Adult Behavior

People are more likely to help beautiful people. In one classic study a group of male college students look at female faces. They were then asked if they would be willing to perform some behavior for that person. The students were more likely to help move furniture, donate blood or a kidney, swim a mile to perform a rescue or even jump on a hand grenade for the women with attractive faces! Other studies show we are more likely to return money to beautiful women and to donate volunteer time to attractive people, even when we know they have criticized us. But interestingly, we are less likely to ask good-looking people for help and we give them more personal space on the sidewalk (Dabbs & Stokes, 1975).

Attractive people are more likely to win arguments and convert people over to their side of an argument. They are more comfortable in social situations and less likely to fear negative opinions from others (Feingold, 1992). They also have greater internal locus of control, believing they are more in charge of their lives and less the victims of fate. They are also more assertive. If kept waiting, they get impatient earlier and are faster to demand attention (Jackson & Huston, 1975). In one fascinating study, women and men spoke to each other over the phone. The men were given either an attractive or unattractive photo of their female phone partner. In reality it was always the same woman they were speaking with. The men given the attractive photo spoke in ways that were bolder, sexier and more humorous. In turn, these women responded by speaking in ways that were more confident and animated (Snyder, Tanke, & Berscheid, 1977). Why all the special treatment? Apparently we want what attractive people have or think they can get us the things we want.

The attractiveness "halo effect" is the positive regard that people give to those with good lucks and has been studied for some time. Attractive people are expected to have happier marriages, better jobs and be more mentally healthy (Dion, Berscheid, & Walster, 1972). Kaplan (1978) had male and female undergraduates judge an essay purportedly written by either an attractive or unattractive female author. The attractive author was rated as significantly more talented by male judges. However the effect did not extend to male authors.

In one study a relatively large sample of college students judged 24 male and female targets varying in attractiveness. They found attributions of sexiness, increased femininity or masculinity depending on the gender of the rated face and liking, especially for females. Attractive people both male and female are considered more intelligent. The effect is especially strong for males (Jackson, Hunter, & Hodge, 1995). Why should we help attractive people and why do we hold them in such positive regard? It may be because they tend to be popular and therefore in positions of power. As such, they can do us favors and advance our own agendas.

Physical Attractiveness and Sex

We next examine physical attractiveness and the role it plays in actual and perceived sexual behavior. People anticipate attractive individuals to be more socially confident, popular and at ease. They are also expected to be more sexually experienced, exciting and responsive. Men think good-looking women have a higher sex drive and that they prefer variety in sex. Participants in these studies expect attractive people to date more often, start having sex earlier and fall in love more frequently. These perceptions often bear out. Beautiful men and women are in fact more popular with members of the opposite sex, get more attention and do date more often. However, attractive women are less liked by other women, even other beautiful women, presumably because of sexual competition.

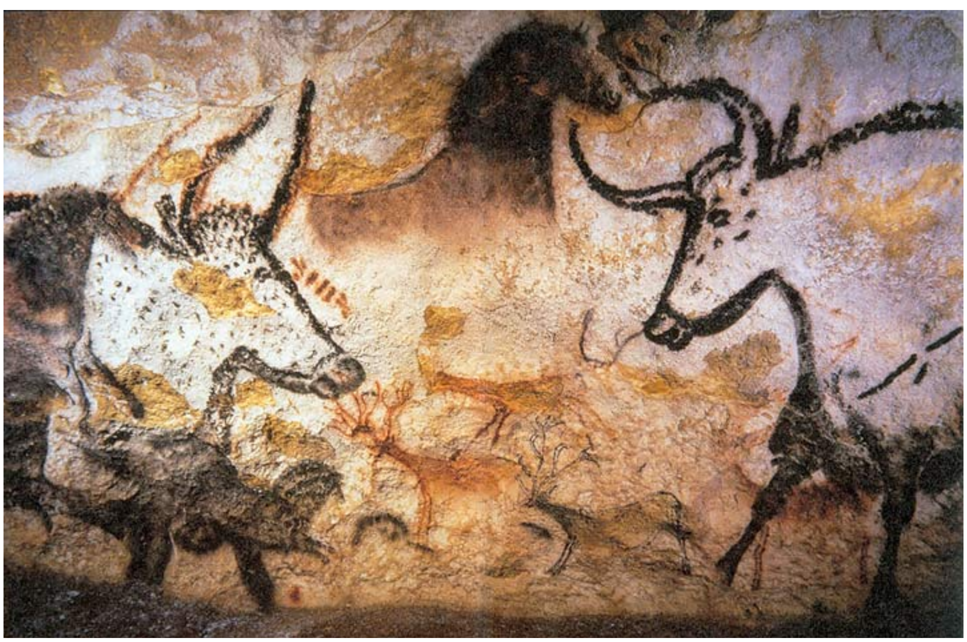
Feingold (1991) in a meta-analysis of nine studies obtained findings indicating men value attractiveness more than women but that women valued similarity (between dating or mating partners) more than men. Women consistently valued attractiveness less than they did similarity. Greitemeyer (2005) found that men always reported a greater willingness to accept a sexual offer if the partner was attractive. The same was true for women when the offer was short-term. For long-term offers women were equally likely to accept an offer from a partner if he had a high socioeconomic status or high physical attractiveness. Men in general report a willingness toward all kinds of sexual offers. There is the assumption of a double standard in promiscuity, where men supposedly rate promiscuous women less favorably than women would rate a promiscuous man. Levesque et al. (2007) found limited evidence for this. In their study women rated a promiscuous man more negatively than men rated a promiscuous woman.

In the "contrast effect", an average looking person will become less appealing if one is exposed to someone else of greater attractiveness (Kenrick & Gutierres, 1980). People under these circumstances also become more publically self-conscious (Thorton & Moore, 1993). The effect applies to one own's sex as well, what is called negative contrast. Women, when shown pictures of idealized women's bodies, have lower perceptions of their own attractiveness and lower social self-esteem. These negative contrast effects were most pronounced in women who had a high public self-consciousness to begin with. However, contrast can work in the other direction as well. Attractiveness self-ratings are enhanced by exposure to an unattractive person of the same sex. This is called positive contrast. The positive contrast effect is associated with marginally increased social self-esteem but not with heightened public self-consciousness. The contrast effect also holds up for avatars, which are digital representations of people. Participants exposed to attractive female avatars rated a photograph of a woman significantly less attractive than those who had been exposed to an ugly avatar (Leding, Horton, & Wootan, 2015).

Prehistoric Art History

Recorded art history only goes back to European cave paintings like those in Lascaux, France that date back to 15,000 to 20,000 years ago (Figure 4.11). Paintings at the site of Chauvet are older still, estimated to be 32,000 years old. What is remarkable is that over this entire time period the style of the art in these caves remained the same. The scenes are all of the same animals (bison, horses, mammoths) in side poses without backgrounds. There was no experimentation with different styles and as Chatterjee (2014) notes, nobody attempted to paint a landscape or a portrait. From a modern day perspective where new artistic styles come in every few years or less, this seems quite strange. Nobody is quite sure why this might be. It is possible that art then served a purely religious or spiritual function and was controlled by "shamans" or their equivalent.

Figure 4.11. A cave painting of animals from Lascaux, France. Paintings from this cave date from 15,000 to 20,000 years ago. Image is in the public domain. Photo by Prof saxx. Sourced from Wikimedia commons.



Prior to this period it becomes very difficult to find evidence of the creation of art. Any art of this time must be of hard materials like those fashioned from stone or bone. Softer materials like fabric or fur would usually disintegrate. What evidence is available from periods before Chauvet come from what is called the middle Paleolithic that dates from 50,000 to 300,000 years ago. These consist of engravings on cave walls and rock surfaces and are found from all over the world, not just in Europe. Beads and shells are also found, some with holes in them that suggest they were strung together and worn as body adornments like necklaces. Table 4.1 provides a summary of dates, locations and types of evidence found from the prehistory of art.

Table 4.1. Prehistoric Art History Timeline

Time (Years Ago)	Archeological Site Location	Artifact Description
15,000-20,000	Lascaux, France	Cave painting
32,000	Chauvet, France	Cave painting
40,000	Malakunanja 2 & Nauwalabila 1, Arnhemland, Australia	Ground blocks of hematite
42,000	Carpenter’s Gap, Kimberly Australia	Painted rocks
75,000-100,00	Blombos Cave, South Africa	Red ochre, criss-cross markings, abstract geometric engraving
82,000	Morocco	Perforated shells with traces of ochre
95,000	Qafzeh cave, Near East	Decorative shells
100,00-135,000	Skhul, Near East	Decorative shells
200,000	Twin Rivers, Central Zambia	Creating of red, yellow, blue, pink & brown pigments
230,000	Northern Golan Heights, Middle East	The Berakhat Ram figure (small stone female sculpture)
250,000	Tata, Hungary	Grave decoration with feathers, use of red ochre (Neanderthals)
400,000	Morocco	The Tan-Tan quartzite figurine (small human-shaped stone sculpture)
290,000-700,000	Auditorium cave in Bhimbetka, India & Daraki-Chattan rock shelter, India	Cupule rock engravings (also found elsewhere around the world)
800,000	Wonderwerk cave, South Africa	Use of colored pigments
850,000	Africa	Collection of quartz crystals (Homo Erectus)
2,500,000-3,000,000	Makapansgat cave, South Africa	Red jasperite cobble, rock fragment shaped like a face (oldest known art object, Australopithecus)

A few conclusions can be drawn from this period. First the evidence does not support the view that creative endeavors began in Europe and then spread to the rest of the world, what has been called the “creativity explosion”. Rather, evidence of artistic works are distributed throughout the world. The consensus is that creation of these artifacts required planning, a social hierarchy, and some technological capability. The artifacts do not seem to be tools, no practical function can be found for them. Finally, the cultures that created them must have had some symbolic capability, the capacity to use symbols to represent things in the world. Chatterjee (2014) makes three conclusions regarding prehistoric art. One, this early art was materially and stylistically diverse. Two, it is difficult to interpret this art in terms of why it was created and how it was used, it resists easy classification or interpretation. Third, local demographic and ecological conditions shaped the production and probably the appreciation of the art.

Art and Evolutionary Theories

It is generally agreed that art requires the ability to represent objects and things in our minds, what is called symbolic representation. What is not clear is exactly when this ability emerged in our hominid ancestors. It probably evolved slowly, long before the emergence of *Homo sapiens* (Flinn, Geary, & Ward, 2005). It may have been present in the form of dancing, music, and social interaction that would have not left any artifacts behind for us to record (Wadley, Hodgskiss, & Grant, 2009). We mentioned earlier the difference between natural and sexual selection. More applied forms of creativity like technology, engineering and tool making, are probably under natural selection pressures. The more ornate and beautiful forms of creativity, such as painting, music and dance, are probably more under sexual selection pressures (Feist, 2007).

Art is everywhere. We find it in all cultures throughout all of human history and prehistory. Anything that is universal suggests that there must be some adaptive purpose at work. In other words, having art seems to have helped us survive somehow as a species. Dissanayake (2007) outlines nine evolutionary hypotheses about what art does, taken from an evolutionary perspective. These are described in Table 4.2. Rather than elaborate upon all of these, in this section we examine five hypotheses about the adaptive function of art. Each of these proposes a different reason for why having art may have helped humans to survive.

Table 4.2. Nine hypotheses about what art does. After Dissanayke (2006).

	Reference	**Hypothesis**
1.	Zeki (1999); Ramachandran & Hirstein (1999)	To acquire a deeper knowledge of objects, surfaces, faces and situations. To help a viewer to solve perceptual and cognitive problems.
2.	Orians (2001)	Promotes selective attention and positive emotional response to components of the environment that lead to adaptive decisions and problem solving.
3.	Miller (2000, 2001)	Art is creativity and/or virtuosity that contributes to mating opportunity.
4.	Irons (2001)	Art communicates an honest signal of commitment, such as art-filled ceremonial behavior found in most religions.
5.	Tooby & Cosmides (2001)	Provides a risk-free practice for later life when similar circumstances might arise.
6.	Aiken (1998)	To manipulate and control other people
7.	Boyd (2005)	To enhance cooperation and social cohesion and continuity.
8.	Archeological researchers	Art is symbolic like language and contributes to higher thought and intelligence.
9.	Pinker (1997)	Art has no adaptive value, it is merely a byproduct of other adaptations.

The Costly Signal

Most often sexual traits like large horns or a colorful tail are energy-intensive and wasteful. They often get in the way and so seem poor candidates for natural selective processes that typically favor efficiency. The same can be said for much of the arts. Artistic pursuits require a tremendous investment of time, thought, energy and skill. So both sexual characteristics and art might better be explained through sexual rather than natural selection. Both art and sex are concerned with the display of beauty. Beauty in the case of sexual selection is a signal. It advertises reproductive fitness. Art to some extent may be saying the same thing. Someone who can afford to purchase expensive paintings or wear fancy jewelry is proclaiming their ability to procure resources and serve as a well-providing parent. This is known as the "costly signal" or "handicap" hypothesis.

Dutton (2009) describes some of the ways in which costliness and waste relate to beauty. Works of art are typically made of rare or difficult to obtain materials like gold that require money to purchase. They are also time-consuming to create. This demonstrates that the artist has leisure time on his or her hands. Increased leisure time is usually correlated with income and social status. Artworks, even if made quickly require skills to create that themselves demand large amounts of time. Art creation in addition requires intellectual and creative resources and so demonstrates the intelligence and creativity of the artist, personality traits we know are sought out by both sexes. So being an artist or being able to possess art are both likely indicators of genetic fitness.

There is evidence to support this handicap explanation. In one questionnaire study, 425 British adults were asked about their creative activity and sexual history. They found that those who invested more time in creating art had more sexual partners (Nettle & Clegg, 2006). There was no sex difference here: women who were more artistically productive also had more sexual partners. Haselton and Miller (2006) found that women rated artistic men as more sexually desirable during the fertile phase of their menstrual cycle. They even valued artistic men over wealthy men when rating for short-term partners.

Art as Ritual

Another evolutionary theory for why art is adaptive comes from Ellen Dissanayake. She argues that art is part of social ritual. Art in this notion is not about how a single viewer experiences it but about how it is used in the social group. Art in this view is part of cultural practice. When objects are used in ways that help bind a group together and make it more cohesive, the process is called “artifaction”. One might imagine for instance music and dance as art rituals that celebrate younger members of a tribe coming of age. Alternatively, one could see cave paintings as ways to record and celebrate a successful hunt. Art is something people enjoy and when people experience it together, it brings them closer emotionally. These tighter bonds between individuals in a group will enable them to cope better with emergencies and to survive to pass on their genes. Less cohesive groups won’t be able to work together as effectively and stand a greater risk of extinction.

Ritualized behaviors are communicative displays that transform ordinary behaviors and make them extraordinary. A ritualized version of a behavior in both humans and animals has several features. It is 1) simplified, meaning it is stereotyped or patterned; 2) repeated with a given intensity or regularity that differs from the performance of ordinary actions; 3) exaggerated, made more salient or obvious; 4) elaborated; and performed with 5) a manipulation of expectation. These are all features that can be applied to the arts. For example, ordinary body movements become dance, ordinary language becomes poetry or literature and ordinary materials like artifacts and surroundings become extraordinary with paint and carving, etc.

Artifaction has an important cognitive effect. It makes something special and important and in some cases magical compared to its ordinary meaning or usage. For instance, ornamenting objects like weapons or jewelry gives them a special power. Placing a crucifix in a new church is a form of sanctifying and protecting it. The utterance of prayers or incantations is a way of making contact with spirits or gods (Brown & Dissanayake, 2009). Art in this way is something very powerful, as it takes on a spiritual and religious-like dimension.

Fiction and Storytelling

Dutton (2009) argues that fiction serves at least three purposes. By fiction, he means oral story telling and mythology in preliterate societies and after this the invention of writing that gave rise to novels, plays, operas, movies and video games. The first of these is that stories provide us with practical advice for how to deal with a potential problem. A movie can warn us for example, about the conditions that might lead to war so that we avoid it in the future. Second, stories even though they are made up can provide us with factual information. A play about love set in Elizabethan England, for instance can inform us about the lives of the royal family at that time in history. Third, stories encourage us to explore the beliefs, values and motivations of others. They help us to understand others better and in so doing hopefully allow us to get along better with them.

Fiction from an evolutionary perspective is the cultural transmission of useful information. Sugiyama (2005) has studied storytelling in foraging societies and concludes that they use stories to acquire information, rehearse strategies and refine skills that will benefit them in the future. For instance, the Kalahari hunters in Africa sit around the fire, describing both recent hunts and those from more distant times. The stories provide information about the habits of animals, how to read their tracks, and ways of approaching and killing them. These stories are often more memorable than the depiction of facts alone because they are dramatized and made more interesting. As a result they are more likely to be recalled and used if necessary.

Booker (2004) has analyzed literature from many different stories including folktales from preliterate societies, epic poetry, novels, operas and film. He concludes that there are nine basic plot types that occur in these forms. He actually started off with seven but then added two more. Each of these plots has a basic lesson. The plots, the lesson they teach and an illustrative example are shown in Table 4.3.

Table 4.3. The nine basic plot types, their possible lessons and examples, according to Booker (2004).

Plot Type	Description	Possible Lesson	Example
1. Overcoming the monster	The hero's ordeals and escape from death. Ends with society being saved from evil	How to overcome a societal threat. The threat could be a lion or a rival tribe	Little Red Riding Hood
2. Rags to riches	How a modest downtrodden character with a special talent or beauty is at last revealed	Tolerance or respect for others	The Ugly Duckling
3. The quest	A hero, sometimes	How to overcome	Odysseus

	with sidekicks travels and gains a treasure and/or conquers evil	a threat or seek out a resource	
4. Voyage and return	The character enters an alien or unfamiliar world then returns, often after a thrilling escape	How to deal with foreign or unusual situations	Robinson Crusoe
5. Comedy	Confusion reigns until a hero and heroine are united in love	Understanding the vagaries and problems of romantic relationships	A Midsummer Night's Dream
6. Tragedy	Human overreaching and its consequences	The often negative consequences of going too far	Oresteia
7. Rebirth	Characters that undergo a transformation	How to improve one's self	Scrooge
8. Rebellion	Characters dealing with an oftentimes evil or corrupt society	How to recognize an evil social system and fight against it	Nineteen Eighty-Four
9. Mystery	A detective confronts and must solve a mystery	How to solve problems such as murders	Sherlock Holmes

Art as By-Product

It may be that art serves no purpose whatsoever. It just happens to be with us as a byproduct of other adaptations. The evolutionary biologist Stephen Jay Gould described byproducts as spandrels. A spandrel is the space in-between an arch and the frame that surrounds it. These are commonly encountered architectural features in many European churches. This space serves no functional purpose. It is just a consequence of the way one builds these structures. Yet these spaces are a great place to put ornamental decoration and they are usually filled with depictions of leaves, curlicues and human figures. In the same way it may be that art serves no purpose, it is just an artifact of other adaptive functions, but because it is not costly it persists and has not been selected out of our behavioral repertoire. This view in effect sees art as "just along for the ride".

Music is a good example to illustrate this. Darwin himself said in *The Descent of Man: "* As neither the enjoyment nor the capacity of producing musical notes are faculties of the least use to man… they must be ranked among the most mysterious with which he is endowed." More recently the psychologist Steven Pinker has referred to music as "auditory cheesecake", meaning that it is pleasing but frivolous. Pinker believes that arts are by-products of two other traits. The first are motivational systems that produce pleasure in response to real adaptive behaviors like eating, sex, safety, and esteem. The second are the technological means to create signals that correlate with those pleasures. In Pinker's view, music has "co-opted" the brain centers that activate when we experience those other pleasures, so those centers now activate in response to music as well. More on this when we discuss music later in the psychology chapter.

Art as a Free-Varying Trait

Chatterjee (2014) tells the story of the Bengalese finch as a third evolutionary explanation for art. In this third scenario, art becomes a trait that is no longer selected for and becomes free to express itself in a greater variety of ways. The munia bird was bred in Japan from the white rumped munia, a wild breed of finch in Asia. Munias have a stereotyped song that they use to attract mates. Over generations, the Japanese have bred the munia to give it bright colorful plumage. Since it is now domestic, the bird no longer needs to sing just one stereotyped mating song. Instead its singing capability has morphed into a great variety of different songs. The songs are now more complex than they used to be and it becomes difficult to predict what sequence of notes the birds will emit (Okanoya, 2004). The Bengalese finches have also become capable of learning new songs and of learning abstract patterns inside of their songs (Yamazaki et al., 2011).

In effect, the Bengalese finch has become an artist. Its genes have undergone drift and the neural programs that govern its singing have altered. In the munia there is one brain structure called the nucleus RA that regulates singing behavior. The neural circuits that govern singing in the Begalese finch by contrast are more widely distributed across its cortex. Other parts of its brain now regulate the activity of the nucleus RA (Hosino & Okanoya, 2000). The Bengalese finch, by reason of analogy, has become an improvisational jazz performer rather than a music box player. These brain changes seem to parallel our own artistic ability, which is itself managed by multiple brain circuits.

Body Adornment and the Evolution of Visual Art

There was a considerable amount of art in Western Europe about 45,000 years ago. One possible trigger for this may have been the adoption of social group living and the development of cumulative social practices which may have first developed much earlier (Carruthers, 2013). It has been proposed that the decoration of bodies with paint and jewelry was a type of visual art. This adornment could have used as a form of visual identification of one's social status and rank in the group. Note that today soccer and other sport fans still apply face paint as a means of identifying with one's team. It may have also served as a form of camouflage to hide while waiting for or stalking prey. Camouflage would have also helped to win wars, gain territory and other resources. There is also a tendency in body adornment to wear animal fur, teeth and other body parts as a form of mimicking animals. Figure 4.12 shows an example of face paint.

Figure 12. Face paint decoration. Art may have started out with the human body as the first "canvas".

Landscapes and Evolution

Denis Dutton in his 2009 book, *The Art Instinct*, provides an overview of findings in evolutionary psychology and how those affect our preferences for landscapes and art. In this section we will summarize his description of findings in these areas. Evolutionary research predicts that we ought to like scenes that helped us to survive and disliked scenes with features that could potentially threaten us. Such genetic predispositions of course must always be weighed against environmental explanations.

The Savannah and Other Environments

The People's Choice project, founded by Vitaly Komar and Alexander Melamid conducted a worldwide poll in 1993 to assess universal preference in art. The participants were asked what types of pictures they liked. These included questions about outside vs. inside scenes, what colors they preferred and the sorts of people they would like to see in a scene. The results of the study showed that people dislike abstract patterns and jagged shapes created using thick paint in colors of yellow, orange, gold and teal. Landscapes with water, people, and animals were the most preferred. Blue turned out to be the favorite color. Realistic paintings were preferred to abstract ones and 60% of those surveyed said they enjoy paintings more when they "resemble a photograph". No less than 88% preferred outdoor scenes. Fall scenes were preferred the most (33%) followed by spring (26%), summer (16%) and winter (15%).

In another study, Orians, Gordon, & Heerwagen (1992) also formulated what might be the content of a desirable painting. This corresponded to an African savannah environment, just the one that our hominid ancestors may have evolved in. This landscape contained a number of features, including open spaces with grass or bushes, and the presence of water directly in view or on the horizon. It also consisted of space opening up in one direction or an unimpeded vantage, evidence of wildlife and a variety of green plants including flowers or fruits. Figure 4.13 shows a photograph of an African savannah scene.

Figure 4.13. An African savannah. There is some evidence that we prefer to view these types of scenes. Photo from PublicDomainPictures.net

If humans evolved on savannahs, it makes sense that we would like scenes of them for several reasons. Savannahs contain lots of animals that can be hunted for protein. They offer food at ground level, unlike rain forests that are more suited to climbing and an arboreal existence. We appear to be less attracted to completely open environments like flat prairies and instead prefer some degree of hilliness, perhaps because we can use hills or mountains as vantage points for hunting.

Trees are also preferred, but not just any tree. Orians and his colleagues determined a cross-cultural liking for trees that branch close to the ground and with moderately dense canopies. Artists such as Claude Lorrain and Jacob van Ruisdael painted these sorts of trees in their 17th century Dutch landscapes. Skinny trees and those with dense canopies were not preferred. Neither were those with branches that were out of reach. This makes sense if our ancestors used trees to escape predators or to spot prey. Lohr and Pearson-Mims (2006) found that people tend to prefer trees with a spreading canopy, similar to those found on a savannah, instead of trees with a rounded or conical shape.

Landscapes with evidence of human habitation were also liked. Low grasses and lawns caused by grazing livestock, roads that go off into the distance and cottages with smoke coming from the chimney are all examples. Such features are commonly found in paintings, calendars and greeting cards. One reason for such preferences may be that signs of habitation humanize the landscape and make it seem less threatening than say a wild jungle.

Work by Kaplan and Kaplan (1982) shows that desired landscapes have a moderate level of complexity. Spaces that are too filled up, such as a dense jungle, or that are too wide open, like a flat plain, were not desired. Optimal terrain was that which could allow orientation to the environment or that invited exploration of it. Cues for exploration include roads or paths that have an even surface. Paths that were partly interrupted were liked. Examples are roads that lead down into valleys or curving riverbanks. These views provide a sense of mystery perhaps because we want to know what lies around the bend or over the hill. Scenes with focal points or that showed the horizon also had appeal.

Appleton (1975) proposes an interesting hypothesis. He claims that scenes with “prospect and refuge” will be liked. These are landscapes that allow one to see without being seen. Prospect in his theory is the ability to survey a scene while refuge is the ability to hide. One can prospect from atop mountains or cliffs and obtain refuge from atop trees or in a cave. Many landscape scenes tend to show such features and place the viewer at elevations greater than eye height. Dutton (2009) notes that real estate prices are higher for more elevated floors in a building, with the penthouse on top usually being the most expensive. So this is an example from the real world that seems to support the hypothesis.

Balling and Falk (1982) examined developmental differences in landscape preference. They showed scenes of different environments to different age groups (8, 11, 15, 18, 35 and 70+ years) and asked which ones they would like to live in or visit. The youngest group, consisting of eight-year olds, preferred savannahs. For everyone greater than 15 years there was an equal liking for savannah, coniferous forest and deciduous forest. The landscapes liked the least were deserts and tropical forests. The evolutionary researchers Erich Synek and Karl Grammer report a preference for simpler savannah type environments. By the age of 15 and the onset of puberty there was a switch to liking more complex mountainous terrain with a greater number of trees. These studies suggest we have a “built in” preference for savannahs that then gets modified as we have more experience with other types of environments.

The hunter-gatherer hypothesis can explain sex differences in landscape preference. Lyons (1983) has shown that women like scenes with vegetation, fruits and flowers more than men. The evolutionary explanation is that women who gathered would have been able to acquire greater food resources in such environments. Men who hunted conversely ought to prefer landscapes with views that provide greater exploration and hunting possibilities. Other studies have shown that farmers more than any other group prefer scenes showing productive farmland. It is unclear whether this is a genetic or culturally induced phenomenon.

It is important to note that humans have lived and survived in all sorts of environments around the globe. This is in contrast to many animal species that have evolved specifically in one ecological niche. Our landscape preferences should therefore reflect a desire for resources that can be obtained in any kind of scene. Similarly our dislikes ought to reflect threats to survival that could occur in any environment.

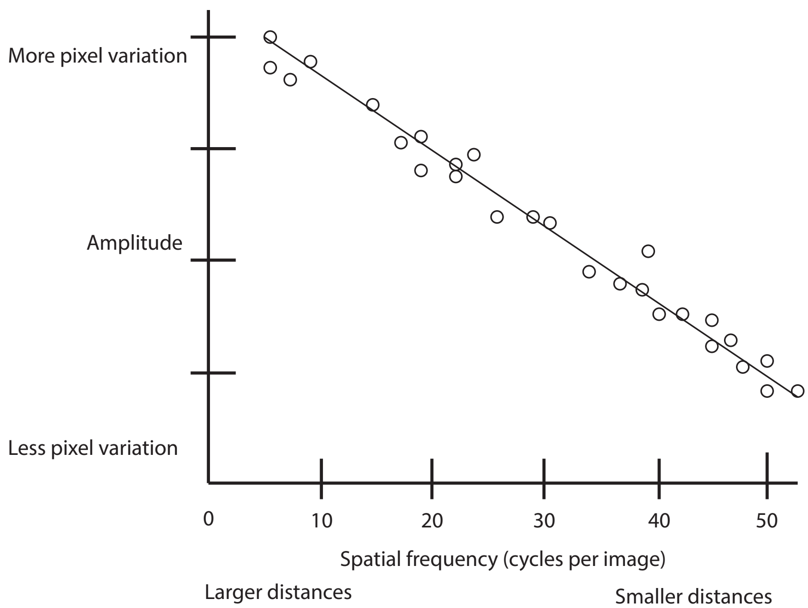
However, there is some controversy surrounding the savannah hypothesis. Scientists do not universally agree on what a savannah looks like. Also, some of the studies supporting it did not directly ask participants about beauty. They asked them whether they would like to live there. This is a different kind of judgment, one that may involve non-aesthetic related factors. Also, during the course of human evolution it is likely that the type of environments our ancestors lived in changed, even if they remained in one geographic region. Finally, there is some evidence that other sorts of landscape scenery are appealing. Han (2007) presented all six types of ecological environments to a group of participants. These were tundra, desert, grassland, coniferous forest, deciduous forest and tropical forest. The most preferred landscapes were the tundra and coniferous forests. Grasslands and deserts were the least liked. Tundra habitats are cold and dry and so do not contain potential resources.

Natural Image Regularity

The visual system evolved in natural environments containing things like clouds, mountains, trees, and water. These sorts of images are characterized by having consistent color, lightness and textural properties in areas that are close together. Two areas that are farther removed from one another in these sorts of images will be less likely to be similar. So, if we circled an area in a picture of a natural scene and then circled another area right next to it, the two would be more alike than if we circled two regions farther apart and compared them. This makes sense because two areas near one another are probably going to be of the same thing, such as two parts of the same cloud. Two areas farther apart are likely to be of two different objects, such as part of a cloud and part of a tree.

Figure 4.14 shows a plot with amplitude on the y-axis. Amplitude is a measure of how different any two pixels or regions are from each other. Higher values indicate greater intensity variations. On the x-axis is spatial frequency. This is a measure of how far apart regions are. When spatial frequency is low, the distances are large and correspond more to the left side of this axis. When spatial frequency is high the distances are smaller and this is more to the right side of this axis. The plot shows data from a natural image. Notice that the line fit through the points has a negative slope. When spatial frequency is low and distances are large, amplitude or variation in pixel intensity between regions is greatest. When spatial frequency is high and distances are short, the amount of intensity variation or amplitude is lower, indicating greater similarity between regions.

Figure 4.14. A plot with spectral slope function. Areas near one another in natural images show less variation. This regularity in the natural world is mimicked by artists in paintings.



The rate at which this fitted line changes is called the spectral slope, designated as S. It is negative because it is trending downward. If we calculated S for a large number of natural scenes we would find that it tends to vary between -0.5

and -1.5 and averages at about -1.2 (Field, 1987). This value is therefore the hallmark of natural scenes. If we evolved in such environments and find them attractive, then artists may recreate scenes that have similar slopes. This is in fact the case. S values in artwork have been found to vary over the same range as in natural scenes although paintings tend to have a slightly steeper slope than photographs (Graham & Field, 2007).

Music and Evolution

Music production and singing may have emerged through animal mimicry. Mimicry can be very useful for deceiving and hunting prey. Humans can copy animal sounds given the structure of the larynx and vocal chords we evolved for language. Animals can hear but not copy human sounds. This gave early humans a distinct advantage. It is possible that early musical instruments may have been designed to copy the sound of animals. Early flutes for instance could have sounded like birds. There is evidence of flutes made from bear bones by Neanderthals 53,000 years ago (Conard, Malina, & Munzel 2009). Many African dances explicitly imitate animals, with chicken flapping, giraffe nodding and ostrich walking. Rothenberg (2013) entertains the interesting idea that our sense of rhythm, synchrony and dance came from insects like crickets and cicadas.

Music as a Form of Communication

Human music is a form of communication. Even though it does not have direct representational capability it can still convey ideas, emotional states and unifying symbols (Loersch & Arbuckle, 2013). The similarities between music and language have not escaped evolutionary psychologists. Languages have symbols that are combined using a grammar or rule system. The same is true for music. It has notes that are combined together in chords and melodies based on a grammar. The psychologist Dan Sperber believes we evolved a cognitive capacity to process complex sound patterns varying in pitch and duration. This appeared in primitive pre-linguistic humans. Music in his view developed parasitically to exploit this capacity, in evolutionary terms it “co-opted” linguistic capability, using some of the existing linguistic neural circuits.

But if music came first it could have prepared our early ancestors with the cognitive flexibility to form mental representations and transformations upon them. Singing and instrumental activities could have also helped to refine motor skills, leading up to the rapid and dexterous actions required to vocalize or sign speech. Cosmides and Tooby (1989) have suggested that music helps to prepare infants to speak. It could be that music helps the infant learn prosody (the melodic contour of speech) even before they have phonetic capacity. Some evidence to support this comes from “baby speak” or “motherese”, which bear some similarities to music. Mother-infant interactions sometimes involve singing and rhythmic movements like rocking and caressing. These behaviors are cultural universals. The elderly amongst us may have learned their first songs in the form of a lullaby although these songs aren’t as popular as they used to be.

Music and Sexual Selection

As in the visual arts, music may have also evolved for purposes of sexual selection. Charles Darwin suggested this as a possibility. The hypothesis is that the louder one can sing or play, the more fit one is and the better one's genes. Song and music making could advertise strong lungs, endurance, energy and health, all valuable genetic traits. Instrument playing could be a signal of strong fingers, hands, and arms. Songbirds use singing for just this purpose. Female birds chose to mate with male birds that sing the loudest and the longest. The power of music as an aphrodisiac is evidenced by "groupies", mostly younger people who bond strongly with a band or performer, sometimes touring with them around the world. Popular music stars like the Beatles and the Rolling Stones have millions of fans worldwide and in the case of someone like Mick Jagger, no shortage of sexual partners (despite his decidedly less than attractive looks).

Miller (2000) argues that music is a form of courtship display, mostly by young males to attract females. In support of this idea is that the number of teenagers who form bands is probably greater than the number of middle-aged men who do so. Levitin (2006) states that dancing to music advertises the type of fitness necessary for successfully hunting, namely the ability to be on one's feet for hours on end chasing down game. Music and dance can also advertise one's creativity. The ability to compose or dance in novel and improvisational ways could indicate the potential for cunning and strategizing while on the hunt. Miller and Haselton (2006) showed that women during the fertile phase of their menstrual cycle are more likely to mate with a creative but poor artist in contrast to a less creative but wealthier man. This was not the case throughout the rest of their cycle.

Music and Social Cohesion

Music seems to have evolved to be performed in groups, which bolsters the communicative argument (Benzon, 2001). Music could have been used as a unifying force, a means of providing group cohesion and unity (Miller, 2001). Singing around the campfire could have been a way for our early ancestors to stay awake and ward off predators. Music today certainly serves this function, considering national anthems, school songs and team sport songs. This is not exclusive to humans either. White-handed gibbons vocalize in unison to cement social bonds between male-female pairs. This practice of chorusing could have preceded human language (Merker, 2000). It is still not clear whether language evolved out of music or music evolved out of language. Another possibility is that they co-evolved at the same time.

There are two disorders that point to the connectedness of music and sociality. One is Williams Syndrome (WS). These individuals score very low on tests of cognitive ability but are good at music and are hyper-social, being very extroverted, gregarious and friendly. In some patients with Autism Spectrum Disorder (ASD) we see the opposite, heightened specific cognitive abilities but lack of social or musical ability. ASD patients are highly introverted and avoid eye contact and conversation. These disorders suggest that there are a cluster of genes that code for sociality and musicality. These genes may affect the development of brain structures serving these abilities. The neo-cerebellum has been found to be larger than normal for WS and smaller than normal for ASD. WS patients utilize more brain areas when they listen to music including emotional centers like the amygdala.

Music and Other Animal Species

Other animals also appear to use song and music as part of their courtship displays. As mentioned above, most bird species sing in order to attract mates. Birds that sing the loudest, the longest, and with the greatest variation in some cases are the ones that are preferred. In one study different male bird songs were played over loudspeakers. The females ovulated more quickly when listening to songs with the largest repertoire, i.e., those with the greatest variety, which may be an indication of creativity or intelligence. This capacity to generate new examples is called generativity. It is also present in human language, as words can be combined to form sentences in a wide variety of ways. It could be that men with sophisticated language skills, those who employ a larger vocabulary and set of grammatical rules, are chosen more often by women as mating partners.

Alarming and Soothing Sounds

Are there certain sounds that are intrinsically pleasing and others that are jarring or fearful? Most of us are born predisposed to react emotionally to particular sounds based on their features. Abrupt (sharp attack), short and loud sounds tend to be interpreted by humans and other animals as an alert. This orients our attention, cueing us that something potentially dangerous is in the environment. Birds, rodents and apes all emit cries with these characteristics as a form of warning. In comparison, slow onset (long attack), longer and quieter sounds are perceived as calming or neutral. Musical composers utilize these features to manipulate the mood of the listener. Tchaikovsky's *1812 Overture* has a sudden and loud volley of cannon fire, chimes and brass near the end of the piece. This is designed to shock and stir the listener. Not accidently, this song is used more than any other to accompany fireworks displays.

Dance and Evolution

Dance in modern society is used many times in a social setting. Nearly all cultures today have large-group ritualistic dances to celebrate holidays and important events. We see this in the form of funerals, ceremonies, festivals and in mate-selection displays. Such widespread usage suggests evolutionary advantage (Merker et al., 2015). There are many different types of dances seen cross-culturally. These include choreographed patterns in which members form a circle or a line and then move to drum, flute or singing. There are also patterns in which a single dancer performs a solo routine, while in other patterns dancers alternate between facing one another and turning away (Welsh, 2010). Examples of group dances from Africa include the stamping dance of the Nguni people, the jumping dance of the Maasai people, the shaking dance of the Xhosa people and the striding dance of the Sotho people (Zaidel, 2016).

Dancers bond with one another socially, promoting social cohesion and group identity, as is the case with music. In one theory boding occurs through the secretion of endorphins released as a consequence of physical exertion (Tarr, Launay, & Dunbar, 2014). Endorphins promote sensations of calm, happiness and focused attention and these feelings in a social setting could promote sexual attraction as well as group affiliation. Dancing today in discos and clubs is a form of sexual display. As with singing, the person who dances the longest or the most creatively is advertising genetic fitness.

Math and Evolution

Why would math be an ability that is selected in the evolutionary process? Presumably math must have been helpful to us in our ancestral past, since it is a cognitive ability found in many individuals. People who were good at math in our ancestral past could have been able to contribute toward group survival. It may seem difficult to imagine the value of a "caveman Einstein" but there has been some thought on why math may have been advantageous. Chatterjee (2014) argues that in the Pleistocene era it would have been important to quantify objects and predict their future quantities. For example it would have been adaptive to be able to count the number of game animals relative to group size. If one deer can feed five people and there are fifty people in the group then there must be at least ten deer available for a hunter-gatherer group to stay in the region. Otherwise, they might be better moving on to another area where there could be more game available. Another example Chatterjee gives is predicting foraging based on the growth of edible plants. It would be advantageous to roughly determine the number of plants available in an area and determine how many of those would be needed for a group of a particular size. Skill at these sorts of problems that involve quantities, probabilities, and correlations would help in assessing present and future resources like food and shelter.

A secondary advantage for taking pleasure in math involves seeing patterns (Chatterjee, 2014). The world is a complex and chaotic place. The ability to see structure in it is useful. Finding structure is a form of simplification. The pattern or structure captures some basic essence of a more complex thing that makes it easier to think and reason about. Math in many cases is about reducing information to succinct and quantifiable relationships that can be generalized. Schmidhuber (1997) argues that minimalist art involves the reduction of something that is complex to something that is simple. He proposes a "low-complexity" art and uses computer algorithms to generate simple cartoons of various objects. It does seem that almost any art process involves a selection of what is in the world. This selection is a simplification. An artist who wants to paint a picture of a tree for example usually does not try to paint every branch and leaf. Instead they will analyze the tree and depict its essential qualities. This may involve the trunk and main branches. It may also involve painting clumps or groups of leaves rather than each individual leaf. We discuss the role of complexity at greater length elsewhere.

Bringing it All Together – Evolution Chapter Summary

Evolution provides us with answers to why we like certain patterns. It gives us reasons for how preference for beauty originated. It can also tell us why we as humans like to create art. These explanations center on motivations to survive and to reproduce, what are termed natural and sexual selection. According to evolutionary psychology it is the desire to maximize reproductive success that motivates male and female sexual behavior. This can explain why men value physical appearance more in a partner while women more greatly value the ability to provide resources in men.

Symmetric faces are preferred in both sexes. One explanation for this is that symmetry signals greater resistance to infection and hence greater fitness. Average faces with features closer to a group mean are also preferred, presumably because they represent stable genetic traits. Men prefer faces that are more feminine while women' preference for masculine faces is more variable. Neonatal or "baby" faces are considered to be cuter and thus elicit caregiving instincts.

There are a number of factors affecting perceived beauty in bodies. Symmetric bodies and body parts are judged more beautiful. Taller men are usually preferred in most contexts. Men are attracted to women with a waist-to-hip ratio of 0.70 as this is associated with greater fertility. Women prefer men with a waist-to-shoulder ratio of 0.60, because it is associated with greater physical strength. Men prefer medium to large sized breasts, while women prefer men with a proportionally larger ring finger, this latter characteristic being linked to greater prenatal testosterone exposure.

Skin with greater carotenoid pigmentation from a diet rich in fruits and vegetables is considered more attractive because it is associated with improved immune defense, sun protection, and reproductive health. Women with cosmetics are judged more beautiful probably because these increase the contrast of facial features. Differences in the amount and distribution of body hair can also be linked to parental quality. Clothes in men seem to display wealth and status while in women it is to reveal or partially reveal erogenous zones.

Newborns spend more time looking at faces that adults judge attractive suggesting these preferences are innate. Moms with cute babies spend more time vocalizing, holding, and looking at them, showing that cute features elicit nurturing behavior. Conversely, "ugly" babies receive less of this sort of care. Schoolteachers judge attractive children as more popular, sociable, and intelligent. Other advantages accrue to attractive people. They are expected to have happier marriages, better jobs, and be more psychologically healthy, what is termed the "halo" effect.

Prehistoric art seems to have served a purely religious or spiritual purpose. Natural selection pressures seem to govern engineering and tool use, which are examples of applied creativity. Ornate and beautiful forms of creativity like painting and dance are probably under sexual selection pressures.

Researchers have formulated numerous theories about why humans create art. According to the costly signal hypothesis, the ability to purchase or spend time creating art shows that one has acquired resources and will make a good provider. Art could help bind a group together through the attendance of a common ritual practice like dance or theater. Art in the form of storytelling entertains and educates. It is additionally possible that art has no functional purpose whatsoever and has simply persisted because it is pleasurable and doesn't impose societal costs. Finally, there is the view of art as a trait that is not selected for any more but is free to vary, as is the case of singing in the Bengalese finch. The profusion of so many theories demonstrates that we really don't know if art serves any adaptive purpose.

Landscapes are among the most popular categories of painting. But what types of landscapes do people like the most? According to one survey, realistic scenes are preferred to abstract ones and outdoor scenes are preferred more than indoor ones. People seem to like landscapes that portray available resources like bodies of water and trees, as well as possible means of escape from predators. Landscapes of moderate complexity that invite exploration are also liked.

Music could have evolved from mimicking animal sounds. Although music is non-representational it may still serve as a form of communication. Language and music share many similarities, including the use of a grammar. Music may help children learn how to speak and can serve as a form of sexual display. It could additional serve to promote social cohesion. Music and dance are at heart group activities, used to celebrate holidays and forge bonds among soldiers at war.

Chapter 5 - Neuroscience

Neuroscience – Get Your Brain in the Game

In this chapter we study the different structures in our brain and the role they play in aesthetics. We will see that there are dedicated brain areas that respond to faces, body proportions, and body poses. We then find that a lot of art seems tailor made to "titillate" the various modules of our visual systems: those areas that process form, color, and motion. Problems with our eyes and damage to our brains can give us clues to the aesthetic response. This is a case study approach and we will look at how such disorders have changed the work of painters and musicians. In some remarkable cases, brain damage has even created art abilities in individuals where there was none. In the section on brain damage and art we describe these types of disorders, including hemifield neglect, visual agnosia, dementia, and autism. Art is not just visual, so there are equivalent case studies of brain damage in the musical world that affect, singing, playing, memory, emotion, and identity.

This chapter continues with a survey of the visual system and art. We examine prominent art works by the fauvists, impressionists, renaissance artists and others and explain these in terms of basic visual system function. These phenomena include color and filling in processes, equiluminant colors and illusory motion, luminance range, spatial frequency and the "what" and "where" systems. Next we turn to "higher-level" perceptual and cognitive operations to see how context affects our perception of surrealist paintings and how prior knowledge and meaning influence the way we see pictures. In the section on music and the brain we look at our perception of rhythm and meter, loudness, pitch, and the role expectation and its violation play in music perception. We also look at the relationship between music and language, music and speech, and music and emotions. The brain responds differently to different arts, so we next describe the brain and these other specific arts, namely literature, dance, and film. The chapter ends with contemporary research on the brain and creativity, with a focus on the cognitive processes that underlie creative thought.

Neuroaesthetics

Recent years have seen the emergence of a new branch of science called neuroaesthetics. Researchers in this field want to know what the brain is doing when we have an aesthetic experience and how that can help to explain our behavior. Neuroscience is often tied closely to cognition, an information-processing approach to mind, and to evolutionary psychology, which attempts to explain the selection pressures that shaped neural structures. These three approaches are best used in conjunction. Evolution explains why we have a particular brain structure, neuroscience explains how that structure operates and cognition translates that functioning into a more general information processing language.

Neuroaesthetics looks not just at what's happening in the brain of a person having an aesthetic response, but also when someone is creating something aesthetic. The "thing" being experienced or created need not only be art. It should be more broadly construed to include artifacts like toasters and natural objects like faces or bodies, as these stimuli too can have aesthetic qualities. It examines the wide span of psychological responses, including perceptual, cognitive, emotional and social processes.

As an example of how neuroaesthetics might proceed, we could scan the brains of people who look at "stylish" and "style-less" objects and look for differences in patterns of brain activation (Skov, 2009). The medial temporal lobe has been implicated in this sort of task so we could specifically look at this structure. We might find for instance that exposure to new styles elicits encoding responses (assimilating new information) and exposure to old styles elicit recollection processes (memory) and that each of these depend on activity in different brain structures (Miyashita, 2004). These results can also help to clarify what we actually mean by the word "style". So the definitions we use as starting points may end up being changed as a result of new discoveries.

Beauty and the Brain

There is a consistent finding in neuroaesthetics. This is that there is no "one size fits all" pattern of brain activation to an aesthetic event. Instead we see activity in specific areas of the brain that respond to beauty of a particular type. These are the same areas that are active in responding to those stimuli when beauty is not being judged. For example the "face" part of the brain (called the Fusiform Face Area or FFA) lights up when evaluating faces in any sort of task but it is also active in judging facial beauty. The "place" part of the brain (Parahippocampal Place Area, or PPA) lights up when looking at scenes but it is also active when seeing a beautiful landscape. In many cases there is also concurrent activity in the brain's "pleasure" center when evaluating beautiful things. So the brain's response to beauty is an ensemble: a collection of different brain regions for aesthetic judgments to different types of stimuli. The neural ensemble to a beautiful song for instance, will be different than the ensemble to a beautiful ballet or to a beautiful painting.

There is also a distinction between "liking" something and "wanting" it. Liking is the pleasure we get from some objects and wanting is the desire we have for those objects. To illustrate, we might like a movie but we want sex or food. These two work together most of the time because we like objects we want and we want objects we like. However, there are different neural mechanisms that underlie these two processes. Cannabinoids (compounds found in marijuana) and opiates are neurotransmitters that work together to produce our sense of pleasure. Wants are driven by the neurotransmitter dopamine. These two neural systems can be dissociated from each other. People who take drugs that block dopamine still like certain objects but they aren't motivated to get them. This state is called "psychic indifference". The "like" response may help to explain our preference for items that are not tied closely to motivational drives.

Chatterjee (2014) makes the distinction between aesthetic pleasure and what might be called motivational or drive pleasures. An example of the first would be the appreciation of a beautiful painting. An example of the second would be the experience of sugar on our tongues. He outlines three ways that aesthetic pleasures differ from the lower-level motivational ones. First, they go beyond basic pleasures by tapping into other neural systems beyond basic drive mechanisms. Second, they are nuanced and involve a mixture of emotions that are more complex than simple desires. Third, aesthetic pleasures are influenced by our cognitive systems. They are affected by knowledge and experience. In sum, our experience to beauty is complex. It encompasses all of the basic human states of mind, these being perception, motivation, emotion and cognition.

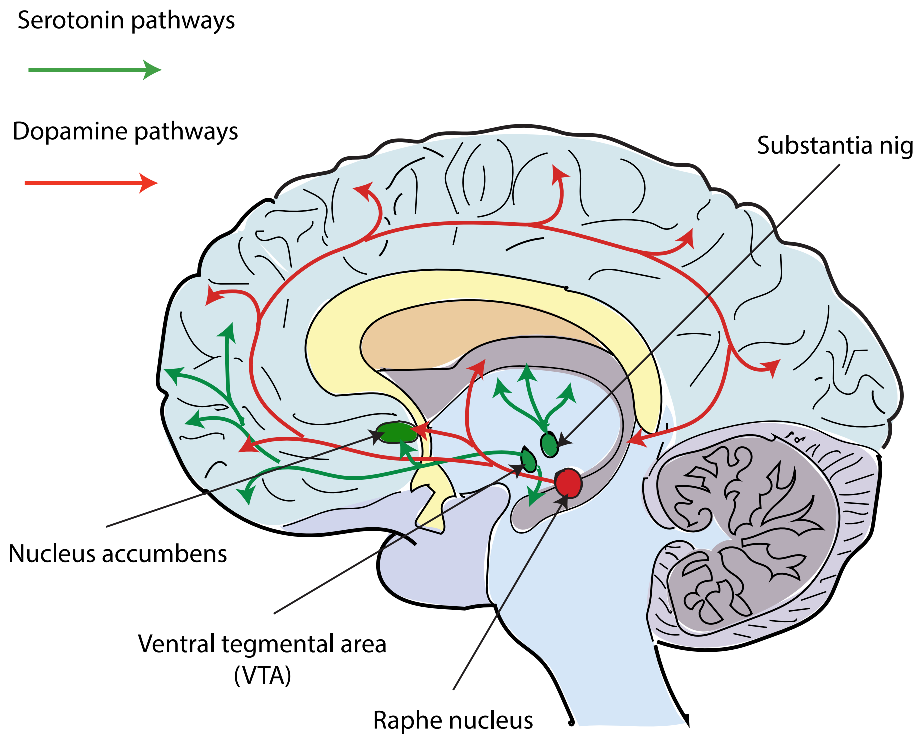
Brain Activation and Aesthetics

The question we ask in this section is: What areas of the brain become active during an aesthetic experience? The answer is complex. As we have mentioned, there is no single aesthetic area of the brain that always lights up whenever we have an aesthetic experience. Instead, we see widespread activity across multiple brain systems. When listening to music, for example we may see activation in auditory cortex, which is part of normal processing of sounds and in the hippocampus if the song is familiar to us, since the hippocampus is responsible for retrieving memories. We may also see activity in Wernicke's area and other centers for language processing if the song contains lyrics. So when looking at the neural underpinnings of aesthetics, there will always be a constellation of different systems that are engaged.

The Reward System

The brain has a built-in way of responding to things that are pleasurable. It is called the reward system and is made up of a number of structures including the ventral tegmental area (VTA), the substantia nigra, striatum, and nucleus accumbens. These areas are shown in Figure 5.1. These regions produce the release of the neurotransmitter dopamine. The reward system evolved to reinforce behaviors crucial for survival or reproduction, like sex or eating high-caloric food. It is the brain's way of telling you that you're doing something "right", at least from an evolutionary standpoint.

Figure 5.1. The brain's "reward system" consists of several structures. These are the ventral tegmental area or VTA, the substantia nigra, striatum, and nucleus accumbens.

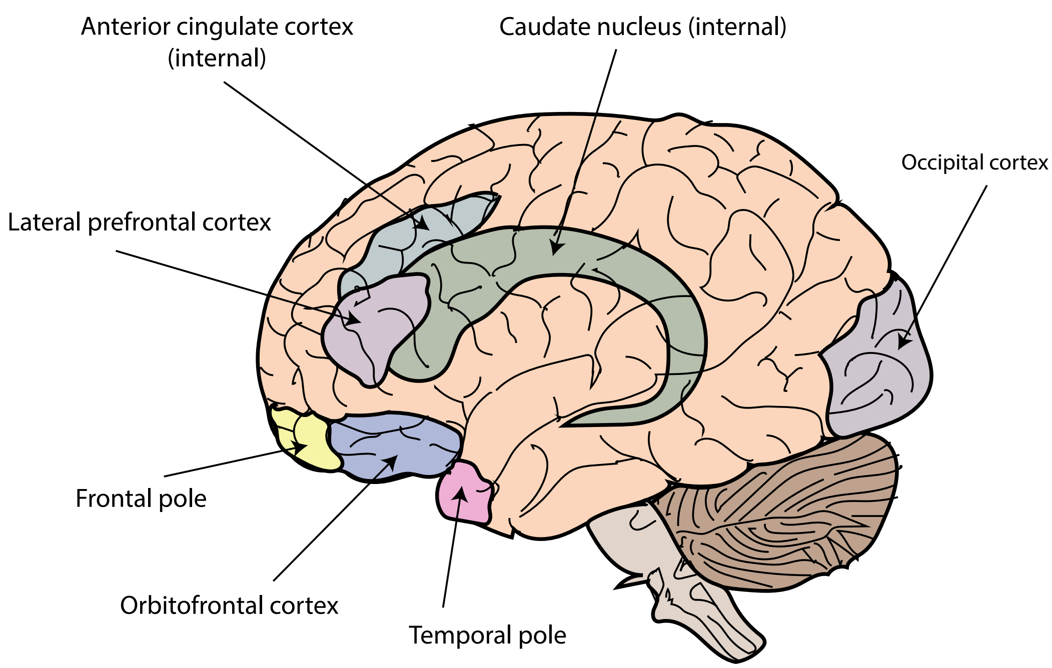


Neuroimaging studies have found VTA activation when people eat chocolate, look at attractive faces, even when they read comic books or play video games. Other research shows reward system activation when participants listen to pleasurable music (Blood & Zatorre, 2001). Increased heart and respiration rate also occurr during this activation. These results show that the reward system can become active in response to aesthetic and artistic experiences, not just those directly tied to food or reproduction.

Additional Brain Regions

The orbitofrontal cortex mediates emotional processes involved in aesthetic appreciation (Kawabata & Zeki, 2004). Other structures involved are the caudate nucleus, anterior cingulate cortex and for visual arts the strengthening of visual processes in the occipital cortex (Vartanian & Goel, 2004). Recognizing aesthetic objects and attributing meaning to them are related to activity in the temporal pole (Jacobsen, Schubotz, Hofel, & von Cramon, 2005). Decisions seem to be mediated by the lateral prefrontal cortex and the frontal pole (Cela-Conde et al., 2004; Jacobsen et al., 2005). Some of these structures are shown in Figure 5.2.

Figure 5.2. Areas in addition to the reward system that are involved in an aesthetic response. Figure showing orbitofrontal cortex, caudate nucleus, anterior cingulate cortex, occipital cortex, temporal pole, lateral prefrontal cortex, and frontal pole.



Work by Vartanian and Goel (2004) showed that activity in occipital visual regions was greater when participants showed a higher preference for paintings compared to when they showed a lower preference for them. Other studies show that preferred patterns activate attention (Poghosyan, Shibata, & Ioannides, 2005) and emotion areas (Lang et al., 1998) that enhance processing at earlier visual stages of processing. This suggests that there is a feedback loop in the visual system, whereby higher cortical regions modulate lower sensory ones as part of aesthetic appreciation.

Jacobsen et al., (2005) presented geometric patterns to observers in two task conditions. The first was to judge if they were symmetric or not. The second was to rate their beauty. The beauty ratings produced greater activity in the left temporal pole compared to the symmetry judgment. The temporal pole in humans is linked to the use of previous experiences that create a meaningful and emotional context for stimuli under consideration. Activity in the orbitofrontal cortex is linked to the reward value of a stimulus, both for primary and abstract rewards (Deichmann, Critchley, & Dolan, 2002). Another area, the anterior cingulate cortex, seems to be related to conscious awareness of emotions produced by pleasing stimuli (Hornak et al., 2003).

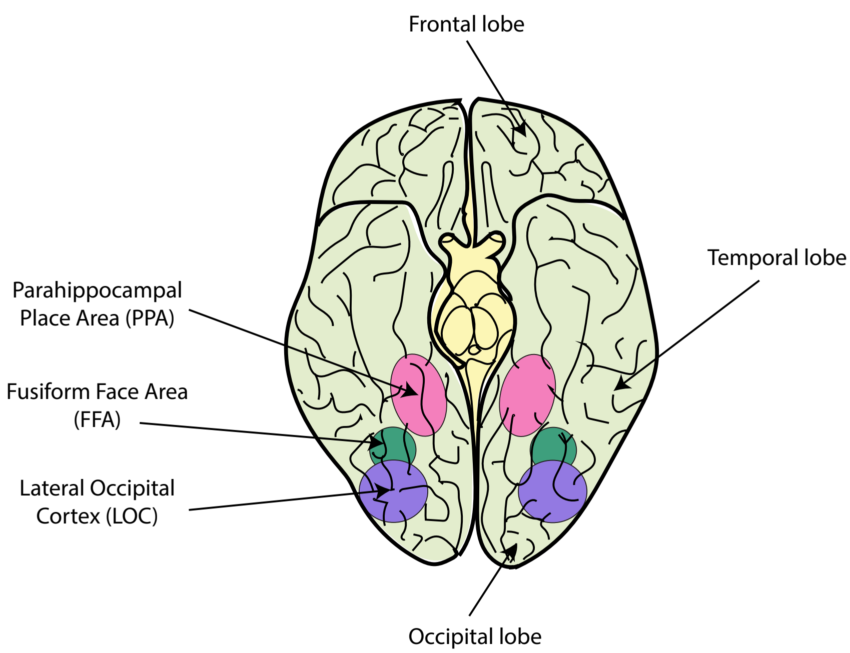
The Neuroaesthetics of the Body

Faces

What part(s) of the brain become active when we look at a pretty face? Chatterjee et al. (2009) designed an experiment to find out. They had people look at pairs of faces that varied in their attractiveness and in how similar they were to one another. There were two sessions, one where the participants judged the identity of the faces and another where they judged their beauty. The identity task was to see if the brain processed facial beauty even when it part of the task. When people were thinking about beauty and saw attractive faces there was activity in the fusiform face area (FFA) as would be expected because this area is responsible for processing facial information, and in the lateral occipital cortex (LOC). There was also activity in the parietal, medial and lateral frontal regions of the brain. These last two areas were probably active because they had to pay attention to the faces and make decisions about them. In the session where the participants were thinking about facial identity there was activity in the FFA and the LOC in response to attractive faces. This was the same pattern as in the other condition, showing that the brain processes beauty even when it is not relevant to the task. In other words, you can't help thinking about someone's beautiful face, perhaps unconsciously, even though you may be busy thinking about something else.

Other researchers in similar studies have found that beautiful faces also activate the orbitofrontal cortex and an area in the basal ganglia called the nucleus accumbens (Aharon, et al., 2001). The nucleus accumbens is part of the brain's reward system. Activity here occurs in response to rewarding stimuli that are crucial for survival like eating or sex. The amygdala additionally shows activity, both to attractive and unattractive faces (Winston et al., 2007). The amygdala plays an important role in fear and emotions. In another study, researchers presented pairs of faces with two tasks. The first task was to judge which in the pair was more attractive and the second task was to judge which of the two was rounder. This secondary task was again to see what unintentional processing to beauty was like. The results were similar. They also found activity in the nucleus accumbens and the orbitofrontal cortex. Both of these studies together show that visual system automatically processes facial beauty whether or not it is required by the task. They also demonstrate that beautiful faces are rewarding in the same way that other pleasurable stimuli are. Figure 5.3 shows some of the areas that become active during the aesthetic judgment of faces, objects and places.

Figure 5.3. Some of the regions in human cortex that become active in response to the processing of faces (FFA), places (PPA), and objects (LOC). The structures are located bilaterally. View is of the underside of the brain.



Body Proportions

In the chapter on math and physics we mentioned the Greek sculptor Polykleitos who used the Vitruvian Man proportions to create his *Doryphoros*, or *The Spearbearer*. This sculpture was supposed to be a representation of an ideal male body. In a modern neuroimaging study, participants were shown different versions of this sculpture (Dio, Rizzolatti, & Macaluso, 2007). One version had the torso elongated. Another version had the legs elongated. The third version had the original, unaltered dimensions. The participants in the study rated the two altered versions as less attractive than the original. A number of brain areas showed increased activation during the viewing. These were the prefrontal cortex, the amygdala and the insula. The prefrontal cortex mediates cognitive decision-making showing that these processes are part of aesthetic judgments. The amygdala activates as part of a fear response, perhaps in this case a reaction to one of the statue images as a perceived threat. The insula activates as part of a disgust reaction, in this case probably to one of two less attractive options.

The image and proportions of the Doryphoros statue may be viewed at: https://www.researchgate.net/publication/5817749_The_Golden_Beauty_Brain_Response_to_Classical_and_Renaissance_Sculptures

Body Poses

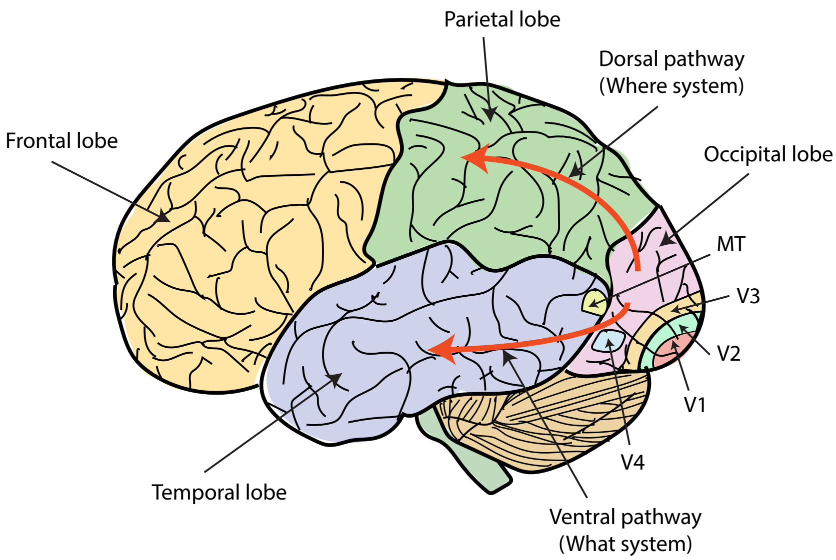
In one particularly interesting study participants viewed video stills of actors who posed different emotions using only their bodies. The actor's faces were covered to block any possible facial expressions that might be used as cues. For example, in one still an actor was arched backwards with his hands out, indicating the emotion of fear. Brain imaging was performed on the observers while they viewed the poses and activity was found in the insula, amygdala, and orbitofrontal cortex. These are all part of the brain's emotional system. It might not be surprising to see activation in these areas in response to a frightful face, but to see it in response to poses only shows that we are sensitive to body cues and that these alone are capable of eliciting an emotional reaction. Many paintings of course are of figures in motion or posing and the artist can use these to make us feel. Take for instance Matisse's 1909 painting *Dance* (*La Danse*) in which five girls holding hands are dancing in a circle. Although we can't see many of the faces clearly, we can still experience the sense of emotional liberation and hedonism the girls seem to feel based on their body postures alone.

The Neuroaesthetics of Art

Visual System Architecture and Art

The visual system adopts a "divide and conquer" strategy. It takes the input from the eyes, which is very complex, and splits it into different processing streams to make it easier to analyze. From a broad standpoint there is a “what” system that processes information about shape. This is called the ventral pathway, named for the lower portion of the brain involving the temporal lobe. The “where” system processes information about location and is referred to as the dorsal pathway, named for the upper portion of the brain involving the parietal lobe (see Figure 5.4).

Figure 5.4. Different processing "modules" of the human visual system. The top arrow shows the "Where" system pathway. The bottom arrow shows the "What" system pathway.



Within each of these systems are locations that specialize in processing information of a particular type, called modules (shown in Figure 5.4). All incoming visual information first is processed the in the primary visual cortex, labeled as area V1. Cells in V1 code for a variety of different features like line orientation, spatial frequency and color. Area V2 receives inputs from V1 and is implicated in processing more complex visual properties such as the orientation of illusory contours and figure-ground areas. Area V3 represents the entire visual field and is in part responsible for global motion perception. It contains dorsal and ventral components. Area V4 codes for color and other object features. Area MT plays a major role in motion perception. Neurons here respond selectively to the direction and speed of motion. The inferior temporal cortex or area IT is part of the ventral stream and represents large features and entire objects. Finally there is the fusiform gyrus located on the posterior portion of the temporal lobe. This area contains neurons that respond to faces, the FFA.

Livingstone (2002) and Zeki (1999) make the interesting observation that certain styles of art seem to be made especially for activating visual system modules. Art with lots of high spatial frequencies and details like spots of color will cause area V1 neurons to become active. Monochrome, colorless art like drawings, etchings and woodcuts that emphasize object contours will generate activity in V1, V2, V3 and IT. Work that is primarily defined by color and emphasizes object interiors and form rather than edges will activate neurons in V4 and some of V1. This art is sometimes referred to as "painterly". Other types of work activate the visual system's motion system and produce activity in area MT and to a lesser extent V3. Op art that produces illusory motion will also stimulate these areas. Pollock's drip paintings may stimulate occipital neurons that are tuned to the statistical properties of natural textures. Portraits that show faces will activate neurons in the FFA.

Of course there will be styles of art that activate more than one module and some that will activate all of them. Cartoons, comics and graphic novels emphasize both exterior contour and interior color so would be expected to cause activity in IT and V4. Art that is abstract and contains just fields of color or texture will probably activate the "where" system more than the "What system" since there are no recognizable objects. Art that has a single large recognizable object that takes up most of the canvas will probably activate the "what" system more than the "where" system because the location of the single object is fixed. A worthwhile research paradigm would be to investigate how this activation maps onto aesthetic experience. Do more beautiful artworks produce a pattern of balanced activation between the "what" and "where" systems or between form and color modules?

Artistic Universals

Most artists aren't neuroscientists. Yet, when we analyze the visual arts we find that many of these works seem tailor made to activate some part of our visual system as has been noted above. Continuing in this vein, Ramachandran and Hirstein (1999) outline a set of heuristics (strategies) that artists consciously or unconsciously use to stimulate different visual areas. The first of these is the peak shift effect. If a rat is rewarded for discriminating a rectangle from a square, it will respond even more strongly to rectangles that are more different from squares, i.e., those that are longer and skinnier. Likewise artists when presenting a female form may exaggerate what is considered sexually attractive. Bronze statues in Indian art are examples of this. They exaggerate both breast size and waist-to-hip-ratios, depicting women and goddesses with tiny waists and broad hips.

A second heuristic is the grouping principle. Artists will often skip over details. Instead of painting every blade of grass in a landscape scene, they will clump them together in groups based on similarity of size, color, and length, etc. This seems to have a basis in the brain. Extrastriate visual areas, those outside the primary cortical regions, seem to have evolved specifically to extract commonalities between features so that they can be grouped together. The Gestalt psychologists saw the importance of this and formulated several grouping rules like proximity and similarity. A third heuristic is that art seems most appealing when it produces heightened activity in a single dimension rather than multiple activations across modules. This is what is mentioned above when artwork seems to exploit just shape, color, or motion modules individually but not together.

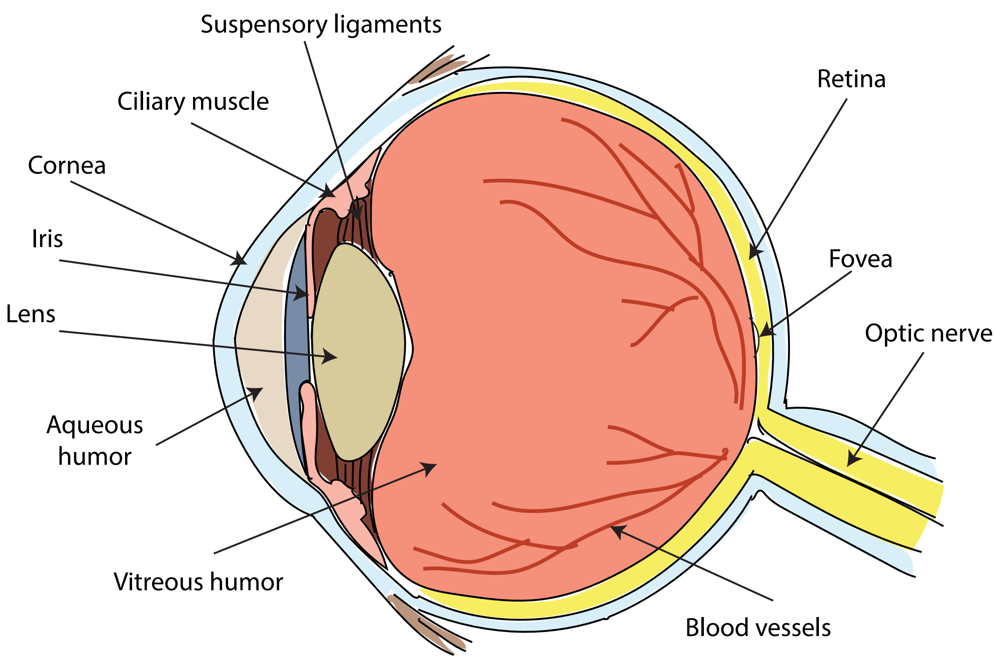
Artwork as an Attentional Guide

Another way to think about the relation between art and neuroscience is that artworks are made to guide our attention to what is important (Seeley, 2011). What is important here is what the artist considers important. However sometimes artists induce effects accidently, so it might be simpler just to look at the features of an artwork and determine how those guide or focus attention regardless of the artist's intent. Noel Carroll provides an example for the domain of cinema. He argues that filmmakers use various camera effects and editing techniques to focus viewer attention on specific parts of scenes that are important for understanding the meaning of the story. Another example comes from glance curves and lead-in lines in landscape art. These are lines that are designed to guide our attention to a focal point. For instance the curve of road may lead to a person in a landscape painting. Also in photography, depth-of-field effects are used to concentrate attention on an object or region. The area of intended focus is literally left in focus and the areas of the picture at other depth planes are fuzzy.

Optical Defects and Art

In this section we examine the things that can go wrong with the eye and how those have affected artists with those conditions. We look first at difficulties in focusing or accommodation. Then we examine astigmatism, another visual disorder caused by a problem with how the eye is shaped, and at cataracts. Next we look at problems with the retina: macular degeneration and color deficiencies. The retina is a layer of cells on the inside portion of the back of your eye. The light that enters the eye stimulates cells in the retina. See Figure 5.5 for the location and function of the major parts of the eye.

Figure 5.5. The anatomy and major structures of the human eye.



You may wonder why we discuss problems with the eye in a section on neuroscience. The reason is that the retina does a lot of neural processing. The image that gets sent to the brain has already had its edges enhanced by a process called lateral inhibition, for example. Some scientists have suggested that the retina is an extension of the brain and from a functional standpoint this is true. A second reason is that problems with the eye produce very specific visual distortions. We can examine an artist's works and medical history to see if these distortions occur and look at the effect it has on their art.

Accommodation

Accommodation refers to how the image entering the eye gets focused and it is affected mostly by several factors. The first is the curvature of the cornea, the outer part of the eye that you can touch with your finger. The second is the length of they eyeball from front to back. If the cornea is not curved properly or the eye is too long, the image gets focused in front of the retina. The result is myopia, or near-sightedness where a person can see close objects but those far away are blurry. If the corneal curvature is off or the eyeball is too short, the image gets focused behind the retina. This is called hyperopia or far-sightedness where a person can see an object farther away as clear but those closer as blurred. These conditions can be corrected for easily by the use of corrective lenses, either in the form of glasses or contact lenses. They can also be corrected through the use of laser surgery. The lens inside the eye can also change its shape to help focus the image on the retina.

Myopia as we stated earlier produces blurred vision for far away objects. Many Impressionists painted in a style where scenes are blurred in this fashion. Cezanne, Pissaro and Cezanne may all have been myopic and supposedly refused to get corrective lenses (Polland, 2004). It is possible they painted this way because they couldn't see properly. Alternatively, they may have seen reasonably well but just chose to paint in this manner deliberately. Given the data available we can't make a conclusion one way or another.

Astigmatism

Astigmatism is another disorder in focusing. In this case the curvature of the cornea or lens is not perfectly spherical but slightly oblong. The result is that a point of light is elongated about an axis so that instead of a point it is more like a line. The artist El Greco painted many of his figures as stretched or elongated and it has been pointed out that this may be due astigmatism or overcorrection with a lens. However this is unlikely because astigmatism causes blur, not shape distortion and people over time can compensate for the blur and learn to draw correctly (Anstis, 2002). Thus, it is unlikely that a painter like El Greco or a sculptor like Giacometti would produce elongated figures as a result of astigmatism.

Cataract

The lens inside the eye changes its shape to fine-tune the focus of the image on the retina. It assumes one shape when looking at close objects and another when we focus on things that are far away. Over time the lens can become clouded due to the build up of protein clumps and yellow-brown pigments. This build up can have multiple causes including exposure to radiation, smoking tobacco or drinking alcohol. The result is blurry vision, halos around light and difficulty seeing at night. A cataract can occur in one eye or both. Claude Monet and Mary Cassatt were both diagnosed with cataracts (Marmor & Ravin, 1997). The effect the cataracts had on Monet's paintings is obvious when one compares his early and later work. His later work dating at least from 1912 onward when he was diagnosed takes on a much more abstract fuzzy style.

Macular Degeneration

The macula is the area around the fovea on the retina. This area contains a high concentration of cone photoreceptors. These cones are responsible for our ability to see details during daylight viewing conditions. In the disorder of macular degeneration, this area begins to deteriorate. The result is the inability to resolve visual details where one fixates. Peripheral vision, which is of lower resolution, is intact. It is likely that Edgar Degas suffered from this disorder (Marmor, 2006). It is reported that he could only see around the area where he was looking, which is the hallmark symptom of this disorder. Degas in his earlier work shows the more precise use of details and shading. His later work lacked this sort of detail and used more coarse hatching. The artist Georgia O'Keeffe was also diagnosed with macular degeneration at the age of 77 and complained of a "cloud in her eyeball" (Marmor & Ravin, 2009). She missed certain areas on the canvas and sometimes went over the same areas twice.

Color Blindness

Color blindness is the decreased ability to see certain color differences. It can affect tasks like reading traffic lights or matching clothing. There are different types, each due to a problem with one or more of the three color cone photoreceptors in the retina. The most common type is known as deuteranomaly and it is characterized by a confusion of colors in the red-green part of the visual light spectrum. Cole and Nathan (2002) tested an amateur artist with deuteranomaly by having him copy an oil landscape painting. He tended to confuse pale green and white and saturated greens appeared with less color. The artist Jen Johannsen got around his deuteranomaly by selecting appropriate labeled tubes of paint (Marmor & Lanthony, 2001). The English landscape artist John Constable and marine artist J. W. M. Turner have been suspected of having color blindness, Constable because he used a relatively narrow range of colors and Turner because many of his paintings were in reddish-yellow hues.

Brain Damage and Art

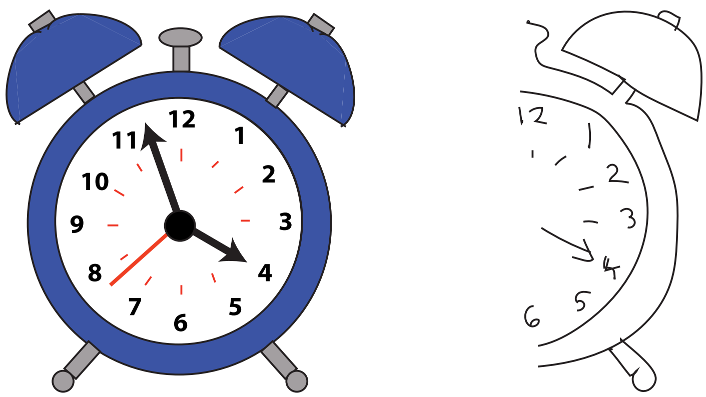
One way to learn about the brain is to destroy (lesion) a part of it in animals and then see how that affects the animal's behavior. If for example you think brain area X is involved in spatial cognition you can lesion it in a rat and then see how the rat performs in a maze. If the rat has trouble navigating the maze then you might conclude the area is involved in that function. Researchers cannot of course use this procedure in humans but an equivalent of it exists. This is when people suffer brain damage naturally through accident or disease. In this section we will examine case studies of visual artists and musicians who have suffered brain injury and how that has affected their art. This in turn informs us about the artistic function those brain areas serve. Because many of these areas are in the cortical lobes, we refer the reader back to their location in Figure 5.4. Many descriptions of the case studies that follow come from Mather (2014) and Zaidel (2016). Those who want to learn more are recommended to consult their two books.

Visual Arts Abilities and Brain Damage

Hemifield Neglect

In a disorder known as hemifield neglect, patients with damage to the right parietal lobe have difficulty paying attention visually to anything in their left visual field. This is the area roughly to the left of one's nose. It can also occur for damage to the left parietal lobe in which case the difficulty would be in paying attention to the right visual field, but in most cases it is right side damage. Patients with right hemifield neglect, whether artists or not, who are asked to draw an object fail to draw the left hand side of the object. Figure 5.6 shows what it would be like for an artist with this disorder to draw an object. Interestingly when these patients are tested further, it turns out that they can actually see what is there but they cannot allocate attention to it so it becomes part of conscious awareness. The problem is thus not perceptual, it is attentional. From analysis of case studies such as these we know the right parietal lobe is responsible for directing attention to the opposite visual field. Any artist in order to draw or paint an object properly would need to be able to direct their attention across the visual scene. This ability is impaired in those with hemifield neglect.

Figure 5.6. A picture of a clock and what a drawing of it by a hemifield neglect patient would look like.



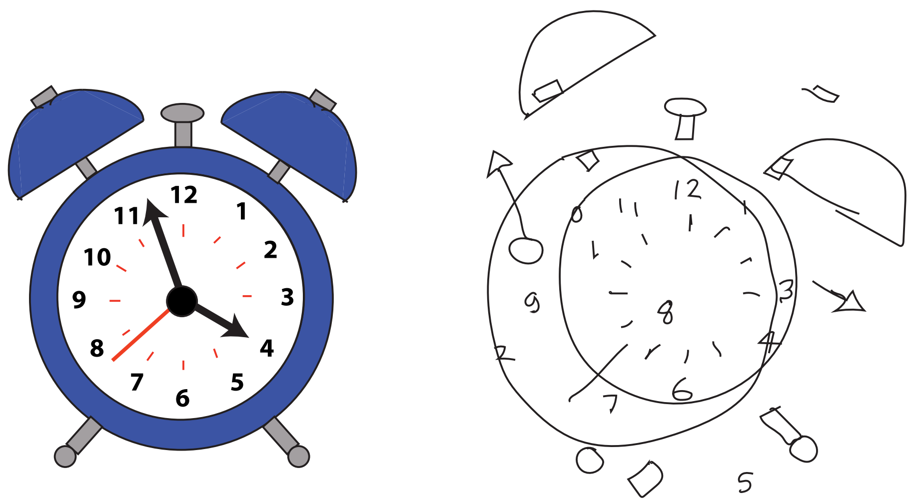
Hemimicropsia

Hemimicropsia is a disorder similar to hemifield neglect in that it affects the perceived size of objects on one side of the visual field (Cohen, Gray, Meyrignac, Dehaene, & Degos, 1994). Specifically, patients perceive the apparent size of objects as being smaller than they actually are. One art teacher who had suffered hemimicropsia due to a stroke reports objects on his left side as being shrunk and compressed. In order to compensate for this he would draw the left half of objects as slightly larger than the right half. When this patient passed away two years after his accident doctors performed an autopsy on his brain. They found damage to the lower part of his occipital cortex. The fact that he could compensate for the distortion is common for many artists who suffer stroke. Once they are aware of the disability they can usually learn to work around it.

Visual Agnosia

A visual agnosia is the inability to recognize an object despite the retention of other visual system processing capabilities like detail, motion or color perception (Farah, 2004). In the apperceptive version, patients when presented with a drawing of an object will omit features or place them in the wrong locations. These individuals can perceive features but they are unable to assemble them together into the right configuration. Figure 5.7 shows an example of what such a drawing would be like. They suffer general damage to the occipital lobes and other nearby areas. Any artist, in order to paint an object or scene must be aware of the component parts that make it up and what their locations are relative to one another. For instance when drawing a face an artist needs to not only see what the nose or mouth look like they must be able to place the nose in the center of the face and the mouth underneath it.

Figure 5.7. A picture of a clock and how a person with apperceptive agnosia would draw it.



There is another version of this disorder known as associative agnosia that is characterized by an inability to recognize or name objects. Patients with associative agnosia can copy or match objects well, but are unable to retrieve the verbal label that goes with the object. For instance if shown a picture of a diamond ring they could draw it but would not be able to say that it is a ring. In this case, the apparent damage is to connections between the parts of the brain that represent objects verbally and visually. Artistic skills in an individual with this type would be mostly unaffected. Paradoxically, they could produce a painting of their own house but be unable to know that they live there!

Dementia

Dementia is the term used for a wide category of brain diseases that are degenerative, meaning they appear gradually but get worse over time. Damage in such cases can be to all of the cortical lobes. Symptoms vary depending on the lobes that are affected but are generally a decline in the ability to think properly. It can affect reasoning, memory, language or other cognitive skills as well as producing mood swings and emotional outbursts. The most common form of dementia is Alzheimer's disease (AD), making up 50% - 70% of the cases. Because artistic ability relies on multiple brain areas, many artists with dementia are able to compensate and still retain some of their artistic skill for many years after the diagnosed onset. One can see the loss of shape and compositional control over time.

Rankin, Liu, Howard, Slama, and Hou (2007) studied a group of AD patients, comparing their drawing ability with a non-diseased group of age-matched control subjects. They were asked to draw a vase of flowers, a room at home based on their memory of it, a self-portrait using a mirror, and an abstract drawing representing emotion. Raters assessed the drawings in terms of quality of expression and technique as well as the content. One group of the AD patients did fairly well. Their drawings were similar to those produced by the control subjects. Another group produced works that were more simple, more abstract and used fewer colors. The patients in this study were in the early stages of the disorder and it is clear that at least some of them were still able to compensate.

Frontotemporal dementia (FTD) is another form of dementia. It is characterized by damage to the frontal and temporal lobes. This type accounts for about 20% of dementia patients. The symptoms include an inability to plan or control actions as well as difficulties with comprehending and producing language. Some versions of FTD that affect the temporal lobe can produce an increased interest in art and in artistic creativity in people who previously did not have much art experience (Mendez, 2004). One patient was a businessman with little prior art expression. At the age of 56 he started painting for the first time. He proceeded to paint in an evolving style and to win awards. His paintings were characterized by sharp edges and bright colors (Miller et al., 1996).

Mell, Howard, and Miller (2003) report the case of a female artist diagnosed with FTD when she was 57 years of age. Like the patient previously described, her style also changed dramatically during the course of her disease. She ended up creating more emotional and expressive drawings with hard, dark edges that differed from a previously subtler and restrained style. Brain imaging revealed moderate damage to her frontal areas and minor damage to her temporal lobes. These paintings show an inability to plan and organize, which is exactly the ability subsumed by these brain areas.

Autism and Art Ability

Autism is a developmental disorder characterized by impaired social skills and repetitive behavior. These children have difficulty reading other people's emotional states, such as facial expressions and can be very inwardly focused and non-communicative. Symptoms usually first appear in childhood prior to the age of three. The causes of autism are currently unknown. A subset of autistic individuals show exceptional abilities known as splinter skills. In some cases these splinter skills take the form of art abilities. One such savant named Stephen Wiltshire can draw detailed black outline drawings of buildings and architectural scenes. Another called Nadia was capable of drawing detailed and proportional sketches of horses starting at 3.5 years of age (Selfe, 1977). Another autistic person who goes by the initials E.C. could depict depth quite well in his art even though he did not understand the rules of perspective (Mottron & Belleville, 1995).

These savant artists are very good at getting proportions, shape and detail correct in their drawings. They also have exceptional visual memories, some being able to draw objects or scenes from memory as good as if they were reproducing them from direct observation. However, they are not very creative or innovative in what they do and their work is lacking in abstraction. They seem to be very tied to the actual appearance of things. They also tend to focus on smaller details and parts rather than see the "big picture" (Pring, 2005).

How can we explain such skills? How is it that a person with such severe social and linguistic disabilities can draw or paint so well? One theory posits that it is a disconnection between the left and right hemispheres. Language and analytical abilities tend to be located in the left hemisphere while spatial, creative and artistic skills tend to be located more in the right hemisphere. In normal individuals there is communication between the two sides of the brain and the left side can control or regulate the left through connections like the corpus callosum. In autistic patients these connections are compromised. The result is that the right hemisphere now has free reign to express itself without any inhibition or control.

Auditory/Musical Abilities and Brain Damage

Musical Composition

The neuroanatomy underlying musical composition is not well understood. This is in part because there are few composers with brain lesions confined to a specific area. It is likely that musical composition requires multiple cognitive abilities in addition to musical skill alone. There is no "center" for musical ability in the brain. The evidence points to coordination between distributed neural networks (Peretz & Coltheart, 2003). Many patients can continue performing for years after diagnosed damage, which also suggests they are able to call on disparate brain regions. Current evidence suggests that the left hemisphere specializes in the timing and rhythm of music and that the right hemisphere specializes in pitch and timbre perception (Ukkola-Vuoti et al., 2013). The temporal lobe in both hemispheres is the predominant lobe involved in music perception. There is no known center involved solely for composition.

Degenerative Brain Disorder

The French composer Maurice Ravel (1875-1937) who wrote the famous *Bolero* suffered from a degenerative brain disorder. He showed signs later in life of motor difficulties such as difficulty writing. This is known as agraphia. He also had difficulty copying (dyscopia) and problems with speaking and comprehending language (aphasia). He could recognize notes and melodies, errors in them, and could detect when a piano was out of tune but could not read musical notes by sight or name notes that he heard, so his problems were not purely on the production side, they included musical receptivity as well.

Ravel also showed apathy and flat affect, the absence of emotional expression, implying damage to the frontal lobes and to the anterior regions of the temporal lobes. It is likely that the pathway of the substantia nigra, the nucleus accumbens and basal ganglia were affected. It was probably the case that the neurotransmitter dopamine was involved also, as problems with this transmitter are associated with loss of motor control. Playing the piano requires bimanual coordination, meaning the two hands must work together. Each hemisphere controls a separate hand so his difficulty in this area means there may have been problems with the fibers connecting the two sides of his brain. It is not entirely clear what specific degenerative disorder Ravel had but the possibilities include Pick's disease or FTD. Pick's disease is a type of FTD characterized by a build-up of tau proteins in neurons called Pick bodies. He was also in a car accident and it is believed that this may have caused additional brain damage accelerating his demise. However, Ravel composed up until five years before his death and wrote *Bolero* and other skilled compositions after his symptoms first appeared. Continued productivity in his case and with other exceptional composers is due to extensive training, musical talent and inherited disposition.

Performing and Listening to Music

Amusia

Whereas the temporal lobes are involved mostly with musical perception, the frontal lobes are involved with musical expression and performance. Both hemispheres are necessary for proper expression. Although the areas for music and language are close to each other, particularly Wernicke's and Broca's area on the left temporal and frontal lobes, there are patients with language deficits who retain musical ability (Basso, 1993). Wernicke's aphasia is a problem with listening and comprehending language, while Broca's aphasia is a problem with speaking and vocal production of language. Some patients with Broca's aphasia can sing and can even sing the words they cannot speak. But patients with aphasia can also suffer amusia. Amusia is a defect in pitch processing, musical memory and recognition. It can be congenital or caused by damage. Diagnosis of amusia is done with the Seashore Musical Abilities Test. this test has measures for several different aspects of ability including pitch, loudness, duration, tonal memory, rhythm, and timber.

Available evidence shows that language and musical abilities draw on some of the same neural circuits but they can also sometimes be dissociable. There are both commonalities and differences between language and music. Both are characterized by sequencing in which the order of sounds determines the meaning. The brain must understand the whole from the parts in speech and language (words into sentences, notes into melodies) and keep the sequence of sounds in memory in order to make sense of them. One difference though has to do with speed. Music is faster than language. The notes that form into musical groupings occur more quickly.

One symptom of amusia in some patients is that musical sounds are not recognized as musical. There can also be disconnection between recognition of a melody and identifying its emotional content (Cousineau, Oxenham, & Peretz, 2015). The neural pathways responsible for processing emotion in music seem to be separate from those that process its structural qualities. There appear to be two subtypes of amusia. One involves tone deafness, which is the inability to discriminate tones on a musical scale. The patient in this case cannot tell if one tone is higher or lower in pitch than another. The other is amelodia, the inability to recall a melody. This involves problems naming or humming a melody, even when clues are provided. In amelodia, patients can name the instruments and identify wrong notes but are unable to name the melody. Tone deafness follows damage to the left hemisphere, amelodia follows damage to the right, although the exact locations of the damage on either hemisphere can vary (Basso, 1999).

Singing

The right hemisphere controls singing more than the left (Zarate, 2013). Some patients with left side aphasia are still able to sing familiar songs. Also, there are patients who have had their left hemispheres surgically removed (a left hemispherectomy) who can still sing. When the left hemisphere is anesthetized but the right is not patients can sing once they utter a word. When the right hemisphere is anesthetized and the left is not patients are able to speak but their singing in most cases is impaired. The right hemisphere plays a greater role in melody for non-musicians, but the left hemisphere still contributes to melody. In healthy individuals both contribute toward production (Altenmuller, 2001).

Playing

Adult musicians who began training before the age of 7 have a larger region in the trunk of the corpus callosum. These are one set of fibers that connect the two hemispheres. The depth of the central sulcus is greater in professional keyboard musicians in both the left and right hemispheres (Amunts et al., 1996). The central sulcus is the spacing between the frontal and parietal lobes. Anterior to this sulcus is the precentral gyrus or motor cortex that partly governs motor actions. Posterior to it is the postcentral gyrus or somatosensory cortex responsible in part for tactile perception. Both have somatosensory maps that represent body areas. For musicians that play string instruments, the postcentral gyrus in the right hemisphere is larger than in non-musicians (Elbert & Rockstroh, 2004).

Other Case Studies of Music and the Brain

Oliver Sacks, the well-known neurologist and musically gifted in his own right, chronicles numerous case studies of individuals with strange or unusual musical abilities. These are described in his 2008 book *Musicophilia*. We don't have the room to describe in detail all of the cases he mentions but will provide the reader here with a short summary for some of the conditions. Following Sacks, we divide these up into four sections. Tables 5.1-5.4 provide a broad overview of select cases, outlining the name of the case study patient or group, the causal incident that may have produced the condition, the symptoms, medical diagnosis and brain areas that are involved.

Table 5.1. Summary of Cases on musical intrusions. From Musicophilia by Oliver Sacks.

Name or Group	Causal Incident	Symptoms	Diagnosis	Related Brain Areas
Tony Cicoria	Struck by lightning	Heard music in his head. Began to compose.	Musicophilia	Brain not visibly damaged
Jon S.	Head injury at 15 yrs. Temporal lobe epilepsy	Hears classical violin music in his head.	Musical seizures	No recognizable damage
Silvia N.	Suffered head injury as a teenager	Neapolitan songs trigger seizures	Musicogenic epilepsy	Anatomical and electrical abnormalities of left temporal lobe
Healthy musical composers and other individuals	None	Ability to vividly imagine music in their minds	Musical Imagery	Auditory cortex, motor cortex, frontal cortex, possibly also the basal ganglia and thalamus
Otherwise normal individuals	Theme music of film and TV, advertisements	Repetitive, unwanted song fragments	"Brain worms" or "Sticky Music"	None mentioned
Sheryl C. and others	Aging brain, hearing impairment and other factors	Intrusive, unwanted songs, like Christmas carols	Musical hallucinations	Widespread activation of neural networks activated during normal perception of music

Table 5.2. Summary of Cases on a range of musicality. From Musicophilia by Oliver Sacks.

Name or Group	Causal Incident	Symptoms	Diagnosis	Related Brain Areas
D. L. and others	None	Hears music as screeching and noise. Can't recognize melodies or discriminate pitch	Amusia and dysharmonia	Melody impairments associated with right-hemisphere damage. Rhythm impairments associated with left-hemisphere and subcortical systems
Sir Frederick Ouseley and others	None	Can identify the pitch of any note	Absolute pitch	Increased size of the planum temporale in the frontal lobe
Martin	Childhood meningitis that caused seizures	Perfect memory for 2,000 operas and all Bach cantatas	Musical savant	Shift to right-hemisphere dominance
Michael Torke	None in most cases, blindness in some	Sees notes in different colors	Musical synesthesia	Cross-activation of visual and auditory cortex

Table 5.3. Summary of Cases on memory, movement, and music. From Musicophilia by Oliver Sacks.

Name or Group	Causal Incident	Symptoms	Diagnosis	Related Brain Areas
Clive Wearing	Herpes encephalitis	Lost semantic memory but intact procedural memory and musical performance	Amnesia	Damage to temporal lobes and hippocampus
Multiple individuals	Stroke or brain trauma	Lack of verbal communication but can still sing	Aphasia	Right "Broca's area" hyperactive suppression of left Broca's area
Anonymous elderly nursing home patient	Hip fracture	Could move leg in response to music	Apparent left leg paralysis	Auditory and dorsal premotor cortex

Table 5.4. Summary of cases on emotion, identity, and music. From Musicophilia by Oliver Sacks.

Name or Group	Causal Incident	Symptoms	Diagnosis	Related Brain Areas
Melanie Challenger and others	None	Hears orchestral music immediately after waking	Musical dreams	Not provided
Lawrence R. Freedman (and in some autism patients)	Concussion in a bicycle accident	Unable to experience the emotional qualities of music	Musical indifference	Multiple cortical and subcortical regions
Louis F.	Developmental onset of brain deterioration	Constant speech, singing and motor movements. Change in musical tastes	Frontotemporal dementia	Damage to frontal and temporal lobes
Some people who suffer from Alzheimer's disease	Developmental onset of deterioration	Loss of cognitive abilities but preservation of musical perception, emotion, and memory	Alzheimer's disease	Music has widespread cortical and subcortical areas and so can sustain diffuse cortical deterioration

Musical Intrusions

In this section Sacks describes patients who hear some form of music in their mind (Table 5.1). A few of these cases are people who suffer head trauma, sometimes to the left temporal lobe. Several also have seizures that originate at this same location. The music in most cases is unwanted and intrusive, meaning it dominates their consciousness and they cannot get rid of it. There are also cases in this category of composers who are capable of imagining entire songs in their "mind's ear" and of otherwise normal individuals who hear a catchy tune from the radio or TV which then replays repeatedly in their mind, what are dubbed "brainworms". Examples of brainworms include the "Plop, Plop, Fizz, Fizz, Oh What a Relief it is" tune from the TV commercial advertising Alka Seltzer, or in another case the soundtrack from the movie *Mission Impossible*. In the case of people who have musical hallucinations, brain imaging reveals that the same areas of the brain used during normal musical perception are also active during hallucinations.

A Range of Musicality

In addition to "normal" musicians and composers there are a variety of people who have exceptional musical talents or unusual reactions to music (Table 5.2). In some cases they are the result of disorder or brain damage, in other cases this is not present. For instance in the case of perfect or absolute pitch, people are able to name in some cases 70 different individual tones. Each tone has a particular "feel" to it for these individuals. In musical synesthesia each note has an associated color. These colors are very specific. For Michael Torke D minor is "like flint, graphite"; F minor is "earthy, ashy". We are born with high neural connectivity between cortical areas, such as those between the visual and auditory regions. These connections are pruned with experience, so that the crossover pathways between different modalities are reduced. In musical synesthetes some of these pathways apparently remain intact. This leaves the intriguing possibility that we are all born with synesthesia but over time the senses separate as the pathways are pruned.

Memory, Movement, and Music

Sacks in this section of his book, describes case studies of people with memory and motor disorders and their relationship to music (Table 5.3). Like the classic case study H.M., Clive Wearing suffered extensive temporal and hippocampal damage, which destroyed his memories for facts but which left skill abilities including music intact. Aphasias are language disorders that occur with damage to for instance Broca's area that controls speech production. These individuals cannot speak, but some paradoxically can still sing. Music therapists have been able to successfully restore some speech ability in these patients through the use of singing. In such people it is suspected that a corresponding "Broca's area" in the right-hemisphere becomes hyperactive and suppresses the corresponding damaged left side region. In another case study, one patient with limb paralysis could move their paralyzed leg only in response to music. This underlies the connectivity between the motor and musical parts of the brain and has important implications for music therapy.

Emotion, Identity, and Music

Melanie Challenger just upon waking from her afternoon siesta reports hearing loud orchestral music. This is an example of strong and intrusive, but not unpleasant musical imagery. Other composers and musicians report experiencing music in their dreams that solves compositional problems they were having while awake. Lawrence Freedman who suffered a concussion was temporarily unable to appreciate the emotional qualities of music. The same effect is reported in some autism patients. This implies that the brain areas that control the cognitive and emotional aspects of music are to some extent separate. Louis F. who suffers FTD is constantly bursting into song and cannot stop tapping his fingers and feet but has semantic memory amnesia and cannot understand some basic level category knowledge. Another man with FTD who formerly liked classical music and hated pop music suddenly developed a passion for Italian pop music and would play it loudly for many hours of the day. In these patients it is hypothesized that damage to the anterior temporal lobe of the dominant hemisphere loses its ability to inhibit the posterior parietal and temporal areas of the nondominant hemisphere. Preserved musical response in patients with degenerative brain disorders shows that the areas that govern musical ability are to some extent separate from those governing cognitive skill. A summary of these cases is provided in Table 5.4.

The Visual System and Art

Margaret Livingstone provides a readable introduction to the biology behind art perception in her book *Vision and Art: The Biology of Seeing*, updated in 2014. She examines many of the basic phenomena in vision and illustrates them using examples from the world of art. We summarize only a few of these in the sections that follow and recommend the reader to her work for a wider treatment of the subject.

Color Processing in the Brain and Art

Area V4 is the region in human cortex that is specialized to process color information. Zeki and Marini (1997) were interested in seeing the role it and other brain areas play in the perception of colored art paintings. For their study they presented normally colored art and abnormally colored art. Normally colored art portrays objects in their usual color, for example a strawberry would be portrayed as red. Fauvist paintings were used for the abnormal case. The Fauvist artists like Andre Derain and Maurice de Vlaminck painted objects in unexpected colors like bright-red tree trunks or blue leaves. Figure 5.8 shows the painting *Landscape near Antwerp* by George Braque that shows a number of abnormally colored objects. The clouds for instance are green, the water is pink and the hills are blue and red.

Figure 5.8. *Landscape Near Antwerp* by George Braque, 1906. Image in the public domain. Retrieved from WikiArt.org.

Both natural and unnaturally colored images activated area V4, as expected. However, the naturally colored objects additionally activated the fusiform gyrus and hippocampus. These areas are related to object color knowledge. Abnormally colored objects showed activity beyond V4 in the prefrontal cortex. This region has been known to activate in response to "oddball events" where there is a deviation from expectation. Keep in mind that deviations from expectation can be reacted to very differently depending on the appraisal of the observer. Those with art knowledge may see this deviation as a challenge and be driven to explore the work at greater length, gaining satisfaction. Naïve art viewers who appraise work as having to conform to realistic standards might have their surprise turn to disgust and turn away from such work.

Color and Filling In

Each cell in the visual system has a receptive field. This is a specific area and size of the visual field that it receives information from. When visual fields are small the cell can only "see" a tiny part of what a person is looking at. Details are contained in small areas, so these cells can process details. Large visual fields take in much larger areas. Cells that receive information from these fields can take in things like movement but not detail. To use a popular saying, cells with small receptive fields see the tree but not the forest. Cells with large receptive fields see the forest but not the trees. It might also help to think about visual fields in terms of resolution. When the resolution is high more details are captured and visible. This corresponds to having more pixels per unit area on a computer monitor or dots per unit area on an image. When resolution is low, fewer details are visible. Some information is lost in this case because the numbers of pixels or dots are too few to capture detail.

The color system in the brain operates at low resolution. Color cells have large receptive fields. All it takes is a small amount of color inside their receptive field and as far as those cells are concerned, the entire area now has that color. In terms of art this means that one does not have to completely fill in regions of color. All an artist need do is put in a small amount of color inside an object border and the color system fills in the rest. This can be illustrated with one of Cezanne's 1894 paintings. This is his watercolor *The Lime Kiln* shown in Figure 5.9. For the walls of the buildings he only loosely paints in yellow. Some parts of the walls are completely white. Yet the walls don't look white. Similarly, the trees in this painting are not all solid-green. Cezanne has put in some green, mostly at the edges. There are areas inside these trees that are still white. Yes, we perceive them as green. Many watercolorists use this technique today, loosely washing in colors in the interior portions of objects rather than filling them in entirely.

Figure 5.9. *The Lime Kiln* by Paul Cezanne, 1894. Image in the public domain. Retrieved from WikiArt.org.

Equiluminant Colors and Illusory Motion

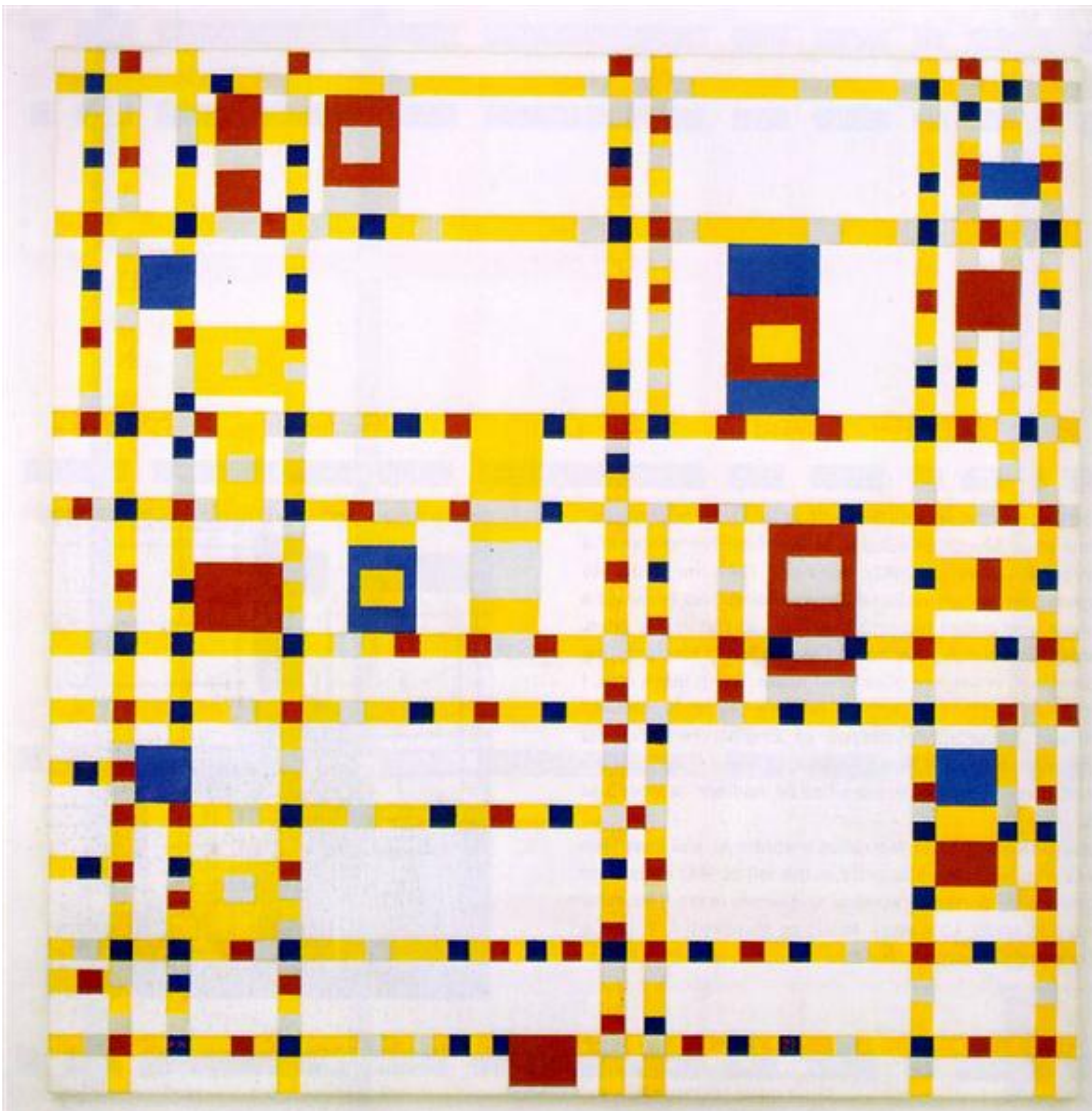
Value, or luminance refers to how light or dark an area of an image is. Most artists know that value is extremely important. Value more than color, determines the shape of what we see in a painting. The sky almost always has a lighter value than the earth. Areas of dark indicate shadows. Bright areas indicate reflections or light sources. In fact the entire structure of an object is based on the amount of light it absorbs or reflects. Lightness tells us not only about the property of surfaces but about the 3-D structure of objects.

A painting with correct values but incorrect color looks approximately right. A painting with incorrect values but correct color appears strange and vague. It is for this reason that painters are encouraged to squint their eyes when looking at a scene or to use software apps like Value Viewer that will convert a color image into a gray-scale image with a variable number of levels. Figure 5.9 shows a color image and then next to it what that image looks like when color (hue) is stripped away. It may not be as pretty, but it is obvious what the objects are in the scene.

Figure 5.9. A color image and one with the color removed. Notice that values (lights and darks) carry most of the information about shape and structure.

Livingstone (2014) makes an interesting observation. She notes that several artists seem to deliberately make colors that are equiluminant (having the same value), in order to produce a shimmering or motion effect. The "where" system in the brain can't process colors with the same luminance. Thus, if an image has equiluminant colors their location can't be pinned down by the "where" system and the result is an effect of illusory motion. One sees these colors as unstable and shifting around. Piet Mondrian's classic *Broadway Boogie Woogie* is an illustration of this (Figure 5.10). The yellow in this painting is close to the same value as the off-white background. The "what" system can see the yellow clearly, but the "where" system can't, making the squares seem to jitter.

Figure 5.10. *Broadway Boogie Woogie* by Piet Mondrian, 1943. Image in the public domain. Retrieved from WikiArt.org.



Luminance Range

The range of luminance values in a real world scene is tremendous. A light in an indoor scene for example may be hundreds of times brighter than a shadow. The range of values an artist can convey is much less than this. The reason is because the values in paints span a smaller range. The whitest white in paint is only about twenty times brighter than the darkest black. This is true for most other media as well, including photographic paper, print or colored paper. So how does a painter convey the large differences in brightness he or she sees in front of them? Prior to the Renaissance period this was achieved by adding white to the lit part of objects and using very saturated paints for the dark areas. Also gold gilding was added in some paintings to make areas more distinct.

Another instance of how pre-Renaissance artists dealt with this issue can be seen in *Madonna with Child and Pope Pasquale I*, an early Christian apse mosaic. The range of values is greater in the lighter colored monk's robes. Here one can see the folds because they are made darker. As a result they look more three-dimensional. In the central figure's darker robes there is a much smaller range of luminance. Here it is difficult to make out the folds because they are all so close in dark values to one another. They have less depth because of this. If these folds were highlighted in a lighter color they would become visible. However, the artist may have deliberately not done this in order to make the child, who is lighter, now stand out more and become the focal point of attention.

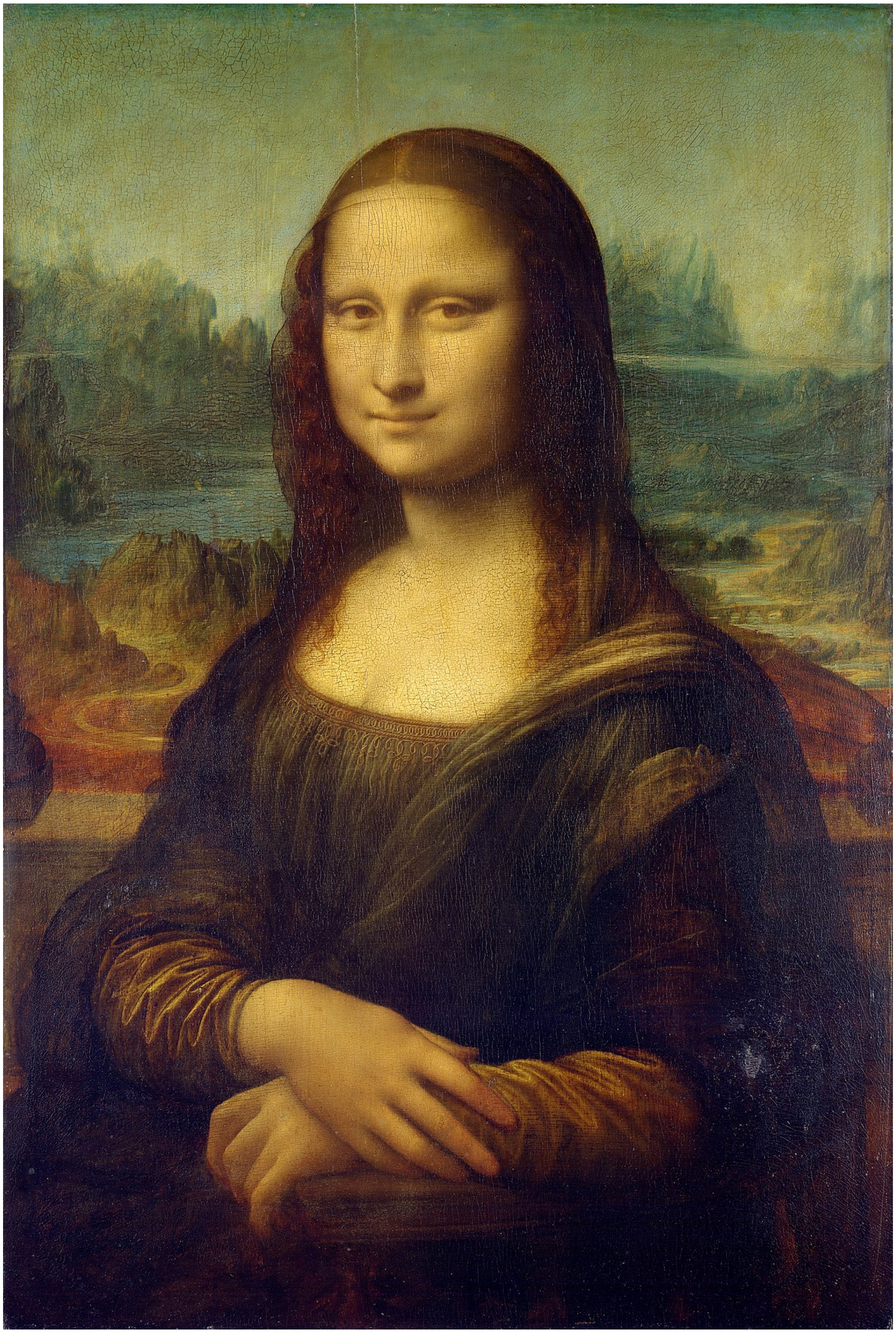
The Mona Lisa and the Two Visual Systems

Starting in the retina there are two visual systems. At the fovea in the middle of the retina there are a high concentration of cone cells. These photoreceptors are sensitive to details and allow you to see in bright light conditions. Cone cells have small receptive fields (the area of the visual field they receive information from) and can only see small portions of the visual field. Farther out in the periphery of the retina the concentration of rod cells increases. Rod cells are sensitive to motion and allow you to see at night in monochromatic conditions. They have larger receptive fields and can thus "see" much larger regions of the visual field. The cone cells feed into the "what" visual system or ventral pathway that runs to the temporal lobe and is responsible for being able to shape and form. The rod cells feed into the "where" visual system or dorsal pathway that runs to the parietal lobe and is responsible for being able to see movement and location.

Livingstone (2014) has formulated a theory to explain the quirkiness of the Mona Lisa's smile that is based on the operation of these two systems. Part of what makes Leonardo da Vinci's *Mona Lisa* so fascinating is its smile. She seems to know something that we don't, as if holding in a joke or secret. What is it about the painting that gives it this quality? Livingstone noticed that when you look directly at her mouth her smile seems diminished. When looking away at another part of the painting though, she seems to smile more strongly. Perhaps the reason is that da Vinci painted the shadows on either side of her mouth to connect with her lips in the shape of a giant smile. This larger smile is visible to the rods and "where" system only and can only be sensed when her mouth is in the periphery, when your eyes are looking away from her lips. Once you fixate directly on her mouth again, you engage the cones and the "what" system. These can only see details over a smaller area, so the smile diminishes.

One way to make this more visible involves spatial frequency. High spatial frequencies correspond to details and small regions of space. This is what is seen by the “what” system. Low spatial frequencies correspond to larger regions of space. These frequencies are processed by the “where” system. We can take an image and strip it of low spatial frequencies, leaving only the high ones. This takes out all the large-scale information from a picture, accentuating details. This is equivalent to what the “what” system sees and here there is less of a smile. However, if we take an image and instead strip it of its details, preserving low spatial frequencies the coarse larger information remains. This is what the “where” system sees. The smile in this case is much more obvious, in part because the shadows at either side of the lips have merged with them to form one large upward smile-like curve. Figure 5.11 show the original, untransformed painting.

Figure 5.11. The Mona Lisa by Leonardo DaVinci. Image in public domain. Retrieved from Wikimedia commons.



The Visual Arts and the Brain

Landscapes and the Brain

The parahippocampal place area or PPA is responsive to natural as well as constructed environments as opposed to faces or other individual objects. It works in conjunction with the retrosplenial cortex (RSC) to organize and understand the space we move around in. The PPA represents local landscape scenes and is quite general, firing in response to landscapes, scenes of cities, the inside of rooms and even arrangements of Lego blocks. The RSC gets activated both during perception and imagination of a scene. Neurons in the RSC fire more strongly in response to familiar places. This is not true of the PPA. So the RSC may be used in retrieving the memory of a place you have visited in the past.

So what pattern of brain activity would we see in response to the aesthetic judgment of a scene? Yue, Vessel, and Biederman (2007) had people view different scenes while being imaged using fMRI. The scenes included natural landscapes, cityscapes and rooms. The participants were asked to judge how beautiful they thought these scenes were. There was greater activity in the right PPA for scenes that were liked compared to those that were disliked. They also found more activity in the right ventral striatum. The PPA activation shows that the part of the brain used in responding generally to scenes is also active when evaluating them aesthetically. Recall that the same is true for faces, where we saw FFA activity in response to face beauty judgments. We can conclude that the PPA both classifies and evaluates faces. If these scenes had been familiar, we can assume there would have also been RSC activation. Note that the striatum is part of the brain's reward system, so viewing beautiful scenes, like viewing beautiful faces, triggers this reward center.

In a study with similar aims, Kawabata and Zeki (2004) presented still life, portrait, and landscape paintings to subjects and had them rate them as ugly, neutral, or beautiful. They found activation in the orbitofrontal cortex and anterior cingulate, both parts of the reward system, in response to the paintings rated as beautiful. These areas are active when we experience many different kinds of pleasures.

Are these same regions active in response to viewing abstract artwork? Abstract artwork is non-representational, meaning that there are no recognizable objects, people or scenes in it. Jacobsen, Schubotz, Hofel and von Cramon (2005) used geometric shapes as their stimuli, since these resemble abstract artwork in some ways. They had the participants judge whether the shapes were symmetric and whether they were beautiful. They found that judgments of beauty, more so than symmetry, activated neurons in the medial and ventral prefrontal cortex, and an area called the precuneus. These areas form part of the brain's extended reward circuitry. So yes, even abstract images if considered beautiful will activate the brain's reward system. Representation is not needed.

Cela-Conde et al. (2011) used a different imaging technique, called magnetoencephalography, to look at the time course of aesthetic appreciation. They presented photographs and artworks and asked their participants for judgments of beauty. There was a greater response from the left dorsolateral prefrontal cortex

400-1,000 msec after the images were shown. Frontal lobes are involved in decision making, so these results mean that we are capable of deciding whether an object is beautiful in some cases in less than half a second. That is fairly fast.

Visual Indeterminacy and the Brain

Visual indeterminacy occurs when viewing images that contain details but which fail to resolve into meaningful objects or scenes. These are images that seem to contain things that are familiar to us, so we continue to look at them to try and make sense out of them. The artist Robert Pepperell produces paintings and drawings that induce this effect where one can almost see human figures and other forms emerging from a swirling chaos of potential shapes. Ishai (2012) reports a study performed in collaboration with Pepperell. The subjects performed object recognition and judgment of aesthetic affect while viewing representational paintings by various artists (containing recognizable forms) and indeterminate paintings (by Pepperell). Reaction times to make a response were longer for the indeterminate paintings, presumably because they had to struggle to recognize forms. However, aesthetic affect ratings were the same for both types of paintings. Participants were then given a surprise memory test. More representational paintings were recalled, as might be expected since these images had semantic content attached to them. This study shows that aesthetic affect can be based on lower level features like color and contour, while perception and memory of art rely on meaningful content.

Fairhall, Scott, Ishai, and Alumit (2008) next conducted another similar study, this time using fMRI imaging. Subjects were asked to perform object recognition tasks. They used three types of paintings: representational, indeterminate, and abstract. The abstract paintings contain no recognizable content whatsoever, not even suggestive. All three paintings produced activation across widespread areas of the cortex, including occipital (vision), limbic (memory), parietal (attention), and prefrontal (planning). Representational paintings evoked stronger activation in the fusiform gyrus compared to the other two types of paintings. The fusiform gyrus mediates responses to a wide variety of objects including tools, houses, animals, and faces. The indeterminate paintings evoked less activation in the right hippocampus than the other types. Hippocampal regions in the limbic region are involved in memory, so without any forms to latch on to, there was less memory retrieval.

Next, these researchers compared scrambled paintings with indeterminate ones. Scrambled paintings evoked activity in the precuneus and the medial frontal gyrus. These areas are part of a system that is used to generate and maintain visual imagery. Debriefs showed that many of the subjects used visual imagery to decide whether they contained familiar objects. In contrast, visual similarity and visual associations were used to try and recognize objects in the indeterminate paintings. There was greater activation in the temporo-parietal junction (TPJ) for representational compared to indeterminate images. The TPJ switches attention from local to global processing and guides allocation of attention across the visual field. Both of these are needed to recognize objects at different locations in a visual scene.

In summary these studies show that viewing of art images activates widespread areas of the brain. Each of these areas subsumes a specific function necessary to process image content. Fusiform gyrus is needed for object recognition, hippocampus for memory consolidation, precuneus and medial frontal gyrus for visual imagery and TPJ for linking the various elements of a visual scene. The authors conclude that the brain automatically wants to make sense of a scene. If it is confronted with an ambiguous image with hints of features and objects, it will work hard to make sense out of it, in the process calling on higher-order cognitive operations, including attention, imagery and memory retrieval.

Meaning and Art Judgment

In the section on titles and names in the psychology chapter we will show that knowledge affects our understanding and appreciation of artwork. This in part explains the different judgments of naïve and expert art viewers. Art experts have a large body of knowledge that they bring to a painting and that certainly influences what they think about it. Here we examine how prior knowledge affects painting perception, focusing on differences in brain physiology.

Kirk, Skov, Hulme, Christensen, and Zeki (2009) presented abstract art stimuli that were labeled as either being generated by a computer or coming from a museum. Ratings were higher for images that they thought came from a museum. These paintings were also accompanied by increased activation in the brain's reward system, both the medial orbitofrontal cortex and the ventromedial prefrontal cortex. So-called museum pieces also elicited greater activity in the entorhinal cortex, a region associated with memory. Perhaps in these conditions the observers were trying to recall if they had seen a work like it in a museum or were retrieving knowledge relevant to the paintings that they had learned previously..

Weismann and Ishai (2010) did brain imaging on participants as they viewed cubist paintings by Braque and Picasso. Half of the group was "educated" for 30 minutes on Cubism and then given practice in recognizing examples of this style. This group showed more activity in the intraparietal sulcus and in the parahippocampal gyrus compared to the other half of the participants upon subsequent viewing of cubist paintings. Hippocampal regions are related to memory, so the results imply that memory processes were occurring during this group's viewing of the images. These participants were most likely applying what they had just learned to what they were now seeing.

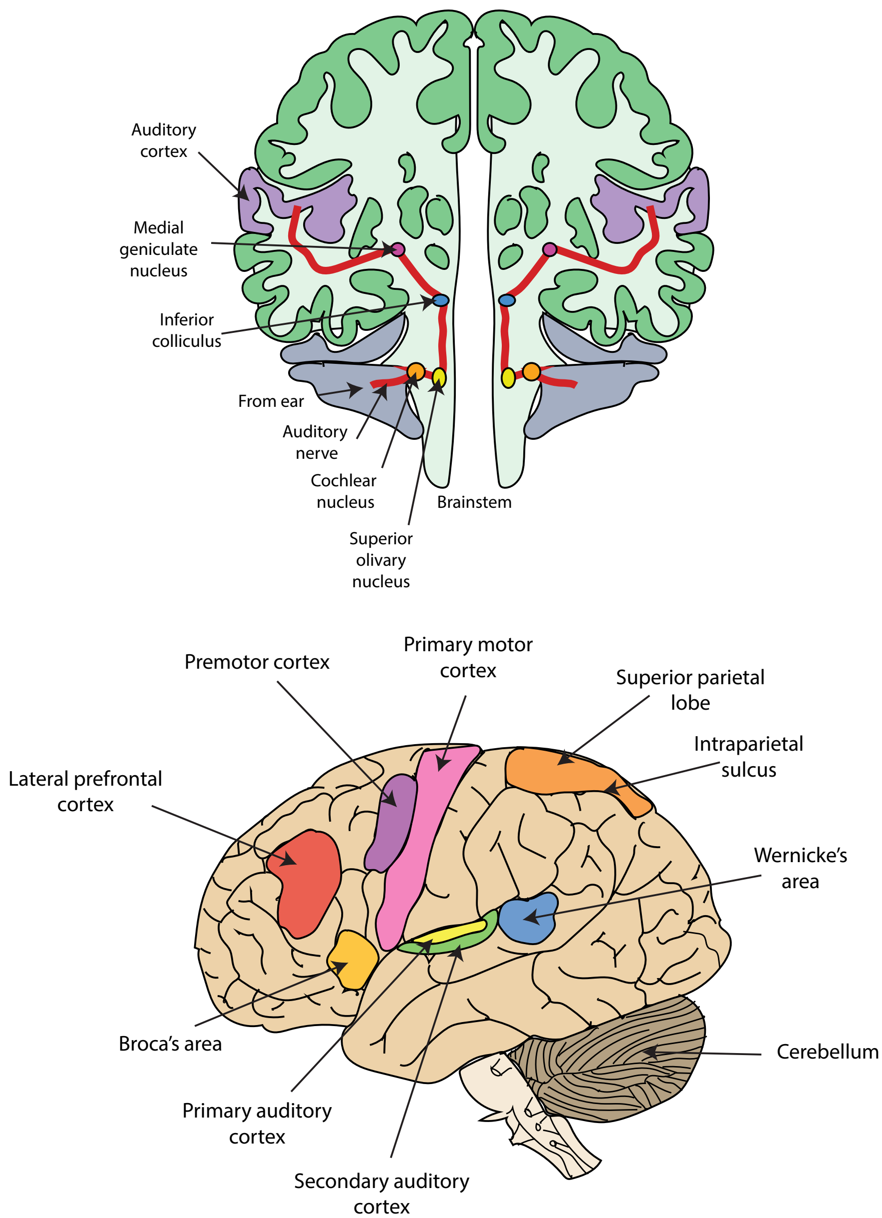
Expertise

Kirk, Skov, Christensen, and Nygaard (2009) recruited both architecture students and other students without extensive knowledge of architecture for their study. Both groups were shown pictures of buildings and faces while brain activity was recorded. The architecture students exhibited more activity in the hippocampus when they looked at buildings compared to faces, presumably because of memory recall. However they also showed greater activity in medial orbitofrontal cortex and the anterior cingulate than the non-experts when looking at buildings. For these students, knowing more about the buildings was associated with their liking them more. In contrast, there was more activity in the nucleus accumbens for beautiful buildings and faces for both groups, regardless of their knowledge of architecture. So the accumbens seems to be a more basic pleasure center, activating in response to any attractive image. But the orbitofrontal and anterior cingulate regions seem to be linked specifically to prior understanding and learned pleasures.

Music and the Brain

Listening to music is a whole brain experience. Nearly every region of the brain and many neural subsystems are activated as part of listening. When we listen to music we find activation first in the cochlea, inside the ear. Basic frequencies are extracted from the sound stream in the cochlea, which then sends that information toward the brain along the auditory nerve. Early processing is performed by subcortical structures like the cochlear nuclei, brain stem and cerebellum. The auditory cortices on both hemispheres are then activated. In most people the primary auditory cortex on the left hemisphere contains neurons that respond to specific frequencies. Areas near that region will code for more complex sounds. Figure 5.12 shows the major structures of the human auditory system and some of those areas that mediate music perception and performance.

Figure 5.12. The human auditory system.



Other brain areas become active depending upon the task. Listening to familiar music will recruit areas like the hippocampus since that structure is involved in memories. If we were to tap along with music, we would recruit the timing circuits of the cerebellum. Performing music requires the frontal lobes for planning, the motor cortex to coordinate movement of the hands and fingers and the sensory cortex for tactile feedback. Reading music uses the visual cortex in the occipital lobe. Listening to or remembering lyrics requires the language part of the brain, usually left hemisphere regions like Wernicke's area for comprehension and Broca's area for production. Experiencing emotion calls upon the amygdala, a brain structure that plays a role in fear and anger.

The first part of listening to music involves feature extraction, determining which frequencies and other components make up the sound. But while this is taking place the higher-order parts of our brain, especially the frontal lobes, are also busy. They are receiving updates and information about what has occurred thus far. They use this data to predict what might come next. Prediction is a big part of listening to music. Once we know the meter we can predict what notes will be accented and which ones won't. Once we learn the melody we can anticipate what specific notes will come next. Feature extraction is a bottom-up process and is driven by stimulus features. Expectation is top-down and driven by our knowledge and understanding. Both of these processes work synergistically to determine our response to music.

Levitin (2006) lists four types of information these higher centers use to make predictions. They are (1) what has already come before in the piece of music we're hearing, (2) what we will remember will come next if the music is familiar, (3) what we expect will come next if the style or genre is familiar, based on our previous exposure to this style and (4) any additional information we've been given, such as a summary of the music or an understanding of the composer. As we discuss elsewhere, violation of expectation in music can go a long way toward explaining how we respond to it emotionally. In this section we summarize a number of findings from Levitin's book *This is Your Brain on Music*. For more details and additional information we refer the reader to his book.

Hemispheric Processing

The two hemispheres specialize to some degree on different aspects of music processing. The right hemisphere processes the contour of a melody, how its overall pitch envelope rises and falls. It is also involved in making fine discriminations between tones that are close in pitch. The left hemisphere specializes in language and underlies the ability to name a song, performer, instrument or musical interval. The left frontal lobes also appear to track the development of musical themes and enable us to think about scales and keys. Interestingly, training can shift some aspects of music processing from the right to the left hemisphere as we learn to think and talk about music using words. All of this demonstrates two things. First of all, there is no single place in the brain that performs all aspects of music perception. Second, different parts of the brain carry out specific component operations and others coordinate to bring all of the information together.

The areas on both hemispheres that are active during the reading and playing of music are the primary motor cortex, pre-motor cortex, superior parietal lobe, lateral prefrontal cortex, and cerebellum. Interpreting a musical score causes activity in the intraparietal sulcus and the superior parietal lobe. If a person is asked to detect or discriminate parts played by different instruments, there is activity in the parietal lobe, cerebellum, and basal ganglia as well as the pre-motor region in the prefrontal lobe. If a person is asked to hear a melody in their "mind's ear" after being provided with a cue, there is activation in the parietal, ventrolateral prefrontal area, and the pre-motor area.

For non-musicians PET scan studies have found activity in the right temporal lobe and the right supplementary motor area of the prefrontal cortex during musical imagery (Halpern, 2001). There is more left hemisphere activation for familiarity, rhythm and pitch. There is more right hemisphere activation for timbre identification (Platel et al., 1997). Timbre refers to the specific qualities that allow us to distinguish one instrument from another. The left inferior frontal gyrus and the anterior region of the superior temporal gyrus were activated for familiarity of melody. Rhythm was controlled in part by Broca's area and the insula. Notice that rhythm and pace are important for speaking, which is the other function of Broca's area. A test with non-musicians for processing the difference between tones showed activity in the right rostromedialprefrontal cortex.

Keeping Time

The tempo of a musical piece has a strong influence over our emotions. Songs with fast tempos (short note durations and intervals between notes) are usually regarded as happy and songs with slow tempos (longer notes with longer intervals) are usually considered sad. Think of a polka vs. a funeral dirge. This difference holds true cross-culturally, over different circumstances and over the lifespan of many people. We also have a pretty good memory for tempo. Levitin and Cook (1996) asked people to sing their favorite rock or popular song from memory. The participants came very close to the actual tempo, only being off on average by four percent.

This sort of accuracy is probably due to the cerebellum. This brain structure helps to pace well-learned motor movements like walking up or down stairs. It also helps to time daily events and to synchronize to music we are listening to. The cerebellum is believed to store settings for the tempo of songs. These are called up when we are asked to sing a song from memory. The basal ganglia, also part of the motor system are likely to be involved in musical tempo, rhythm and meter. Keep in mind that every neuron in our brain is like a small clock. Each "tick" of this clock is an action potential or firing of the neuron. So it should not be surprising that our brains are good at things that involve timing.

Preferred music may also correspond to certain body tempos. Marching music corresponds roughly to the rate at which our feet hit the ground while marching. Dance music is faster and corresponds to the increased tempo of dancing. Relaxing music may have a tempo closer to sixty beats per minute, which is our resting heart rate. The cerebellum could play a role in this. In addition to pacing behaviors it becomes active when we listen to music we like. There thus seems to be a three-way connection between repetitive actions, emotions and music.

Recall that meter refers to the accented structure of notes. A group of three notes for example could have an accent on the first, second or third note of the triad. The accent is an emphasis and we tend to hear accented notes as louder or more salient even when they are played the same as the rest. When we snap our fingers, clap our hands or tap our feet to a song we are tracing out the meter and make the actual movement on the accented note of a group. Evidence suggests that we prefer small-integer ratios of durations like 2:1, 3:1 or 4:1.

Our brains tend to treat note durations that are similar as equal. We "round up" if a note is less or "round down" if it is more to regularize them and make them fit a simple ratio. There are neural circuits that detect and track musical meter and the cerebellum also plays a role in this. A common meter in music is 6/8, meaning we count six beats to a measure and each eighth note gets one beat. 2/4 and 4/4 meters are easy to walk, dance or march to. Because they are even numbers, the "tap" always ends up with the same foot hitting the floor on a strong beat.

Rhythm and meter perception are served by different parts of the brain. Patients with left hemisphere damage can lose the capacity to perceive or make rhythm but can still perceive meter. Conversely, patients with damage to the right hemisphere have problems with metrical extraction but not with rhythm. Both meter and rhythm appear to be independent of melodic processing. Lesions (damage) to the right temporal lobe affects the perception of melodies but the same is not found with damage to corresponding areas in the left hemisphere. Also, the right hemisphere has been found to contain a melodic contour processor that allows a melody to be recognized later. These areas are functionally independent of the regions that subsume rhythm and meter perception.

Loudness

Some younger people seem to like loud music. Those who go to concerts report a special feeling or state of excitement when music is played really loud, over 115 dB. This is dangerously loud and sustained listening at this level can damage mechanisms in the cochlea that code for frequency. This conscious state may be due to neurons in the auditory system firing at their maximum rate. The result could be an emergent property or pattern of activation not present during normal hearing.

Pitch

In the math chapter we reviewed the role that ratios play in pitch perception, and found that octave (2:1) and fifth (3:2) relations among others are preferred. Notes that are played in these relationships are found to be pleasing or consonant. The rule again is that small integer ratios are liked. This is true for meter or pitch. The dorsal cochlear nucleus and brain stem underlie our ability to differentiate between consonance and dissonance. These are very primitive brain areas, ones shared in common among all vertebrates. It is not clear why such older brain structures should be involved in this function.

Expectation and its Violation

An Event Related Potential (ERP) involves the use of sensors applied to the scalp to measure brain activity in response to a controlled event. The P600 component of the ERP is a peak in electrical brain activity elicited by hearing or reading grammatical errors. Besson, Faita, and Requin (1994) presented melodies to listeners with unexpected ending notes based on melody, harmony and rhythm. They found that these musical stimuli too elicited the P600 response. This suggests that there is shared neural machinery between linguistic and musical systems for judging unexpected events. In this study the response was stronger and earlier in musicians than in nonmusicians when the unexpectancy was melodic or harmonic. However the rhythm violation condition did not differ between those with or without musical talent. Rhythm perception may thus be a more fundamental brain skill that does not require training.

Other studies have looked at unexpected chords that were either dissonant or in the wrong mode and in a nearby vs. distant key. Dissonant and wrong mode chords evoked strong responses at about 300 ms, while wrong key chords did so at about 600 ms after chord onset. In all of these studies there was a greater neural response the greater the subjective degree of unexpectancy. The brain seems to track musical syntax the way it tracks language syntax, predicting ahead of time what will occur and then reacting if there is a discrepancy.

Music and Language

There are some commonalities between music and language. They both have a grammar or syntax that specifies how basic units like words or notes get combined. For the English language these rules include placing an adjective before a noun. For music they include what notes can be played one after another or combined to create a chord. Music and language also both have semantics or meaning. Words and sentences carry meaning in language. Since music includes singing and lyrics for songs, it also has linguistic meaning. As a result, we might expect that some of the brain areas for music and language overlap.

Koelsch et al. (2004) played chord sequences that either resolved in a standard and satisfying way or an unexpected and unsatisfying manner. They did this by varying the chord the sequenced ended in. Within 150 - 400 ms after onset of this chord they observed electrical activity in the brain associated with musical structure. About 100 - 150 ms later there was activation of brain regions that mediate musical meaning. The brain areas that process musical syntax are located in the frontal lobes near the areas that process linguistic syntax, such as Broca's area on the left hemisphere. The areas for semantics are on back portions of the temporal lobe on both hemispheres, near Wernicke's area, which underlies linguistic comprehension.

Levitin and Menon (2003) using fMRI found that listening to music while attending its structure activated the pars orbitalis, as subset of the region called Brodmann Area 47. This region has some overlap with areas devoted to syntactical processing of language but they also found unique activation in response to music alone. This was in the left hemisphere. On the right side they found activation in a corresponding region. So paying attention to the structural characteristics of music requires both sides of the brain while syntactical processing of language typically involves the left hemisphere only.

This and other research shows that brain's music system functions with at least some independence from the language system. This other evidence comes in the form of individuals who lose language but retain musical ability and others who lose musical capacities but retain language. This is called a double dissociation in clinical neurology and we will describe examples in the case study sections of musical ability. However, this does not mean that the neural substrates responsible for music and language are completely separate. The close proximity and partial overlap of the regions in the frontal and temporal lobes suggests that at birth the areas for these two abilities are undifferentiated but then become more separated with experience and learning.

Speech and Music Perception

The behavior of brain-damaged patients along with other data suggests that the left auditory cortex dominates for speech perception while the right auditory cortex dominates for music perception. The first experimental study showing this involved positron-emission tomography (PET) using participants who were exposed to verbal information (a detective story) and nonverbal information (musical sounds, chord pairs) to one or both ears (Mazziotta, Phelps, Carson & Kuhl, 1982). Verbal stimulation activated more widespread regions in the left hemisphere while nonverbal information activated more widespread regions in the right hemisphere. In another study subjects either categorize phonemes (basic sound units of speech) or perform a pitch discrimination between two sounds. There was more left side activation for phoneme categorization and more right side activation for pitch discrimination. Chord discrimination has also been found to evoke stronger right side activation (Tervaniemi et al., 2000).

Tervaniemi et al. (2006) found that speech and music activated discrete brain regions in the temporal and frontal lobes. They used fMRI recording in response to pseudowords and saxophone sounds. The speech sounds activated the superior temporal gyrus and superior temporal sulcus. Music sounds activated the superior temporal gyrus and Heschl's gyrus. Besson et al. (1998) played excerpts from opera songs to professional opera singers that had a congruent or incongruent ending note. If the note was incongruent it could be either in the lyrics, in the tune or in both. If lyrics and melody had separate neural systems then both the N400 and P600 potentials should occur. This is in fact what they found. The N400 occurs over the centro-parietal electrode sites and is part of the brain's normal response to words and other meaningful stimuli including visual and auditory words, as well as pictures, faces and other kinds of patterns.

Music and Emotions

One of the most pronounced responses we have to music is emotion. Many of us feel energized when listening to rock songs while exercising, calmed while listening to ambient music and sad when we hear a song that reminds us of a failed relationship. But exactly what parts of the brain become active during these moments? That is what we will examine at in this section.

Blood, Zatorre, Bermudez and Evans (1999) varied the degree of dissonance between a melody and set of accompanying chords. The subjects rated their emotional states while listening. None of the manipulations affected how they felt along a sad/happy dimension but they did affect their feelings in terms of pleasantness: they felt more tension, irritation and anger with increased dissonance. The manipulation was found to produce activity changes in several subcortical structures. The right parahippocampal gyrus and the precuneus were more activated by increased dissonance. Other brain imaging studies using fMRI have found changes in the amygdala, hippocampus and temporal poles (Gosselin, Peretz, Johnsen, & Adolps, 2007).

Blood and Zatorre (2001) had musically-trained participants choose musical excerpts that would induce positive emotions and chills. None of the excerpts included lyrics, to eliminate linguistic meaning. They were also minimally associated with previous events to rule out the effect of memories. The music that gave them chills produced changes in neural activity to several cortical and subcortical areas. These were the amygdala, ventral striatum, midbrain, orbitofrontal cortex and ventromedial prefrontal cortex. Some of these areas are associated with motivational drives like sex and food, showing that music, like these basic reinforcers, can serve as a form of pleasure and reward.

Literature and the Brain

Reading a novel or other form of literature such as a poem is an aesthetic experience, one that is now drawing more attention from researchers. What parts of the brain are active when reading such materials? Are their properties that can distinguish literature from other verbal materials like an instruction manual or an advertisement in a newspaper? Can we identify different patterns of activation in the brain in response to different literary genres like detective novels or romance novels? These are the sorts of questions that scientists are seeking answers to in the field of neuroaesthetics.

David Miall and his colleagues in much of their research start by presenting a short literary passage to subjects, who are instructed to read and then comment on their experience. The comments fall into two categories, linguistic and narrative. At the linguistic level are comments related to stylistic features like the sound of words. Readers take longer to read these segments and report elevated levels of feeling in response to them (Miall & Kuiken, 1994). At the narrative level readers process information like the characters and locations of the story. Over the course of reading readers follow the plot, identify with the characters and feel emotions like surprise, curiosity or suspense. They also form an implicit relationship with the narrator (Bortolussi & Dixon, 2003). Readers who are engrossed in a narrative world additionally show positive feelings toward sympathetic characters (Green, 2004). After the reading, they reflect on the relationship between the passage and their lives.

Literary texts provide access to the minds of characters and may even help readers to better assess the minds of real people in the real world (Zunshine, 2006). The understanding that others are conscious and can think and feel in much the same way we can is known as a Theory of Mind (TOM). Mirror neurons are those that activate not only when we perform an action but also when we watch someone else perform an action. They may underlie our ability to have a TOM and to empathize with literary characters. Hauk and Pulvermuller (2004) found activation of motor areas in the brain controlling different body parts (face, arm, and leg) when reading passages about those same areas. This activation occurred very early, only 210-230 ms after reading. This implies that we actually produce commands to move our body when reading about a character's actions but then hold it in check. This motor enactment seems to be part of simulating the world we experience while reading.

So what particular brain areas are involved in reading literature? Kane (2004) argues that the right hemisphere controls the language processes characteristic of poetry. These are characteristics like alliteration, imagery, paradox, irony and subtlety, among others. It may also provide a "coarse" semantic representation of the story (Beeman, 1998). The amygdala is likely involved when reading a passage that is striking and unfamiliar and which then arouses emotion (Robinson, 2005). Miall (2009) proposes that the same brain regions active when perceiving are probably also activated during imagination. For example, imagining what a scene looks like visually will activate the occipital, temporal and parietal areas that are also active when actually looking at a scene. This has been shown to be the case for pure imagination and is also likely the case when inspired by literature.

Another aspect of reading is immersion, the extent to which we are transported away from reality and engaged in a compelling way with a story (Green, 2004). This absorption may be caused by a description of a scene or a character. It may facilitate identification with the character, with his or her motives and goals. This feeling may be strong enough on occasion to elicit bodily symptoms like perspiration, increased heart rate and muscular tension (Auracher, 2006).

Dance and the Brain

Dance is an area that is under-researched in the arts, especially when it comes to neuroscience. Calvo-Merino, Jola, Glaser, and Haggard (2008) had people watch 24 short dance movements. Half of these were from classical ballet and the other half were from Capoeira, a Brazilian martial arts-dance form. The participants judged how much they liked each of these dance performances. Those that were liked involved movements of the entire body and jumps rather than smaller body motions like movements of just an arm or leg. There was greater bilateral activation (on both sides of the brain) of occipital cortex and in the right premotor cortex for the pieces that were liked. So both the visual and sensorimotor parts of the brain become active during aesthetic evaluation of dance. What is interesting is that these areas would also be active when one is actually dancing. It seems we unconsciously act out what we are seeing when watching someone dance in an evaluative manner.

It is possible that aesthetic judgments of motor action may have their basis in observational learning, where we watch someone perform a movement in preparation for performing it ourselves.

Brown, Martinez, and Parsons (2006) were perhaps the very first to investigate what goes in our brains while dancing. They had amateur dancers perform a repeating tango movement while listening to tango music and having their brains scanned by positron emission tomography (PET). They discovered that a particular part of the cerebellum, called the vermis, was active when the dancers entrained their movement to music. This type of entrainment involves synchronizing one's motions to the music, as opposed to self-pacing of movement.

The cerebellum is a large structure at the rear bottom portion of the brain that is responsible for learned motor movements. These researchers found greater activation in the right putamen for metric movements. Metric movements are those performed to a regular repeating metered rhythm. The putamen is part of the basal ganglia, another structure involved in motor behavior. The medial superior parietal lobule was also active when the dancers moved their legs in a spatial pattern. The parietal lobe governs spatial cognition as well as somatosensory function, which is perception of touch from different areas of the body. Proprioceptive brain regions, that regulate the relative location of different body areas were implicated as well.

This study shows that many different brain areas are active during dance because dancing involves many different component skills. It involves awareness of where one's arms and legs are in space as well as haptic (touch) feedback of what those limbs feel like. In addition these limbs must be moved and controlled, so there is activity in the parts of the brain that control motor performance.

Film and the Brain

Film is considered to be "total art", because it utilizes so many other art forms, including visual images, a musical soundtrack, script as a form of literature, architecture as set design, etc. The same can be said however for virtual reality, video games and theater. Unlike theater, film has the ability to manipulate the observer's point of view through camera angle, close-ups, panning, and special effects. Films need to be engaging in order to compensate for the viewer's lack of freedom and inability to interact voluntarily with the film's environment. However, after a movie, most people don't remember much of these visual style elements. They tend to recall more of the narrative elements, the locations, plot, the characters and their motivations.

Most films can be characterized as portraying people moving through space and time in pursuit of some goals (Grodal, 2009). They show characters that are actively coping with some problem. These problem situations can elicit fight or flight sympathetic nervous system responses as we see in the horror or action genres. Typically at the end however there are situations that evoke parasympathetic reactions because the character's goal has been achieved and there is a sense of closure. Muscle tension measured through EMG rises during a compelling story and then drops after the conclusion (Malmo, 1975).

Film, along with mythology and folktales derive most of their focus and interest from a main character or hero. This character's concerns are what generate the value and emotions in the story. The central actor need not be human. Many animated children's films have animals as the central characters. A recent example is *Zootopia*, where a rabbit plays the protagonist. The hero can be thought of as representing some aspect of the viewer's core self. According to Panksepp (1999) the core self is supported by structures in the periaquductal gray (PAG). The PAG is hypothesized to contain a body map as well as neural representations of pain and basic emotions like fear and anger. These emotions are tendencies toward actions and when activated can elicit behavior. The temporal cortex is also believed to play a role in merging together perception, emotion and action by providing a feeling of a body image (Ramachandran & Hirstein, 1999). Grodal (2009) ties these together in his PECMA view of the hero's narrative, the acronym standing for Perception, Emotion, Cognition, Motor Action.

Vogeley and Newen (2002) showed two stories to viewers. One was a self-story, designed to activate the viewer's sense of self, while the other was not. Self-stories activated the anterior cingulate cortex and the right tempoparietal cortex, but also produced an increase in the right pre-motor and motor cortex and the precuneus bilaterally. The right inferior tempoparietal cortex may be used for navigating around spaces and scenes. It may also serve as a body representation with regard to experiential space. Stories in this study that concerned TOM activated the right anterior cingulate cortex.

Movies are known to elicit emotional responses in viewers (Shimamura, Marian, & Haskins, 2013). Aalto et al. (2002) studied the amount of cerebral blood flow in female participants who watched films with emotional content. The stimuli were 12 movie clips taken from films like *The Champ*, *Kramer versus Kramer*, and *When Harry Met Sally*. They were chosen to represent amusing, sad, or neutral situations. The clips lasted on average two and a half minutes. They found bilateral activation of the amygdala, a brain area responsible for processing emotions like fear. There was also activation in the temporal-occipital region, the anterior temporal lobe and the cerebellum in response to the amusing and sad clips. More specifically the right temporal pole was active for these two emotion conditions. There was little subcortical activation except for the amygdala. This research is in accordance with the view that multiple brain regions are active during emotion-related tasks (Shobe, 2014).

Math Aesthetics and the Brain

Because the research on math and beauty is scant, Chatterjee (2014) describes what parts of the brain might become active during the aesthetic appreciation of math. We would expect activity in those brain areas that process numbers coordinated with those that process pleasure and reward. This is the pattern we have seen so far, where activation of a brain area that processes a particular type of information like faces or places, also gets activated along with reward centers. When numbers are represented symbolically, there would be activation in left parietal cortex. When they are represented as approximate quantities, we would expect bilateral activation in the intraparietal sulci. A sulcus is a ridge or convolution in the cortical surface, as opposed to a fissure or space. When math relationships are involved, there ought to be an increase in neural firing in the parietal cortex along with areas of the dorsolateral prefrontal cortex. This latter structure is involved with maintaining and transforming complex information. Appreciation of math beauty would most likely correspond to a "liking" response rather than a "desire" response to the beauty of things like faces or bodies.

Creativity

Genetics and Creativity

Chavez-Eakle (2007) reports a study in which some genetic markers for creativity were discovered. In a sample of 100 individuals, forty percent were famous scientists or artists known to be highly creative. The remaining participants were healthy control individuals. All were administered the Torrance Tests of Creative Thinking (TTCT) and a personality inventory. Blood samples were also taken. Those who scored high on the TTCT showed the presence of allele 7 of the dopamine receptor DRD4 gene. Those with the polymorphic variation of the serotonin-transporter/promotor region gene scored high on emotional overexcitability. Finally, there was also an association between sensual overexcitability and the polymorphic variation of the DRD4 gene.

Lower levels of dopamine reduce arousal and are associated with greater creative ability. We discuss the role dopamine and norepinephrine play in regulating creativity later. Serotonin mediates bipolar disorder and there is a relation between this mood disorder and creativity, also discussed later. So it is likely that these two genes regulate the amount of these two neurotransmitters in the brain. These amounts in turn affect attention and emotional processing which impact upon creativity. The authors note that these findings do not mean these genes cause creativity. Any single gene will only contribute a small amount to a complex trait. There are almost certainly other genes involved as well as environmental factors that contribute.

The Brain and Creativity

Early research on the brain and creativity shows that highly creative people are physiologically over-reactive to stimulation compared to less creative individuals. They habituate more slowly to stimuli and rate electric shock as being more painful (Martindale, 1978; Martindale, Anderson, Moore, & West, 1996; Martindale, Hines, Mitchell, & Covello, 1984). These researchers also found greater right-hemisphere activity as measured by EEG in the parietal and temporal areas but only in highly creative people while engaged in a creative problem-solving task (Martindale et al., 1984). Less creative individuals show lower alpha wave activity on many cognitive tasks, including creative ones. Alpha waves are slow waves (8-12 cycles per second) that are associated with internalized attention and a less aroused brain state. Highly creative individuals in contrast show alpha blocking only during noncreative tasks and alpha enhancement during creative tasks (Martindale & Hasenfus, 1978).

Divergent tasks are those associated with open-minded association. Carlsson, Wendt and Risberg (2000) measured regional cerebral blood flow (rCBF) in high and low creative individuals while they performed a divergent thinking task. The high creative people showed more prefrontal RCBF in both hemispheres, while the low creatives showed activation primarily in the left hemisphere. Bekhtereva et al. (2001) measured EEG and CBF in two groups of students. High creative performance was associated with higher CBF in the left and right frontal lobes, especially in Brodmann's areas 8-11 and 44-47. It was also associated with greater spatial synchronization in anterior cortical areas.

Martindale (1999) points out three aspects of brain activity correlated with creativity. These are low levels of cortical activation, more right- than left-hemisphere activation, and low levels of frontal lobe activity. People who are highly creative do not show all three of these features all of the time, but only when engaged in a creative act. He speculates that these conditions underlie what happens when our attention is defocused, when we are allowing our attention to wander, or to take in many things at once.

Creativity can be explained in terms of modules. A brain module is a center that is specialized in processing information of one type. It is proposed that we have modules for processing specific aspects of visual perception, like color and form. We may also have modules for specific aspects of language processing. A module is localized to a particular brain region. Modules are assumed to be functionally independent but there is some degree of interconnectivity between them. Creativity, according to Heilman occurs when one module activates another normally unrelated module. The classic case of synesthesia is seeing numbers as colors. This can be thought of as a combination of information from two sensory modalities. In this case the number and color modules, which normally don't operate together, seem to have become co-activated.

A neurotransmitter based explanation for this exists. Kischka et al. (1996) found that administration of L-dopa to study participants made them less likely to make associations between distantly related words. They hypothesized that the L-dopa reduced spreading activation in semantic neural networks. In these networks neurons or groups of neurons represent individual words. Words that are closely related like "car" and "truck" can activate one another more easily because the connections between them are shorter and the spread of activation doesn't die out. Words less semantically related, like "car" and "giraffe" are farther apart and activation can more easily die out before traveling from one to the other. The assumption here is that the strength of neural activation decreases with distance.

L-dopa becomes transformed into dopamine in the body. Dopamine, along with norepinephrine, belongs to a class of neurotransmitters called catecholamines. These transmitters, especially dopamine, are known to increase our attention to outer stimuli and decrease attention to internal mental activity. So in order to increase creativity, we would want to *decrease* levels of catecholamines. It is the norepinephrine system that turns on in response to stress, increasing levels of arousal and alertness, the so-called "fight or flight" response. Stress, not unsurprisingly, reduces performance on tests that require cognitive flexibility. Faigel (1991) administered propranolol to a group of teenagers prior to taking the SAT. This is a beta-blocker used to lower high blood pressure by reducing stress hormones. In this group there was an average increase of 130 points on the test scores, a significant amount.

Martindale and Hasenfus (1978) show that slow alpha waves facilitate creativity. In their study they compared creative to non-creative individuals. During a resting state there was no difference in their brain activity levels. But during a creative state the creative participants had more alpha brain wave activity than the non-creative group. This shows they had lower levels of arousal during moments of creative thinking. Elevated levels of norepinephrine decrease alpha wave activity.

The locus coeruleus, located in the brain stem controls the amount of circulating norepinephrine in the brain. This structure has widespread connections to the thalamus and the cortex. There are also projections to the inferior parietal lobes that regulate attention. High levels of activity in the locus coeruleus increase alertness and orientation toward external perceptual sources of novelty. It follows then that lower activation in this nucleus would favor inward direction of attention and the facilitation of creative problem solving. The dorsolateral frontal lobes control the locus coeruleus, and are capable of lowering its activity level.

Heilman (2005) investigated these ideas in an experiment. He tested three groups of people, a placebo group, a second that was administered ephedrine, which increases norepinephrine levels. The third group received propranolol, the beta-blocker that decreases norepinephrine. All of the participants were asked to solve anagrams as a test of creativity. As predicted, the beta-blocker group scored higher than controls.

The Brain and Creative Cognition

Vartanian and Goel (2007) present both their research and that of others investigating the different brain areas that underlie creative cognition tasks. Although most people use the term “creativity” in a general way, there are several different ways of reasoning creatively and these are associated with distinct brain regions. Also in light with what we have seen previously in this chapter, there is no one part of the brain that is creative. Instead, it involves the interaction of multiple regions on both hemispheres that carry out cognitive, emotional and social processes.

According to the hemispheric asymmetry hypothesis, the right brain is more creative than the left, but this oversimplification requires further explication (Martindale, 1999). Springer and Deutsch (1998) suggest that the left hemisphere is more “analytic” and the right is more “holistic” and that this is a better way to think about the asymmetry rather than to label the left as verbal and the right as visual. Analytic thinking involves breaking wholes down into parts and holistic involves assembling parts together into wholes, although this is also an oversimplification. Recent research shows that it is the task, not the stimuli, that determine the mode of processing (Stephan et al., 2003).

Another way to think of this hemispheric distinction is between veridical and adaptive decision-making (Goldberg & Podell, 1999). Veridical decision-making occurs in response to a problem with a definite structure and a predetermined correct answer. Examples of these include the Tower of Hanoi task and other logic puzzles. Adaptive decision-making occurs when there is no easy pattern that can be determined in the task. This is the type of open-ended decision-making that happens most often in real world problem solving situations.

Although the right hemisphere has been credited as the more creative of the two, the research suggests otherwise. It is likely that there is bilateral involvement of the two hemispheres in the creative process regardless of the medium, although in asymmetric but complementary ways. If we look at savant art skills in autistic individuals it is assumed that their right hemisphere controls their abilities based on the fact that their left hemisphere language capabilities are deficient. As mentioned previously, their art, although realistic and technically accurate, shows little actual creativity. There is no abstraction or innovation. This suggests that it is the left hemisphere that is in fact the more creative (Zaidel, 2016). It is this hemisphere that seems more capable of reshaping existing ideas and of producing more original and innovative work than the right.

Studies of people with frontal lobe lesions show that the left prefrontal cortex (PFC) is activated more in response to patterns in the environment while the right PFC is activated more to novel environmental situations where there is no pattern. Goel and Vartanian (2005) wanted to know if these two sides would be engaged differently for hypothesis generation, which is one cognitive component of creative thinking. They had participants solve Match Problems while measuring brain activation using fMRI. Successful solution of this problem requires hypothesis generation in what is called a set shift, or "lateral transformation". Mental representations that are vague or imprecise facilitate such set shifts. Lateral transformations were found to activate right ventral lateral PFC, left middle frontal gyrus, and the left frontal pole. In a second study they found these results could be extended to a verbal anagram task. The findings show that it is the open-ended nature of the task and not the stimuli (visual vs. verbal) that determine activation of right PFC.

Another research question is whether insight problems and divergent thinking (lateral thinking) tasks call upon the same neural sites. Several studies have shown that the right temporal lobe and specifically the right hippocampus are used while solving insight problems while the right PFC is used for lateral thinking tasks. Schneider et al. (1996) measured rCBF in response to solving anagrams and found hippocampal activation. Luo and Niki (2003) presented their participants with unsolvable Japanese riddles and then gave them the answer. For example: What is the thing that can move heavy logs, but cannot move a small nail? The answer: A river. These sorts of problems were supposed to induce the experience of an insight. Right hippocampal activation was observed. Jung-Beeman et al. (2004) had their participants solve a divergent thinking task. Here is a sample problem: What do the following three things have in common? (pine, crab, sauce). The answer: Apple. Those who reported solving these problems with an experience of insight showed right superior temporal gyrus activity.

We can derive several conclusions from these experiments. The first is that lateral transformations and insight solutions both rely on different parts of the brain. This suggests that they are separate cognitive components of creative thinking. The PFC is used for lateral thinking and the right temporal gyrus and hippocampus are used for insight problems. Second, the left PFC will most likely be used for problems that involve the extrapolation of patterns to solve. The right PFC will be used for problems that have no predetermined response but which allow for multiple possible strategies. Other work shows that the ventral portion of the right PFC is involved in set-shift hypotheses, while the dorsal portion mediates executive aspects of creative thinking (Goel & Grafman, 2000; Goel & Vartanian, 2005). Executive functions include such things as working memory, cognitive monitoring, and conflict resolution.

Bringing it All Together – Neuroscience Chapter Summary

One of the most important discoveries in neuroaesthetics is that there is no "one size fits all" neural response to an aesthetic event. Different patterns of brain activation are seen depending on the type of experience. A painting for instance will activate the visual parts of the brain while music will activate auditory areas. For aesthetic events that involve motivational stimuli like food and sex there is activation of the brain's dopamine reward center. However it is still possible to like and appreciate stimuli that are non-motivational because these reactions are based on neurotransmitter systems other than dopamine.

When looking at pretty faces we see widespread activation in multiple brain areas including the FFA, LOC, orbitofrontal cortex and the nucleus accumbens. This last structure is part of the reward system. When judging the attractiveness of bodies we see activation in the prefrontal cortex, amygdala and insula, among other regions.

There are different modules in the visual system that are specialized for different visual features like lines, color, and motion. Different types of art that are made up of one type of these features will preferentially stimulate the areas corresponding to it. For example art that is very colorful will stimulate area V4 because that region is devoted to color processing. Art that contains motion like film or dance will activate area MT that is specialized for motion processing.

Many artists exaggerate attractive features like large breasts or enhanced waist-to-hip ratios. They will also skip over details and group them together, a function our brains do normally when looking at a complex scene. A third heuristic artists use is to exaggerate one visual feature over another, preferentially activating one module rather than multiple modules. Artists will also design their works to guide the visual system to important aspects of an image. Examples of this include glance curves (lead-in lines) that guide the eye to a focal point in paintings or blurred areas (depth of field effects) that lead to focused areas in photographs. All of these heuristics capitalize upon the brain's natural processing, so we might say that a general aesthetic rule is to produce artwork that capitalizes upon the brain's normal way of processing a particular stimulus.

There are many eye disorders such as errors in accommodation, astigmatism, cataracts, and macular degeneration. Investigators have analyzed the work of artists with these disorders and have found they could have affected their creative process. Brain disorders too seem to affect the way in which various artists create. For example some autistic artists are capable of drawing with great detail and precision but lack the ability to abstract or think globally about composition. Oliver Sacks has pointed out a number of case studies of musical disorders. These include melodic intrusions, musical synesthesia, and language aphasias that impair speech but leave singing unaffected. Correlating patterns of damage to type of symptoms can provide clues to the operation of normal brain function.

Given an understanding of the visual system it is now possible to analyze paintings and then account for their psychological effects. For instance areas that are of equal luminance but differing color appear to shimmer. This is probably because the brain's "what" system can see the color differences while the "where" system cannot. The Mona Lisa's smile may be the result of two perceived smiles in that painting, one smaller and more detailed, another larger and less so. Different processing channels for high and low spatial frequencies represent these two smiles and so they both can't be processed effectively at the same time. This results in her odd-looking appearance.

Our prior knowledge affects our perception of art. Studies show different patterns of brain activity for familiar stimuli. Architects for instance demonstrate greater activation of the medial orbitofrontal cortex and anterior cingulate than non-experts when judging the aesthetic qualities of buildings.

Many different parts of the brain are activated while listening to music. These areas are stimulus and task specific. The right hemisphere processes melodic contour and tone discrimination. The left hemisphere underlies our ability to name a song, performer, or instrument. Distinguishing instruments is a right hemisphere ability while familiarity, rhythm, and pitch judgments are performed by the left hemisphere in non-musicians.

Certain aspects of music can be mapped onto emotional states. Slow tempos and minor keys are associated with sadness. Fast tempos and major keys are associated with energy and happiness. Increased tension, irritation and anger are linked to dissonance. Music that gives us chills produces activity in the amygdala, ventral striatum, midbrain, orbitofrontal cortex and ventromedial prefrontal cortex.

Simply reading about a particular body part like an arm or a leg is enough to activate the motor areas of the brain corresponding to those parts. It thus seems that a command to move one of these parts is produced during reading but then held in check. This shows how closely we relate to the described movements of a fictional character. We are literally walking in the shoes of the character, as the expression goes. This absorption into a novel is called immersion and is strong enough in some cases to produce sweating and an increase in heart rate.

People like dance moves that involve movements of the entire body such as jumps rather than movements of a single arm or leg. Both motor and visual parts of the brain become active when performing these evaluations. As was the case with reading, we seem to implicitly perform the same movements dancers do when we evaluate them. This may be rooted in observational learning.

Film involves many other component art forms including literary narrative, musical soundtrack, visual imagery, etc. Stylistic elements of films are not usually remembered while the characters, storyline, and locations are. Many films follow the tension-resolution model of aesthetics where characters encounter and must solve multiple problems en route to a goal. Films incorporate elements of mythology such as hero on a quest. They activate multiple brain structures related to the self as we identify with characters, especially emotional centers.

Creative individuals show a different pattern of brain activation. They are over-reactive to stimulation and show greater right hemisphere activity in parietal and temporal lobes. Highly creative people also show increased bilateral blood flow in prefrontal areas. This physiological pattern may correspond to a defocused attentional state as occurs when we let our mind wander. Neural creativity could also be the result of cross-talk between independently functioning modules that don't normally communicate with one another.

Catecholamine neurotransmitters like dopamine focus attention on external states rather than internal mind wandering and seem to decrease creative thinking. Slow alpha wave activity and decreased arousal is associated with creative individuals. The locus coeruleus in the brain stem regulates arousal through the catecholamine transmitter norepinephrine. High levels in this brain area increase arousal. Participants in one study who were given a drug that blocks norepinephrine were found to be more creative as measured by an anagram test.

Creative thinking does not involve just one part of the brain. There are multiple types of creative thinking that will activate different constellations of brain areas. The left hemisphere has been labeled as more analytic while the right is more holistic, but in most creative tasks both hemispheres are called upon.

Chapter 6 - Psychology and the Visual Arts

Psychology I – The Visual World

Let's look now at the discipline of psychology. There is a lot to say here, so we divide this material up into two chapters. Chapter six examines psychology and the visual arts. Chapter seven looks at psychology and the remaining non-visual arts. The psychological study of aesthetics is now an interdisciplinary program in its own right with journals and international conferences. Its development can be traced to the work of Gustav Fechner in the nineteenth-century, the continued work of the Gestalt psychologists, and the work of Berlyne and Arnheim, whose research we will discuss in greater detail. We begin this chapter discussing visual characteristics and art perception. A large body of research exists on color so we describe what color is and what preferences are for single and multiple colors for infants, children, adults, and those with psychological disorders. A discussion of color mixing and color harmony in paintings ensues. Another important visual characteristic is depth. Artists have for centuries employed the principles of linear perspective to induce a sense of depth in paintings, so we provide a brief introduction to linear perspective and how it affects the perception of paintings. There are many other monocular and binocular depth cues that affect how we see paintings and so we devote the next few sections to modern research on these topics. Even though paintings are static, artists have for some time known how to induce motion using certain cues like still-shots, leaning, motion blur, motion streaks and perceptual agency.

Continuing on we describe the perception of objects and scenes. Although we may think we take in everything that we see around us, this is actually not true. Artists who recorded the details of a scene in a meticulous manner were Canaletto and Vermeer. We will see that to accomplish what they did they probably "cheated" by using assistive devices like a camera obscura and mirrors. One way to examine how we perceive a painting is to track where we look. This is the focus of the section on eye-movements. Composition is the way artists arrange objects and scenes. We start this topic off by looking at the division of space using techniques like the rule of thirds and rabatment for dividing up the canvas. The center is all-powerful in composition as we show by describing Rudolf Arnheim's work in this area, followed by descriptions of lighting, reflections, exposure duration, and familiarity. Perceiving visual art is in many cases a powerful emotional experience as Berlyne shows. We complete the chapter with appraisals and research on positive and negative emotions.

The Psychological Study of Aesthetics

What is studied within the field of psychological aesthetics? Because the scope of beauty, art and creativity is so broad the short answer would be a lot. Some of the main areas of investigation include symmetry, complexity, familiarity, proportion and composition, semantic content, prototypicality, mere exposure, emotional state, social status, educational and cultural background, setting or situation such as a museum, individual differences and more (Jacobsen, 2009).

Notice that these factors can be aspects of the stimulus, of the person, or of the environment. The psychological study of aesthetics can also examine any type of reaction a person can have, whether that is perceptual, cognitive or emotional. Although psychology can be considered an independent discipline, it has connections to all of the other disciplines described in this book. The field takes on theoretical and methodological inspiration from other areas of inquiry such as philosophy, neuroscience and evolution.

The psychology of aesthetics is a new but rapidly expanding field. The number of publications in this area has risen dramatically in just the last five years. There are two journals devoted entirely to publications in aesthetics, these being *Empirical Studies of the Arts* and *Psychology of Aesthetics, Creativity and the Arts*. There is an active and growing international community of researchers in aesthetic science. The International Association of Empirical Aesthetics (IAEA) has members in over 20 countries. It is dedicated to the empirical study of aesthetic experience and behavior and is strongly interdisciplinary. Its members study a variety of domains including literature, film and theater. Investigators come from multiple perspectives, like sociology, musicology and art history. The organization also hosts a conference every other year in locations around the world.

As of now the psychology of aesthetics is not taught as a standard course in psychology departments. Some faculty may offer the course if that is their area of research or interest. There are no typical aesthetic programs within psychology departments or interdisciplinary aesthetic programs. The reason for this is that the topics of study and the approaches to it are so diverse. This may change in the near future though. We may be on the cusp of seeing aesthetics become an established academic discipline both at the teaching and research levels, as is the case with cognitive science, another cross-disciplinary program that has achieved this status.

Ecological Validity

One debate in scientific methodology and in the psychology of aesthetics is about ecological validity. This is the idea that researchers should use stimuli that are as realistic as possible. The results obtained with such stimuli then generalize best to real-world behavior. Applying this to aesthetic science we would want to use stimuli like paintings or photographs. These capture the complexity of the world and are most likely to predict well how people rate and react to them. On the other hand, the complexity of such stimuli makes it difficult to isolate component independent variables. What is it about a Monet painting that makes it so beautiful? Is it the color? The textures? The use of human figures? To understand and manipulate these variables means going to the opposite extreme and using stimuli like random polygons and random dot patterns. With these we can establish causality and begin to say something about what specifically drives aesthetic judgment. So there is a tradeoff between these two methodologies: one either maximizes generalizability but minimizes causal explanations or minimizes generalizability but maximizes control over variables and causal explanation. It is clear that neither type of study is superior to the other. They each simply have their own strengths and weaknesses. The best way to advance understanding of aesthetics is to allow both forms of research to forge ahead but to encourage communication and collaboration between researchers utilizing the two approaches.

Empirical Aesthetics – A Short History

The word empirical refers to experimental, or the practice of using science to answer questions about the world. Aesthetics refers to beauty but also more generally to an aesthetic experience, which can include the experience of sexual attraction, the sublime or of what is pleasing. We will present a short history of this movement here up to the present time. Interestingly, some of the very first experiments ever conducted in psychology were about beauty. In 1876 Gustav Fechner published his book titled *A Primer of Aesthetics*. Rather than deal with abstract philosophical notions of beauty Fechner analyzed the properties of simple shapes, studying rectangles of different proportions to see which was most appealing.

Other researchers continued in this tradition looking at objects, colors and sometimes paintings, presenting these to observers and recording preferences. The approach was bottom-up, looking at how basic sensory qualities like color and shape affect perception of the entire stimulus. In the early 20th century the Gestalt movement emerged, founded by the psychologists Max Wertheimer, Kurt Koffka and Wolfgang Kohler. The Gestalt approach is holistic, looking at the entire pattern. They argued against breaking a shape down into its component attributes and instead emphasized how the interaction of parts produces the whole. They were seminal in listing the "Laws" of perceptual grouping, how parts combine together to produce a complete percept. The saying "The whole is greater than the sum of its parts" came to characterize the Gestalt approach.

Rudolf Arnheim applied the Gestalt approach to visual aesthetics. His 1954 book *Art and Visual Perception* describes how artworks conform to different perceptual "forces" to predict aesthetic preference. For example the placement of objects, their balance, shape and symmetry can help to explain perceived beauty. Another researcher, Daniel Berlyne, developed a detailed theory of how objects produce feelings in an observer. He thought that optimally pleasing artworks are those that create moderate levels of tension and arousal. He studied how features of art like familiarity, complexity, and uncertainty create arousal. Berlyne thought past experience helps to determine how surprising or novel a painting is.

The cognitive approach began in the 1960s. This view stresses information processing. Cognitive psychologists attempt to provide descriptions of what goes on in the mind when we perceive, pay attention, remember or problem solve. They see the mind as a type of computer that represents objects in the form of symbols or images and then performs transformations on those representations. Currently, the cognitive approach has been combined with neuroscience to produce cognitive neuroscience, which blends information processing with neural anatomy and physiology as an approach to understanding the mind. We now also have neuroaesthetics, a brain-based approach to the study of beauty. Researchers in this field measure brain activity in response to stimuli using EEG, fMRI and PET technologies. They attempt to correlate activity in different parts of the brain with presentation of an aesthetic stimulus.

Yet another perspective on beauty comes from evolution. Evolutionary psychologists try to understand how selection forces led to certain features we consider beautiful. The focus here is on biological stimuli like faces and bodies. Properties such as symmetry, averageness and sexual dimorphism have all been found to affect preference for the human form. See the evolutionary chapter for information on this perspective.

Today the experimental study of aesthetics can be considered a blend of all these approaches. Paintings and objects are still studied in terms of their basic features and how those affect preference. There are also some researchers who continue to use a Gestalt perspective, emphasizing the whole over the parts. The field of neuroaesthetics is going strong with lots of neuroimaging studies being published. So are the cognitive and evolutionary approaches. When we describe an experiment on aesthetics in this chapter see if you can determine which of these influences is most prominent.

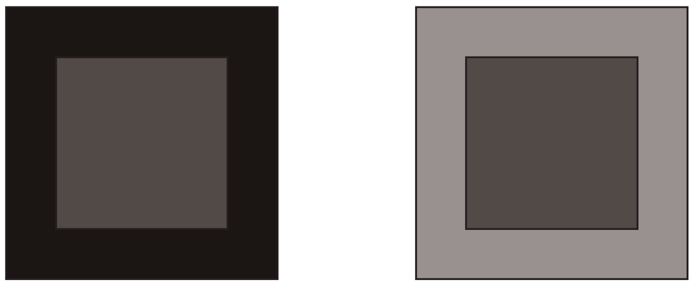
Visual Aspects and Art Perception

In this section we will examine aspects of visual perception and how those affect the aesthetic experience of art stimuli. We will describe low-level features like brightness, color, depth and motion as well as the perception of higher-level features like objects and scenes. In some cases, research in these areas has been going on for many decades, as is the case with color. In others, the research is more contemporary. We present also in this section the research on eye movements and art, since those reveal quite a bit about how we process paintings. Since there is a lot of work on composition, we group work in that area into the following section.

Perceived Brightness

Perceived brightness is in part due to the difference between a figure and its surrounding context. Figure 6.1 shows two squares with different surrounds. Which of the squares looks lighter? Most people will report that the square surrounded by the darker frame is lighter and that the square surrounded by the lighter frame is darker. In reality both are exactly the same shade of gray, they only appear to be different. This is an example of lightness contrast. How light something appears is due in large measure to what is next to it.

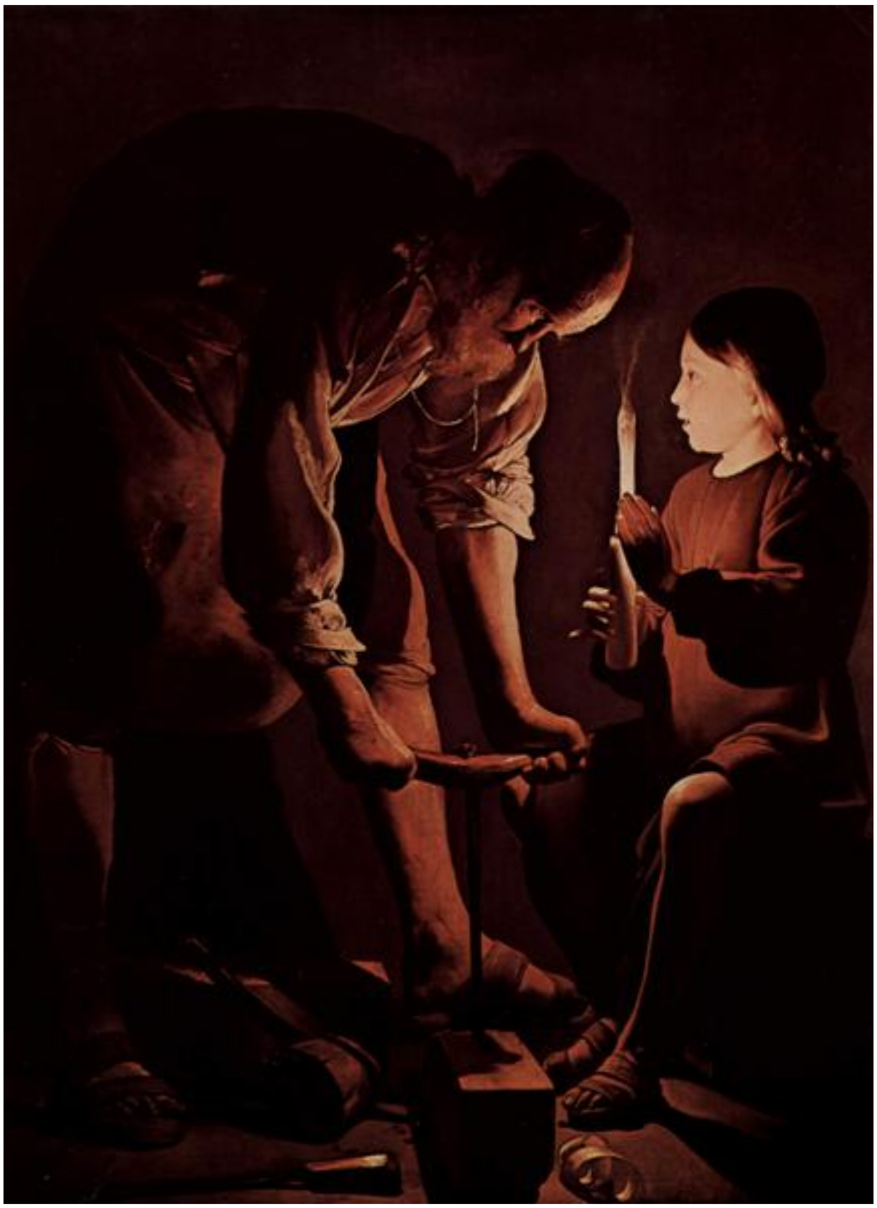
Figure 6.1. A demonstration of lightness contrast.



Artists have exploited this effect. Georges de La Tour's *Joseph the Carpenter* shows us Jesus as a child being instructed in carpentry by Joseph (see Figure 6.2).

The candle brilliantly illuminates the child's face. Because this is the only light source, the rest of the room is dark. The contrast between these bright regions and the rest of the room accentuates Jesus's face and draws our attention to it. This is another example of how the artist can use various effects to direct our gaze toward a desired location in a painting.

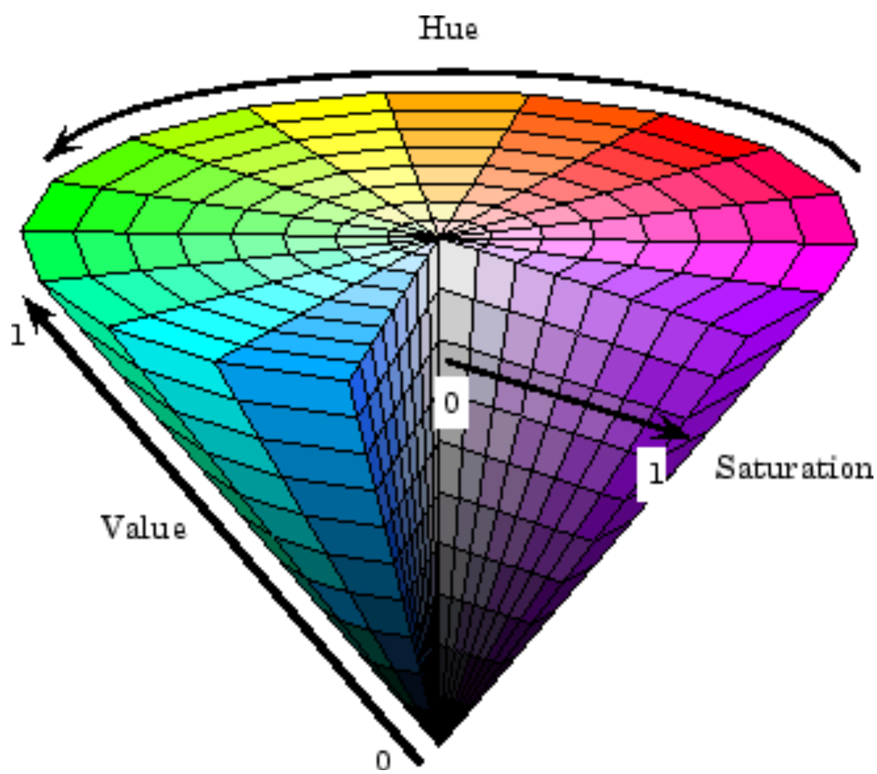
Figure 6.2. *Joseph the Carpenter* by Georges de La Tour, circa 1645. Lightness contrast draws our attention to the face of the child Jesus.



Color

Many of us might think that color is unidimensional, meaning that it consists of just changes in wavelength or what is called hue. But color consists of three dimensions that all contribute to our perception. Hue is that part of color that we most closely associate with the rainbow, changes that go from red to orange, then through yellow, green, blue and violet. The second major component of color is lightness. This refers to changes in how light or dark a color is. Lightness corresponds to value in the art world and is very important because it specifies the basic structure of objects. The third major dimension of color is saturation. This refers to how intense a color is. Intense colors contain very little white in them. Those that are less saturated appear whiter. Figure 6.3 show how a color spectrum can differ along these three dimensions. It should be mentioned that another important aspect of color is temperature. Colors can warm, as are red, orange and yellow. They can also be cold as in green, blue and violet. Earth tones in art are also sometimes considered a separate color group, as are the gray-tones. Shades of gray are determined by lightness differences in the absence of hue or saturation.

Figure 6.3. Color consists of three dimensions, these being hue, lightness, and saturation, which can all be varied independently.



In artistic technique there are several other color definitions we need to keep in mind. A tint is a color plus white. A tone is a color plus gray and a shade is a color plus black. Neutral gray is a balanced combination of white and black. Primary colors are red, yellow and blue. They are primary because they cannot be created by mixing any of the other colors. Secondary colors are orange, green, and violet. Mixing two primary colors makes these. There are six tertiary colors, each made by mixing one primary color with an adjacent secondary color. These would be red-orange, yellow-orange, yellow-green, blue-green, blue-violet and red-violet. Warm colors are considered to advance or come forward in depth. Cool colors are considered to recede. The color combinations of the sort we are discussing here are subtractive because they involve paint, as opposed to additive mixing of lights that produce different outcomes.

Single Color Preferences

Studies with Infants and Children

One question we can ask about color preference is whether we are born liking certain colors or learn to like them. Studies with infants can shed light on this issue. Infants early on can distinguish colors from each other. They can for instance, tell the difference between a blue and a green (Bornstein, Kessen, & Weiskopf, 1976). However they don't show the same preferences as adults. Newborns don't spend more time looking at any one color than another but they do prefer to look at colored patches rather than patches that are achromatic, i.e., those that have no color at all and are gray. Infants that are three months old spend more time looking at blue and red than other colors. They do not prefer green to orange and yellow. This evidence suggests that these preferences are probably more learned than innate.

Another question we can ask about color is what colors infants and children prefer and whether children can discriminate along the basic color dimensions. A number of studies have looked at this. Adams (1987) recorded color preference in 20 infants exposed to blue, green, yellow, red and gray squares at a constant luminance. Twenty adults also rated the same stimuli. Newborns showed a preference for colors of lower brightness. Both groups preferred colored to non-colored patches. Three-month olds preferred warmer colors (red and yellow) to cooler colors (blue and green). Adults demonstrated the opposite effect.

Zhang, Lin, and Mao (1984) tested 120 children in three age groups, 1.5, 2, 2.5 and 3 years of age and found the ability to match and name colors increased with age. The sequence of color preference was red, yellow, green, orange, blue, white, black, and purple. The age difference in naming color is believed to be dependent on the children's capacity to abstract and generalize colors. Franklin, Gibbons, Chittenden, Alvarez and Taylor, (2012) replicate the finding that human infants respond favorably to red in hospitable contexts, but unfavorably in hostile contexts. Following presentation of a happy face, 1-year old infants looked first at red and blue more than green. Following an angry face preference for red and blue was reduced. They argue that an angry face disrupts the infant's encoding of color.

Staples and Conley (1949) observed 3- and 4-year olds finger painting and found they tended to use all colors freely with little preference for specific hues. They tended to cover most of the paper with fairly dark paint, thick in texture and to use their entire hand for manipulation. The children differed in the lightness and darkness of their paintings, in how much color they used and in their unique designs. Corcoran (1954) showed that 3-year old children will pick colors for painting based on the order in which they are presented in the easel trough and not necessarily based on preference. In another study 976 Jewish children in Israel were interviewed as to their most beloved color. Red was the preferred color, followed by blue and yellow.

O'Hare and Cook (1983) had children of different age groups complete a partially drawn scene. They were instructed to complete the scene in colors that varied in gradation, harmonic, and pure ways (lightness and saturation differences). Those 5-6.5 years in age displayed little capacity to produce consistent differences in their pictures. The 7.5-8.5 year age group could perceive the differences but showed a limited capacity to produce them. The 10.5-11.5 year age group was able to both perceive and use all of these colors consistently. This study highlights the difference between perception and production. Children may be able to discern the difference between a dark and a light blue, for instance, but this does not mean that they will use them in an art production context.

Studies with Adults

There have been many studies looking at which colors adults like. A number of early studies did not account for secondary color factors like saturation, which is how intense or vivid a color is. They also did not account for brightness. When these are controlled we find that people like saturated over unsaturated colors. They also prefer bright colors to dark colors. Blue is liked more than any other color (44%). Red and green are both preferred equally and are in second place (11%-12%). Purple is the third favorite color, while yellow and orange are preferred least (Ball, 1965).

Gotz (1974) examined color preference among art students. He found they judged red and blue as pleasant while gray and pink were unpleasant. Black and white were counted as neutral while yellow and orange were also among the most preferred. There were very few differences between the sexes except for the color green. In a follow up study a year later Gotz used a greater number of colors, including different reds, blues and yellows. The greatest affective difference in preferences was for the reds and yellows. The art students agreed the most on the oranges, pinks and grays. The most preferred colors were reds, blues and yellows. The least preferred was a greenish-yellow, a penetrating red-violet and all five of the pinks presented. Sex differences for eight colors were also found. These studies show that despite individual variability there is some consistency in preference for colors across the sexes. Also art students are trained to use color, so their preferences may not correspond to those of the general population. Ge, Liu and Xu (2005) using a paired-comparison method measured the order in which a group of people aged 4 to 21 developed color preferences. The sequence was blue, orange, red, green, purple and green. This sequence held despite differences between the sexes and age groups.

Color preference is one factor related to the products we buy and has been studied as such by consumer researchers. Huang, Lin, and Chiang (2008) explored color preferences in a group of Taiwanese college students containing 189 women and 63 men using brand logos. The most preferred colors were white, light blue and black. The three least preferred colors were light orange, dark violet and dark brown. In a second experiment they showed that color affected recall for the logos. Accuracy was highest for the logos with the most preferred colors. Kareklas, Brunel, and Coulter (2014) studied people's automatic (unconscious) preference for white and black using the Implicit Association Test. They found automatic preference for white over black for colors, products, races, and advertisements. The results were true for both Caucasian-Americans and African-Americans.

Nelson, Pelech, and Foster (1984) tested the hypothesis that seekers of high stimulation would prefer the color red and seekers of low stimulation would prefer the color blue. They had 170 adolescents complete the Sensation-Seeking Scale and then indicate their preference for the two colors. The findings did support the hypothesis. Red apparently is associated with greater arousal while blue is associated with calmness and states of lower arousal. The data support an earlier study finding that college students classified as introverts on the Eysenck Personality Inventory preferred cooler, calmer colors to those more warm and intense, with opposite findings for extroverts (Robinson, 1975). Walters, Apter, and Svebak (1982) in two experiments found that long-wavelength colors, those on the red side of the visible light spectrum, were found to induce feelings of high arousal. Short-wavelength colors in contrast were found to induce feelings of low arousal.

Why do people like the colors they do? Palmer and Schloss (2010) developed an ecological valence theory where color preferences arise from affective (emotional) associations with particular objects. People like colors strongly associated with objects that they like, for example, blues with clear skies or clean water. Correspondingly, they dislike colors associated with objects they dislike such as browns with feces and rotten food. Schloss, Poggesi & Palmer (2011) also discovered patriotic and cultural associations with participants liking the color of their country's flag or their college motto more. They provide empirical data that supports the model and claim that it fits the data better than alternative theories. Taylor and Franklin (2012) replicated and extended these findings. They obtained an inverse relationship between the number of objects associated with a color and preference for the color. In general, participants liked colors associated with few objects and disliked colors associated with many objects.

We also associate colors with particular emotions. Zentner (2001) showed three-year-olds and adults pictures of a happy, sad, and angry face and then asked them to associate each with a color from a set of nine colors. Sixty percent of the participants linked yellow with happy, 67% linked black with sad and 73% linked red with angry. These associations seem to be learned over time, as the children were more variable in their choices. In general the children associated dark colors with sadness and bright colors with happiness.

Studies of Psychological Disorders

Another question we can ask regarding color is whether they are perceived differently in psychotics. Van Gogh was diagnosed with schizophrenia and his disorder may have influenced his use of color. Many of Van Gogh's paintings show use of intense saturated colors. It has been suggested also that his paintings were affected by visual hallucinations as seems evident in the swirling heavens of his painting *Starry Night*. Robertson (1952) tested 689 psychotic patients in art groups and found they used or like colors of the blue-red series more than others. Hartwich (1971) compared the paintings of 10 25-55 year old schizophrenic inpatients to those of a control group of normal, non-disordered adults. The participants were given 10 colors, including black and white and instructed to paint in whatever way they wished. The results showed that schizophrenics used more white, yellow, and violet than red, black, grey and brown. They additionally used higher contrast values and brighter colors than those of the normal group. It is not known whether an analysis of Van Gogh's paintings would have revealed greater preference for these colors and use of contrast and brightness.

However, two more recent studies fail to find a difference in color preference between normal and disordered populations. Cernovsky and Fernando (1988) compared color preferences of 20 schizophrenic inpatients with those of 24 normal controls using the Luescher Color Test (LCT). They found no significant differences. Another study examined color preferences for manics, schizophrenics and normal controls, again using the LCT. There were no significant differences for any of the 8 colors used (Fernando, Cernovsky, & Harricharan, 1992). Holmes, Fouty, Wurtz, and Burdick (1985) tested a large sample of psychiatric outpatients stratified by gender and age using the LCT. They obtained a sex difference but only minor variations in age. They conclude that there are both consistencies and discrepancies of their study with past data. So given the available research it is difficult to conclude that disordered populations have different color preferences than normal populations.

Multiple Color Preferences

Artists for many years have used the color wheel as a way of organizing which colors go together and which are considered harmonious. The wheel is shown in Figure 6.4. There are several different color schemes for color harmony and these are outlined in Table 6.1. Monochromatic color schemes are those using any tint, tone or shade of just one color. For example an artist might decide to create a painting using only blue in different values to induce a sense of calm. Analogous colors are those that are adjacent to one another on the color wheel. Analogous schemes use at least two but no more than five consecutive colors on the wheel. For instance, one could pick for a painting the following five colors: yellow-green, green, blue-green, blue, and blue-violet. Since these are colors are cool in nature they might go well together as the colors of an ocean. Next are complementary colors. These use any two colors directly opposite each other on the wheel. For primary colors the complements are red-green, orange-blue, and yellow-violet. But we can also have complements for non-primaries like red-orange and blue-green or yellow-green and red-violet by reading in a straight line from these colors to their opponents on the opposite side of the circle.

Figure 6.4. The color wheel. Color preferences can be best understood as relationships between colors in the wheel. Image sourced from lifehacker.com

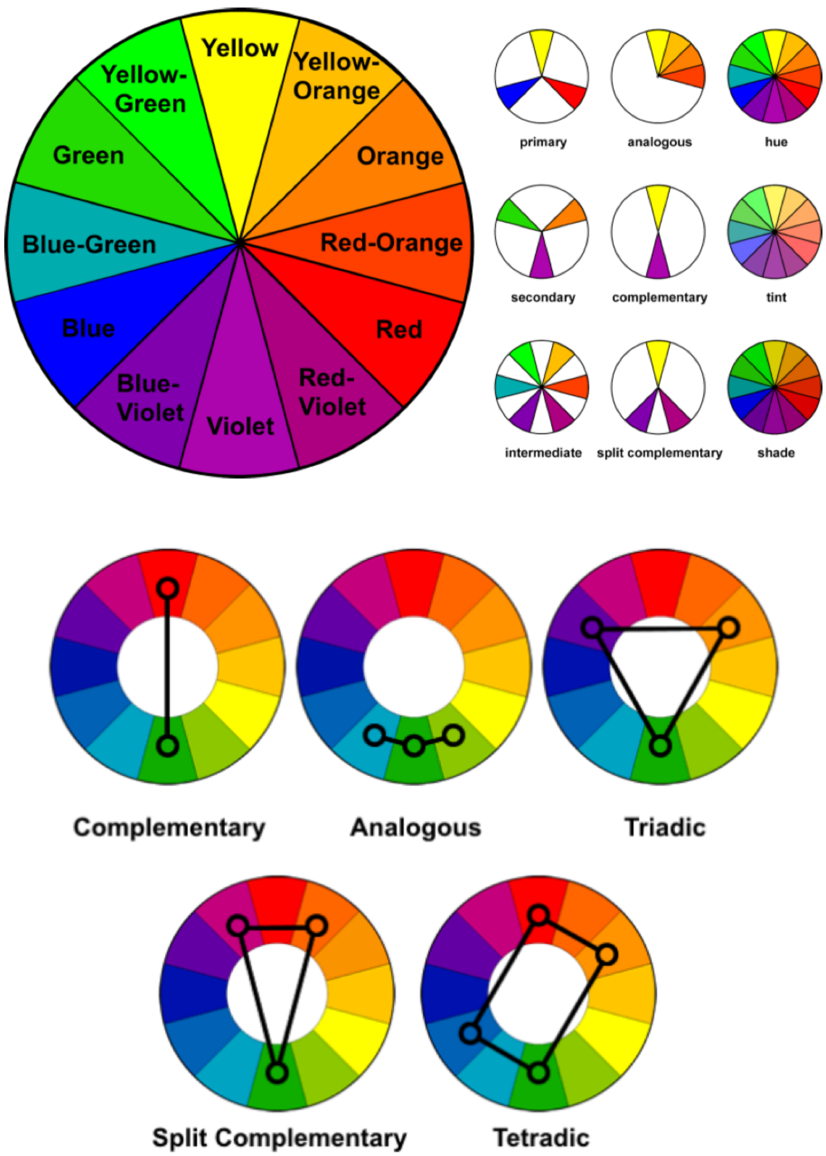


Table 6.1. Harmonious Color Schemes Table

Monochromatic - Any tint, tone, or shade of just one color. Example: dark and light blue.

Analogous - Any colors adjacent to each other on the color wheel. Example: Red and red-orange.

Complementary - Any two colors directly opposite each other on the wheel:

Red and Green
Orange and Blue
Yellow and Violet
Red-Orange and Blue-Green
Yellow-Orange and Blue-Violet
Yellow-Green and Red-Violet

Split Complementaries: Any color with the two colors on each side of its complement. Examples:

Red and Yellow-Green and Blue-Green
Red-Orange and Green and Blue
Orange and Blue-Green and Blue-Violet
Yellow-Orange and Blue and Violet
Yellow and Blue-Violet and Red-Violet
Yellow-Green and Violet and Red
Green and Red-Violet and Red-Orange
Blue-Green and Red and Orange
Blue and Red-Orange and Yellow-Orange
Blue-Violet and Orange and Yellow
Violet and Yellow-Orange and Yellow-Green
Red-Violet and Yellow and Green

Triads: Any three colors equally spaced from each along the wheel.

Red and Yellow and Blue
Red-Orange and Yellow-Green and Blue-Violet
Orange and Green and Violet
Yellow-Orange and Blue-Green and Red-Violet

Tetrads – Any four colors on the wheel that are two sets of complements.

Red and Yellow and Green and Violet
Red-Orange and Yellow-Green and Blue-Green and Red-Violet
Orange and Green and Blue and Red
Yellow-Orange and Blue-Green and Blue-Violet and Red-Orange

Yellow and Blue and Violet and Orange
Yellow-Green and Blue-Violet and Red-Violet and Yellow-Orange

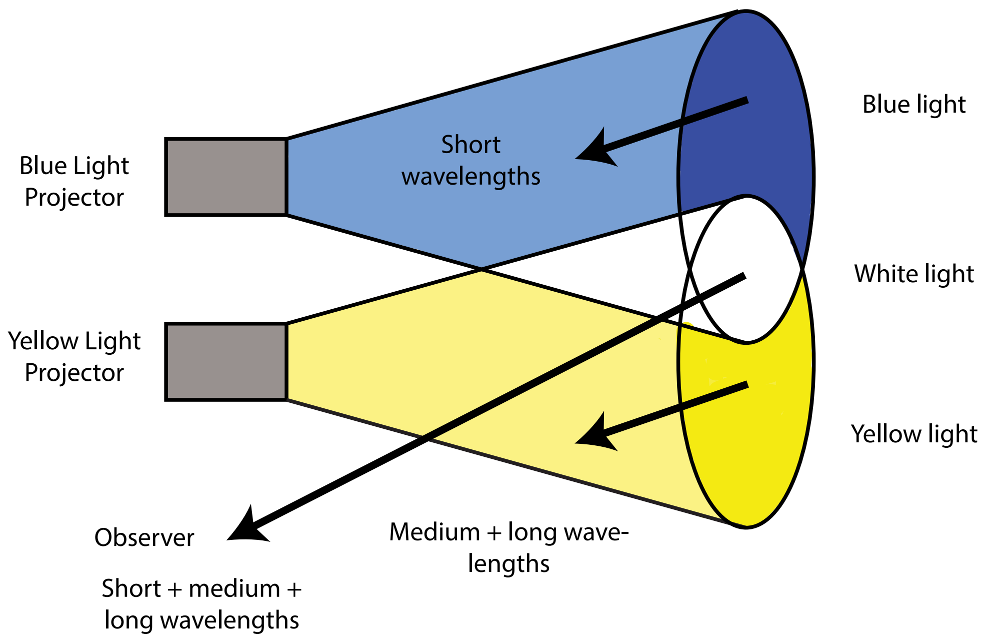
Split complementaries are those using any color with the two colors on each side of its complement. So for green the split complement is red-orange and red-violet. One simply goes to the color directly across on the wheel and then takes the two colors on either side of that color. A triad uses three colors equally spaced from each other on the wheel. An example would be orange, violet and green. To determine triads impose an equilateral triangle on the color circle and the colors will be at the three points of this triangle. Tetrads are a combination of four colors on the wheel that are two sets of complements, for example blue and orange with red and green. One can obtain tetrads by drawing a rectangle and superimposing it on top of the wheel. The four colors would then correspond to the four corners of the rectangle. Finally in art there is the notion of a key color, which is the predominant color in the scheme of a painting or other creative project.

Color Mixing

The colors that we can see run between 400 nm and 700 nm, which is the range of the visible light spectrum. Light that has a lower wavelength, between 400 nm and 500 nm, is perceived by the eye as blue. Medium wavelengths between 500 nm and 600 nm are perceived as mostly green. Longer wavelength light, that between 600 nm and 700 nm is perceive mostly as red. There are shorter wavelengths outside of this range corresponding to the ultraviolet and longer wavelengths corresponding to the infrared, but we can't see them. The colors that we do perceive in the world are the result of wavelengths that are being absorbed or reflected by a surface. A tomato is perceived as red because it reflects light mostly from the upper end of the spectrum and absorbs the rest.

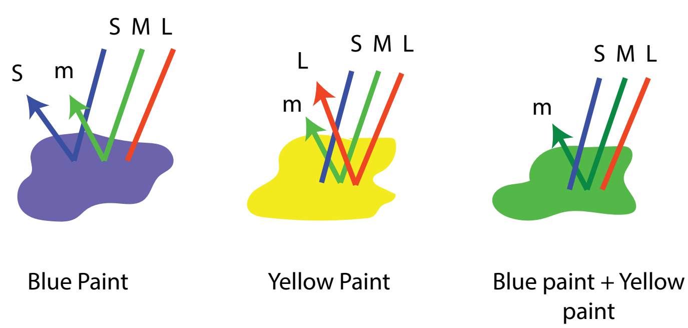
There are two types of color mixing. In additive color mixing nothing is absorbed and what we see is a direct consequence of all the wavelengths bouncing back from an object. For example, if we shined a blue and yellow light onto a white surface the area where they overlapped would be perceived as white. That is because blue reflects low wavelengths and yellow reflects medium and long wavelengths. The area where they overlap is thus reflecting low, medium and long wavelengths, which together combine to create white, since white is the combination of all wavelengths across the spectrum. Figure 6.5 show what colors would result if we additively combined different colors in equal parts.

Figure 6.5. Additive color mixing of blue and yellow lights.



In subtractive color mixing the surface absorbs some wavelengths and bounces back others. Blue paint absorbs long wavelengths but reflects short and medium ones. Yellow paint absorbs short wavelengths and reflects medium and long wavelengths. If we were to mix the two together only the wavelengths that are reflected by both in common are perceived, in this case that would be medium wavelengths so what is perceived is green. Figure 6.6 shows what colors result from the combination of blue and yellow paint.

Figure 6.6. Subtractive color mixing of blue and yellow paints.



Most oil painters combine paints to create other colors using the subtractive method. For example, if they wanted to create blue, they would combine magenta and cyan. If they wanted to create red, they would combine magenta and yellow. The nice thing about subtractive color mixing is that you don't need to carry every single color around with you. All that is needed are the basic colors and those can then be combined to create any other color needed. So an artist who used mostly subtractive color mixing could combine yellow and cyan oil pigments in varying amounts to make a shade of green that he could then apply to the canvas to form a leaf.

The pointillist artists like Georges Seurat took a different approach. They did not mix colors. Instead they placed small dots of colored paint next to each other on the canvas. When two dots of different colors reach the eye, they are combined additively. This process is called optical blending or optical mixing. So Seurat, if he wanted to create a magenta (reddish-purple) colored shadow would not need to use magenta. He could instead place red and blue dots next to each other. When seen from a distance the viewer's eye would optically blend these together using the additive rules and the result would be seen as magenta. Figure 6.7 shows a painting by Seurat that illustrates this. Take a close look to see the individual dots then view the image from farther back to see how they combine.

Figure 6.7. A painting of the Eiffel Tower by the French pointillist artist Georges Seurat. Image is copyright free in the public domain. Sourced from Wikimediacommons.org.

Color Harmony

Color harmony refers to those colors that when seen together are "harmonious" or aesthetically pleasing (Westland, Laycock, Cheung, Henry, and Mahyar, 2007). Determining color harmony experimentally is a complex endeavor. That is because human responses to color are and cognitive. They involve both an emotional response and a judgment and are open to a wide number of influential factors. These include individual differences like age, gender and personality, as well as cultural and social influences such as the way colors have been seen together in the past. There are in addition contextual effects like simultaneous contrast that affect judgments to color pairs. Contrast refers to the influences of contextual colors. A patch of red will appear differently depending on whether it is surrounded by gray or green, for example. These factors complicated research on the topic and explain why results from experiments are sometimes inconsistent and why there is no unified theory of color harmony. But in any case we will in this section sketch out a brief history of thinking on the topic.

The color theorist Wilhelm Ostald (1853-1932) developed some criteria for which colors go well together. He believed that colors harmonize if they have equal white content, equal black content or equal hue. So in this view, two hues that are equivalent tints or shades will harmonize. The American art instructor and painter Albert Munsell (1858-1918) developed some principles of color harmony. He believed that one could calculate the strength of a color based on its area, lightness and saturation. Colors that are larger in area, darker and more saturated would presumably be stronger. In his system a small area of high color strength would balance a large area of low color strength. Munsell's ideas have received some empirical support (Rapoport and Rapoport, 1984). Other harmonious combinations were colors of the same hue and chroma (saturation) and complementary colors of the same value and chroma. Other recent color theorists include Johannes Itten (1888-1967), and the artists Robert Henri (1865-1929) and Wassily Kandinsky (1866-1944).

Holtzschue (2006) proposes that colors at equal steps around the color wheel are harmonious, that intermediate values are harmonious (hues of extreme light or dark are not pleasing) and that equal values in different hues are harmonious. Koenig (2003) believes in three types of color harmony based on simplicity, contrast and balance. Simple harmonies are based on a small number of neutrals or hues. Contrasting harmonies are either complementary hues or temperature contrasts, this latter a contrast between warm or cool colors. A balanced color harmony is a palatte with hues that are well spaced along the color wheel.

Moon and Spencer (1944) formulated one of the earliest scientific models of color harmony. Their quantitative model is based upon color difference, area and aesthetic measure. Although subsequent analysis shows that the model does not perform well, it was well received. Since then experimental psychologists have attempted to make color harmony more empirical and less theoretical by presenting pairs or other groups of colors to observers and having them rate the colors on criteria like harmony, beauty and pleasantness. There is then an attempt in some cases to match this data to existing quantitative or qualitative models of color harmony.

Polzella and Montgomery (1993) used Munsell measures of hue, chroma, and value to scale responses to color pairs. The data were obtained from undergraduate ratings. Harmonious color combinations were for colors that were similar on these attributes and on the psychological attribute of "pleasantness". Katz (1999) created a mathematical model of color preference based on color contrast in which the perceived color of an area is affected by surrounding colors. The model accounts for a number of color phenomena, including the finding that preference should increase with increasing saturation. It also predicts that complementary colors should be preferred more than non-complementary pairs, as is the case.

Ou and Luo (2006) created another quantitative model based on experimental results with the following rules:

1. Two colors that differ only in lightness will appear harmonious.
2. Small lightness differences between two colors may reduce the harmony of the pair.
3. The higher the lightness of each component in a binary pair, the more likely it is that they will appear harmonious.
4. Blue is the most likely hue to create harmony in a two-color combination, with red least likely to.

Schloss and Palmer (2011) argue that three different types of ratings have been used in the literature and that understanding the differences between them helps to explain some of the contradictory findings. They propose three distinct ways of evaluating color combinations. The first is aesthetic preference. This is how much the observer likes the color combination as a whole or gestalt. The second is perception of color harmony. That is how well the two colors go with one another. The third is preference for the figural color against its background. Empirical support for the distinction are that pair preference and harmony both increase as hue similarity increases but that preference is more affected by lightness contrast. Figural color ratings also increase as hue contrast with the background increases. These results help to clarify some of the inconsistent findings in the literature.

A few comments are in order to summarize thinking on color harmony. History has shown that there are several types of research on the topic. Early thinking was mostly theoretical, based on the physical aspects of color and artistic observation and not motivated by empirical data. Within the scientific realm there are quantitative models that attempt to predict ratings based on experimental data. Those doing the experiments seem to fall into two camps: operational studies based on features like area, hue and power spectrum, and speculative studies based on things like harmony, mood, and fashion trends. The former are more psychological and scientific in nature. The latter are more applied and in some cases, about product design. There is currently a gulf between most of these researchers and the artistic community, which is unfortunate because the two areas can mutually inform one another. We discuss some of the literature on color and art in the next section.

Color in Paintings

Guillot (1978) acknowledges that preferences for which colors go well together (color harmony) are subject to individual differences and to educational and artistic trends. However in the majority of people there are a set of rules that govern harmony. Some of these reflect the color combinations that are found in nature. For example, the combination of Prussian blue with brown or yellow ochre corresponds to the colors of the sky and earth. Artists frequently however deviate from these preferred combinations to produce specific artistic effects. He lists El Greco's use of bright colors in this regard to express spirituality.

Traditionally, warm colors are believed to advance so a red surface is perceived as perceptually closer to the viewer of a painting. Cool colors recede, so a blue area in a painting ought to be perceived as being farther away in depth. The reasoning behind this is that colors get both more bluish and lighter in the real world due to atmospheric haze. The greater the distance, the more atmospheric particles there are between the observer and the object. Many paintings depict far distances near the horizon as faded, lighter and blue to achieve this effect. Pratt (1979) discusses the use of color and depth cues in painting. He suggests that areas of identical pigmentation on different parts of a picture surface are interpreted as being on the same depth plane. When this interpretation clashes with other depth cues the result is a "visual tension". The strength of this tension depends on the relative strength of the cues involved. By illustration if two areas are both painted a pale blue, they will be interpreted as far away. However if one of those areas is grouped with a region that is closer, the visual system will be in a state of tension because it won't know which depth plane to assign this blue. It will perhaps even be seen as fluctuating in depth.

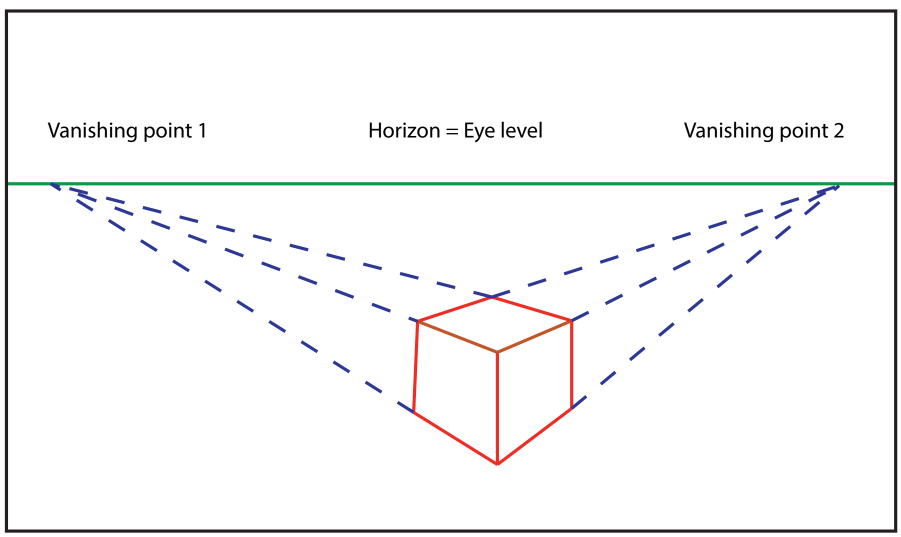
Polzella, Hammar and Hinkle (2005) had 60 college students rate 20 paintings on various semantic scales. The paintings were portraits and landscapes and represented two styles, both traditional and modern. Half of the viewers saw the paintings in black and white. The other half saw them in color. The removal of color from the portraits increased their perceived beauty and pleasantness. It also reduced tension. Removing color from the landscapes on the other hand reduced their perceived beauty. They argue that color is critical for landscapes as it provides depth cues. For portraits is may be distracting or superfluous.

One of the ways painting is traditionally taught to students is that object boundaries are drawn first before consideration of color. For example, an artist sketching a landscape scene might sketch in the boundaries of the mountains in the distance and then that of a lake and the trees. Then he or she would add blue to the sky and lake and green to the trees, etc. Pinna (2011) sought to test this order. They argue that there is an object "microgenesis" both perceptually in the way we perceive a visual scene and in the way we paint it. The order of processing in both of these is the same, namely that shape properties are determined prior to color properties. They support this conclusion based on data from the use of color contours in a watercolor illusion, by studying descriptions and replications of visual objects in children and adults, and in a free naming task on the attributes related to shape and color.

Depth, Linear Perspective and the Arts

Recall that linear perspective is a method of producing compelling depth in a two-dimensional painting. In this method lines in the scene such as those on the sides of a building are made to converge to vanishing points on the horizon. Figure 6.8 show some aspects of linear perspective with two vanishing points. Linear perspective is an example of a depth cue. We know that straight parallel lines converge, so we can use this information to tell us how far away objects in a painting are. An object next to lines that are more convergent will be judged as farther away than an object next to lines that are more parallel.

Figure 6.8. A drawing of linear perspective with two vanishing points.



Artists in the Renaissance made widespread use of linear perspective but it is certainly not used or adhered to rigorously by many artists either of that era or currently. If we look at some of the major movements in art history we see more and less adherence to the rules of perspective. It was used very little in prehistoric art and hardly at all in flat Egyptian hieroglyphs. The ancient Greeks didn't use it very much either but it was more widely adopted in Roman art. The Renaissance period as noted used it the most. Impressionists used it quite a bit as well. Modern art with its abstract expressionist paintings stopped using it again. Table 6.2 shows these different periods and the specific types of depth cues they employed.

Table 6.2. The different types of depth cues employed at different periods in art history. After Solso (1999).

Period	Relative Size	Occlusion	Shadow	Elevation	Texture Gradients	Atmospheric Perspective	Linear Perspective
Prehistoric	Yes	Yes	Limited	Yes	Not Generally	No	No
Egyptian	No	Yes	Not Generally	Yes	No	No	No
Greek	Limited	Yes	No	Limited	No	Limited	Limited
Roman	Yes	Yes	Yes	Yes	Limited	No	Limited
Renaissance	Yes	Yes	Yes	Yes	Yes	Limited	Yes
Impressionist	Yes	Yes	Yes	Yes	Yes	Yes	Limited
Modern	Sometimes	Yes	Sometimes	Limited	Not Generally	Not Generally	Not Generally

An interesting use of linear perspective is in works called *Trompe-l'oeil*, which in French means to "fool the eye". One such example is by the Italian artist Donato Bramante who at the start of the sixteenth century designed the church of San Satiro in Milan. A street blocked the extension of the church, so to make the interior space look larger he painted a false linear perspective view of how the extension might have looked. This false space shows a vaulted ceiling supported by pillars that converge toward an imaginary vanishing point. The illusion is especially compelling when one first enters the church but less illusory when viewed from certain angles.

Van Eyck's *Ghent Altarpiece* is a good example of a painting that violates the rules of linear perspective. Human figures are seen head on regardless of their location in the scene. Many objects are also presented close to the observer and against the picture plane instead of at their proper depth. Verstegen (2010) reports two other errors in perspective that artists make. The first is a tendency to normalize a foreshortened form toward frontality. The second is a tendency to flatten a three-dimensional object to reveal its hidden sides. He lists many examples of these errors as applied to human figures, architecture and the relation of figures to space.

People who observe these paintings however often fail to notice such violations (Cavanagh, 2005; Hockney, 2001; Kemp, 1990; Mamassian, 2008). The reason as stated by Mather (2014) is that we retain very little detail of a scene in each glance. We are thus unable to effectively compare one region of a painting to another to check if parallel lines are converging or whether objects are at their proper relative size based on their distances.

Kadar and Effken (2015) report that many Japanese artists may have made mistakes in linear perspective. This could have been due to the earlier influence of the parallel projection method that is part of the Chinese artistic tradition. However, some of these so-called mistakes may have been deliberate on the part of the artist. For example, it appears that Hokusai, the well-recognized Japanese woodblock print artist, used linear perspective for his own reasons, such as to create a more effective composition or to introduce a dynamic effect. It thus becomes difficult to say when an artist has either made a mistake or is knowingly violating the rules of linear perspective for his or her own ends.

Topper and Simpson (1981) tested whether observers could use perspective cues in four pictures from European art. Some of the pictures were rendered in linear perspective while others were rendered using reverse perspective. In this type of perspective objects farther away from the viewing plane are drawn as larger and closer objects are drawn as smaller. In this technique parallel lines instead of converging to the horizon, diverge from it. Vanishing points are placed outside the painting. This form of perspective was used during the Byzantine period, in some Russian Orthodox icons, and sometimes in cubism and modern art. Eight participants in this study were asked to place a lamp at the same apparent depth as various objects in the pictures. They were able to do this successfully regardless of the technique. The results show that individuals can use linear and inverse perspective to judge depth in artistic paintings, whether the rules of linear perspective hold or not. Dobias and Papathomas (2014) in a more recent study also found no difference in perceived depth for a reverse-perspective stimulus.

In addition to inverse perspective, there are other types. These include curvilinear, subjective and hyperbolic forms of perspective. Curvilinear perspective uses curved perspective lines instead of straight converging ones. This approximates the image on the surface of the retina, which is spherical. It uses four, five, or more vanishing points. Perceptually, objects in this system appear to bulge outwards or inwards. Such images correspond to a "fisheye lens" view. Cameras with wide-angle lenses have built in software that can correct for the distortion. Pepperell and Haertel (2014) compared artistic depictions of real-world scenes with linear perspective versions (photographs) of those same scenes. The artistic versions were a series of paintings made by one of the authors, a selection of landscape paintings by Paul Cezanne and a set of drawings made by individuals with art training. Compared to the photographs, the central visual field was enlarged and the peripheral field was compressed. So it appears that when creating works, artists do show some aspects of curvilinear perspective.

Other Monocular Depth Cues

There are many other monocular cues in addition to linear perspective in paintings that can tell us about object distances. Monocular cues, sometimes called pictorial cues because they are found in pictures, are sources of information in an image that tell us about depth if viewed with one eye. There are six additional such cues that can all be used in paintings to induce a sense of three-dimensionality. Examples of these are shown in Figure 6.9 and we will discuss each of them next.

Figure 6.9. A photograph of a city street scene. See how many of the monocular depth cues you can spot here.

The first pictorial depth cue other than linear perspective is occlusion. If an object is occluded it is partially covered up by another object. This tells us that the covered object is farther away than the object doing the covering. In relative height an object below the horizon line that is higher up is farther away. The reverse is true for objects such as clouds that are above the horizon line. For these objects, the lower down they are the farther away they are. Familiar size is another monocular depth cue. If we know the size of an object we can use this to estimate how far away other objects are. For example, if you see a tree and a person in a painting and they are both the same size you can conclude that the tree is probably farther away because trees are typically larger than people. Shadows are another source of depth information. If the light source is known and one object is casting a shadow onto another, it can reveal whether that object is close or far.

In the cue of relative size we can also use our knowledge of objects to judge distance. Imagine that there are two cars on the road. One is larger and the other is smaller. Because you know the cars are about the same size you can judge that the smaller one is farther away. In atmospheric perspective objects that are farther away are fuzzier and have more of a blue tinge to them because there are more atmospheric particles between them and an observer. Artists are typically well trained on this principle and are taught to make farther objects more indistinct and soft, lighter in color and with a blue tinge. Texture gradients are the last of the cues we will discuss. A texture gradient consists of a field of objects all around the same size. The farther away these objects are the smaller they will get and the more densely packed they will become. Crowds of people or a field full of flowers are examples.

The artist William Hogarth (1697-1764) mocks the use of depth cues by deliberately violating them in his frontispiece to *Dr. Brook Taylor's Method of Perspective*, dated to 1754 and shown in Figure 6.10. See if you can count how many violations there are! The Dutch artist M. C. Escher also plays with our sense of perspective and depth. He creates a never-ending staircase in his work *Ascending and Descending*.

Figure 6.10. Frontispiece to *Dr. Brook Taylor's Method of Perspective* by William Hogarth, 1754.

Of course no artist can ever completely convey a sense of three-dimensionality. There will always be some light that reflects off the surface of a canvas or the glass that covers it. Also, we have two eyes and our brain calculates the difference between them to estimate depth. This is called binocular disparity. To overcome this Leonardo da Vinci said one must look at paintings through one eye and at a far distance. Hundreds of years ago it was fashionable to look at a painting through a dark curtain with a small hole in it. This also diminishes the binocular depth cues and makes the painting look more compellingly three-dimensional.

Monocular Depth Cues and Art

For some time after the European colonization of Africa it was believed that the so-called "natives" could not interpret the contents of pictures. At the time it was believed that the ability to interpret a picture was learned, or transmitted through culture. This belief was reinforced when Hudson (1960) administered a test of pictorial competence to people in South Africa. He found that those with less schooling were unable to utilize depth cues and interpret the three-dimensional structure of line drawings. Hudson's work has since been interpreted as flawed. It is now known that the ability to interpret depth in pictures and otherwise understand them properly comes naturally and is not the result of training or schooling.

Perhaps in response to this, Nicholson and Seddon (1977) tested the ability of 105 13-20 year old male Nigerian students to interpret depth. They changed the number of cues by presenting monochrome photographs (many depth cues, including shadows), regular line drawings (with many depth cues) and line drawings only with elevation cues (relative height). The students varied in the amount of formal training they had in technical drawing. There was no difference in performance between the photograph and fully cued drawings but the difference between these two and the minimal cue drawings was significant, indicating usage of the depth cues in the stimuli. There was no effect of training. This work shows that these students could utilize the cues available in the drawings and did not need to be trained to do so. People when looking at two-dimensional artwork automatically interpret cues to infer depth the same way they would when viewing non-art images.

Sinha and Misra (1975) analyzed 60 paintings made by children aged 4-15 years. They found that younger children used depth cues for "near" space more often whereas older children used depth cues for "far" space more often. Interposition (occlusion) and relative size were the cues used most often. Texture gradients and linear perspective were used the least. With an increase in age the children used a great number of cues and also used each of the cues more often. Higashiyama (1982) investigated children's ability to use familiar size information. Thirty-two 1st-, 3rd-, and 6th-graders estimated the distance and size of familiar objects (a car and a dog) presented on transparencies. They were then allowed to familiarize themselves both visually and haptically (by touch) with the real sizes of a toy car and toy dog from which the transparencies were made. They were then allowed to make the same judgments again. The younger participants based their estimates on the size of real dogs and cars. They estimated the objects as farther and larger, while the older ones based them on the sizes of the toys, estimating them as smaller and farther. The visual information was used more than the haptic information. This study shows that even young children are capable of using information about familiar size to estimate depth in drawings.

Cook, Yutsudo, Fujimoto, and Murata (2008) investigated depth cues in illusory images with reverse perspective. You may remember that reverse perspective is one where farther objects are larger and lines converge toward the picture plane, not away from it. They manipulated several depth cues. The perceived illusory depth effect was greater with an increase in the number of perspective grid lines. After this shading/shadows, and texture/color information contributed the most to the depth effect. They conclude that pictorial depth cues of the sort found in pictures produce the same feeling of three-dimensionality as those found in photographs or real world scenes. In other words, artists and illustrators can use these cues to induce a feeling of depth in a two-dimensional image that is not actually three-dimensional. They are used by the visual system in the same way as they are used to interpret natural scenes.

The farther away an object is when one focuses on it the more postural sway there is (Paulus, Straube, Krafczyk, & Brandt, 1989). Postural sway can be measured and used as a proxy for depth perception. Kapoula, Adenis, Le, Yang, and Lipede (2011) had participants in their first experiment view two abstract paintings by Maria Elena Viera Da Silva (1908-1992) and then view those same paintings after they had undergone cubist transformations that neutralized depth cues. There was less postural sway in these cubist versions indicating that the unaltered ones induced a more compelling sense of depth. In their second experiment they used a Renaissance painting by the artist Piero Della Francesca (1415-1492) because it induces a strong depth effect. Participants this time were told to focus either on a foreground area (closer based on painting cues) or a recessed area (farther based on painting cues). There was greater measured body sway in the recessed focus condition demonstrating a compelling depth effect in this painting.

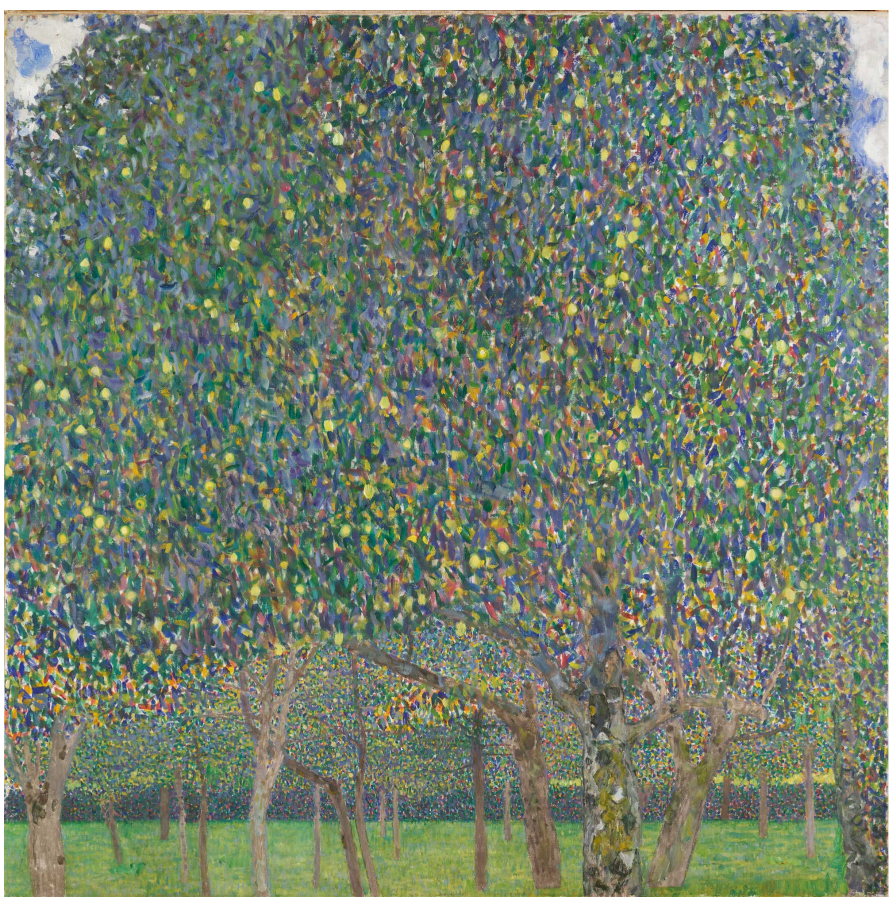
Binocular Depth Cues and Art

In addition to monocular cues there are also binocular ones. These are cues to depth that involve the use of both eyes. Oculomotor cues are examples of these. When we look at nearby objects our eyes converge and move inward. Conversely, our eyes diverge or move farther apart toward a straight angle when viewing distant objects. We can "feel" these changes to our muscles and they can tell us whether we are focusing on a close or far object. Enright (1986) had nine participants aged 10-43 years monocularly view drawings and paintings with perspective cues. Under these conditions the covered eye continues to make vergence movements that can be measured. He found that the amount of vergence between two points different in depth for the paintings was in many cases too little or too much. In other words the participants under- or over-compensated, converging or diverging in amounts not called for by the actual depth distances in the painting. If this was not due to the observers in the study then it would be attributable to the depth cues in the painting with some artists exaggerating the distances present and other under-representing them. As indicated elsewhere, this is not necessarily an accident. The artist could be inducing such effects deliberately.

For instance he or she may want to make two characters in a painting seem farther away in order to induce a sense of loneliness.

Another way our brain perceives depth is by determining corresponding points on the retina. Normally when we look at an object on a flat surface an image of the object is cast at corresponding points on the retina of both eyes. When looking at a three-dimensional scene objects in front or behind the plane of fixation will cast images in non-corresponding locations on the two retinas. It is up to the brain to determine which of these images go together. Patterns that have many repeated elements can cause problems for this process because the brain has trouble figuring out which points go with which. Take a look at Figure 6.11. This shows an image painted by the Austrian artist Gustav Klimt. It is titled *Pear Tree* and dates from 1903. Most of the surface of this painting is covered with small, similarly colored dots. This image causes the visual system to match non-corresponding points in the pattern while the eye is focused on the depth plane of the painting. It perceives some of the points as being behind this plane and others in front of it. The result, according to Livingstone (2014), is a feeling of depth that doesn't actually exist. One sees the leaves in the tree as being both close and far away, even when there is very little in the way of monocular cues to suggest it.

Figure 6.11. *The Pear Tree* by Gustav Klimt, 1903. The leaves of the tree should appear to fluctuate in depth. Image in public domain from wikiart.org.



Motion

Paintings are by definition still. They can't move, but this hasn't stopped artists from trying to represent motion in a static medium. One way they can do this is through narrative paintings that tell a story over a period of time, usually by showing scenes set at different times located in different panels. A good example of this is *The Altarpiece of Ghent*. But narrative paintings tell a story over a longer period of time rather than suggest actual physical movement. To do this some artists show figures in the midst of performing an action, by using body posture. The painting *Saint Michael and the Dragon* by Raphael shows the saint slaying a dragon. One can imagine the upraised arm with the sword swooping down to cut off the dragon's head. Sculptors also do this. Frederic Remington was famous for showing many of this American West figures in action. His 1909 bronze sculpture *The Bronco Buster* shows a cowboy atop a bucking horse. This work is shown in Figure 6.12. We can imagine the cowboy falling off backwards or one of the horse's legs kicking. Other methods artists use to create motion include still-shots, leaning, motion blur, motion streaks and Op Art. In this section we will examine these as well as the principle of perceptual agency and the use of animation in film.

Figure 6.12. *The Bronco Buster* by Frederic Remington, 1909. Image in public domain. Sourced from wikimedia.org.

Implied motion

Implied motion uses body posture and positioning to induce a sense of movement in the viewer. Part of this effect is anticipating where an object or object part will be. The area of the brain that processes motion is called area MT, this abbreviation stands for the medial temporal region. Cells in area MT fire selectively to particular directions of motion. If a pattern of random dots all moving to the left is shown on a computer screen certain cells in MT will fire. If that direction is then changed so they move in another direction, a different set of cells will then show increased activity. Researchers however have shown that dynamic still images, ones with implied motion, also activate cells in area MT (Senior, Barnes, Giampietro, Simmons, & Bullmore, 2000). Kourtzi and Kanwisher (2000) presented pictures of implied motion such a basketball player dribbling a ball, with static images of a person sitting or a picture of an object that cannot normally move, like a house. They found greater area MT activity in the dynamic motion case than in the other cases. The idea that the motion depicted in a picture tends to continue in the observer's mind is called representational momentum (Senior et al., 2000).

The Japanese artist Hokusai Katsushika is well known for his colored woodblock prints. He was also a cartoonist and sketched many line-drawing cartoons of people. This body of work is referred to as "Hokusai Manga". Osaka, Matsuyoshi, Ikeda and Osaka (2010) presented Hokusai manga figures that were engaged in challenging tonic poses, high in instability. They found activation in area MT. This study shows that even simple line drawings of this sort are enough to activate the brain's visual motion center. Figure 6.13 shows an example of one of Hokusai's manga figure drawings.

Figure 6.13. A sketch of a figure in action by the Japanese artist Hokusai. Public domain image from Wikimedia commons.

Friedenberg, Keating, and Liby (2012) presented outlines of human figures in symmetric and asymmetric poses. Undergraduates were asked to estimate the center of the figures (their center of mass). For asymmetric poses, estimates were biased in a direction opposite that of the limb extension, even when the true center was shifted in the limb extension direction. For example if a figure's leg was extended to the left, the true center would shift to the left but observers would estimate the center as being to the right. The data imply that observers anticipate the perceived direction of motion and place the center at a location that will counterbalance it. So observers treat imbalanced human forms dynamically and use implied motion to judge where their centers should be.

Twentieth-century artists like Balla and Duchamp tried to portray motion on canvas by superimposing a series of still-shots of an ongoing action. Kim and Blake (2007) found that observers rated images like these as higher in portraying motion than other abstract paintings without the effect. This was true even for those who had never seen such artworks before. In a second experiment they used fMRI to measure brain activity in observers for paintings rated the highest and the lowest in perceived motion in the previous study. They found activity in area MT for the high implied motion images but only in those who had prior experience viewing those types of paintings. So this style of art does activate real motion detectors in the brain but some knowledge or familiarity with them seems necessary.

Implied motion effects occur with sculpture as well. Nather and Bueno (2012) presented four sculptures to 42 university students. The sculptures varied in their degree of implied motion based on their ratings using the Body Movement Ranking Scale. The students were naïve with respect to the visual arts or ballet. They were allowed as much time as they needed to view the images and then recorded the subjective duration of the event. This was how long they thought the action in the sculpture took. The subjective time estimates for the sculptures representing implied motion were greater than those without it. So sculpture that appears to be moving actually dilates subjective time, even though an event in which something is happening is not necessarily longer than an event without action.

Nather, Fernandes and Bueno (2014) showed 20 abstract paintings from different artistic schools to undergraduates who rated them on emotional arousal, implied movement and estimated time duration. Each image was presented for a 3-second duration. The schools were cubism, constructivism, expressionism and futurism. Time distortions (increased estimated duration) were perceived in the case of two cubist paintings depicting human forms. In a second experiment they used only cubist paintings and time exposures of 3 and 9 seconds. The students overestimated the time duration of a cubist painting rated high in emotional arousal but only in the 9-second condition. Overall, implied motion better predicted time distortion than emotional arousal did. It may be that the emotional impact of a painting takes some time to process and so its effect on perceived duration will only occur for longer viewing times.

Forward Lean, Motion Blur and Motion Streaks

Mather (2014) mentions three other static cues that can be used to infer motion. Forward lean is part of what makes us think an object is moving in a particular direction. When a person is walking or running, they lean into their direction of movement. Lean goes along with motion because it helps to overcome inertia and to compensate for wind resistance. Inertia is the resistance of any physical object to a change in its state of motion. Most objects tend to continue "doing what they're doing", whether that is being still or moving. Lean makes even an object that does not normally lean look as if it is going faster. This effect is frequently used in cartoon animation to increase the perception of speed.

Motion blur is another technique used by artists to convey the impression of speed. The impressionist artists employed this, including both Monet and Renoir to portray people walking by on the street or of gusting wind. Time exposure photography is good at showing this effect. If a camera shutter is left open for longer periods moving objects will blur. A runner or moving cars can be photographed this way. Related phenomena are motion trails or motion streaks. These are lines that are left by the moving object. These have also been put to use to convey speed in cartoons. Roy Lichtenstein used motion streaks in some of his pop art paintings. Motion streaking in the lab has been found to improve motion detection (Edwards and Crane, 2007).

Perceiving Objects

In this section we will examine how we view objects. We will see that there are certain preferred ways we like to see them. The research on shape constancy shows that although we can accommodate to different viewing angles of a simple two-dimensional shape we still internally represent shapes in canonical ways and these in term affect how we remember or draw them. Canonical in this context simply means a regular and acknowledged way. We also prefer seeing three-dimensional objects from a particular viewing point, one that maximizes the amount of information or features available. Finally, we see a preference for objects at a canonical size, with bigger objects being preferred at proportionally larger sizes relative to the viewing space.

Shape constancy is our ability to recognize that a shape remains the same regardless of viewing perspective. A rectangle in three-dimensions is never a perfect rectangle but will always be distorted based on viewing angle. Yet if you saw distorted rectangles in a photograph of a room you would know that they have not warped or changed shape. You would recognize that they are all rectangular objects of the same dimension, just seen from differing vantage points. They could for instance be the way a rectangular window looks from various locations. Cohen and Jones (2008) showed participants shapes like these and asked them which ones looked the closest to a rectangular window from a photograph. They found that participants over-regularized and tended to match shapes that were closer to undistorted rectangles (ones with 90° angles and parallel sides) than they were to the actual window shape. This suggests that we mentally represent shapes in their canonical or undistorted configuration.

It turns out that we are better at recognizing objects when they appear at certain orientations, usually the ones that provide the most information (Palmer, et al, 1981). For example, cars are recognized more easily from three-quarter views, clocks from frontal views and teapots from side views. Each of these views affords the observer with more information about the features and three-dimensional shape of the object. Again, these findings have implications for drawing. Artists when selecting a composition for a still life may arrange objects so that they are positioned at these canonical views. This is in fact what the evidence shows. Matthews and Adams (2008) had participants draw a cylinder from memory and then draw another one from observing an actual cylinder. The observational drawing was biased toward the way they remembered it, which was assumed to be the canonical representation.

Konkle and Oliva (2011) have found evidence for a canonical size effect. They found that real-world objects have a consistent visual size at which they are drawn, imagined, and preferentially viewed. For instance a mouse is preferred at a smaller size than an elephant because we know that mice are smaller than elephants. The preferred visual size is proportional to the logarithm of the assumed size of the actual object in the world. It is characterized not by a fixed or constant visual angle but scaled to the size of the frame around it. What this means is that we don't always prefer to see an elephant that is 15 cm across on a computer screen from a standard viewing distance. The actual size would change for different sized frames and viewing distances but would always be a constant proportion of whatever frame it was being seen inside.

Perceiving Scenes

Although it may seem as we take in everything around us in a glance this is actually an illusion. Research on scene perception shows that we actually retain very little of what we see in memory. Studies of this typically present a drawing or photograph of a scene. This is then replaced with a blank screen for a short interval, followed by another picture of the same scene where something has been altered These changes can include the appearance or disappearance of an object or a change in the color of an object or background. The two frames alternate with the intervening blank screen between them for some fixed amount of time. The task of the observer is to detect the change. Most observers fail to notice even large changes to these scenes. The effect is called change blindness (Simons & Levin, 1997)

There is a reason for change blindness. If we took in everything we see we would be overwhelmed with information. Instead, we are aware mostly of where we fixate. Changes to a scene at our point of focal attention are detected more easily than those in the periphery (Rensink, O'Regan, & Clark, 1997). The assumption here is that there is a limited amount of visual attention and we can conserve that by focusing it at the point of fixation. If we need to see the details of an entire scene we do so by moving our eyes (making a saccade) from one area of the scene to the next.

Now what are the implications of this for art? Artists who are sketching or painting a scene will need to take in more details than a casual observer. That means they must make more eye movements. This is in fact what they do. Trained artists make more frequent saccades when drawing from a model than non-artists (Cohen, 2005). Their fixations are 1.5 seconds in duration. The accuracy of drawing produced by both artists and non-artists was rated as better for those who made more frequent eye movements. So we can compensate for our poor ability to retain what we see by looking back and forth more often between the scene and the drawing or painting surface.

Mather (2014) points out two examples of artists who created meticulously accurate scenes. The first is the Italian artist Canaletto who painted very detailed depictions of city street scenes in Venice. Canaletto most likely used a camera obscura for some of his works (Bombford & Finaldi, 1998). However not all of his work could have been created this way because he deviates from proper perspective views in some cases. The Dutch painter Vermeer is renowned worldwide for his use of realistic light and his detailed views of interior scenes with people. An analysis of his work shows that it is so accurate that he undoubtedly used a camera obscura (Steadman, 2001). A 2013 documentary film called *Tim's Vermeer* also shows that Vermeer must have used a mirror to get the values of light on surfaces as exactly as he did. In this film the inventor Tim Jenison reproduces an exact copy of one of his paintings using a mirror system. Another artist who may have used a camera obscura is the Austrian landscape and architectural painter Rudolf von Alt whose watercolors of Vienna and other European cities are incredibly detailed and realistic.

Is it cheating to use optical devices like these when creating artistic works? The temptation is certainly great as getting a perspective drawing exactly right by hand takes a lot of work. However photography by itself is considered an art and it does not require the working out of perspective. It would seem that the use of such devices is unethical only if the artists use them but deny that they do so. Note that linear perspective becomes much more important when portraying constructed scenes that contain streets and buildings with straight lines. It is less prominent when portraying purely natural scenes with objects like trees, clouds and mountains.

Eye-Movements

Where do people look in paintings? In order to answer this question we must look at eye-tracking studies. In these experiments a stimulus like a photograph of a natural scene is presented to a participant while a device analyzes where they look. Two key features are measured. The first are fixations and the second are saccades. Fixations are places where the gaze is held for a brief time. These focal points indicate where people are directing their attention. In-between fixations are saccades. These are brief moments where a person's eyes jump from one area of interest to another. Saccades during reading are around 200 ms. For the viewing of art they are a bit longer at around 300 ms. However there can be great variability in these times. Whenever our eyes jump from one point to another our brain suppresses perception of the movement. This is called saccadic suppression and is necessary because otherwise our visual world would jump wildy every time our eyes move.

When we fixate and saccade a face we don't look at all regions equally but instead look and scan between certain features and areas more than others. The interior features of eyes, nose and mouth are the most fixated regions. Eye movements tell us something about the intent of the viewer. They tell us what her or she is interested in or what he or she does not understand about an image. If looking for relationships such as between two figures in a painting, then it is likely your eyes will move back and forth between the two figures in order to resolve whether they are, for instance, a father and daughter or perhaps two lovers. If you are interested in a painting's narrative, your eyes might wander around the scene taking in the people, objects and background. When looking at paintings our brain takes in successive "snapshots" of different areas and then attempts to integrate them together mentally and make sense of the painting's meaning.

Berlyne (1971) identified two kinds of eye movements in art. In diversive exploration, there is a hunt for stimulation without regard for content. In specific exploration the viewer is deliberately seeking out specific information. Each of these types has a characteristic scan path signature. In diversive looking the saccades are widely dispersed throughout the image. In specific looking the saccades are clustered in particular regions of the image with a concentration of fixations and smaller saccades within each of those areas. Locher and Nadine (1987) recorded eye movements for initial and subsequent viewing of art images. The results showed that initially, the participant's had widely distributed fixations with shorter durations of around 300 ms, characteristic of diversive exploration. For subsequent viewing, there was an increase in the fixation duration to about 400 ms suggesting a shift to more specific information-gathering processes.

Molnar (1981) had two groups of fine arts students in Paris view art works while their eye movements were recorded. One group was instructed to answer questions regarding the aesthetic quality of the paintings. The other group was instructed to answer questions about the painting's meaning or semantic qualities. The aesthetic group held their fixations longer than the semantic group (365 ms vs. 315 ms). One of the paintings they looked at was Manet's *Olympia*. An analysis of where the fixations occurred was informative. Viewers focused their attention on the head and bust region but also allocated a lot of fixation time on the hand and leg region. The results show that features rich in information such as the head are often looked at, but so is the center of the image. In an earlier work Molnar (1974) found that the style of art also makes a difference. Classical art produces eye movements that are large and slow reflecting the expansive nature of that style with wide-open landscapes. Baroque paintings instead involved small and quick eye movements, reflecting the dense clutter of objects and detail characteristic of that style.

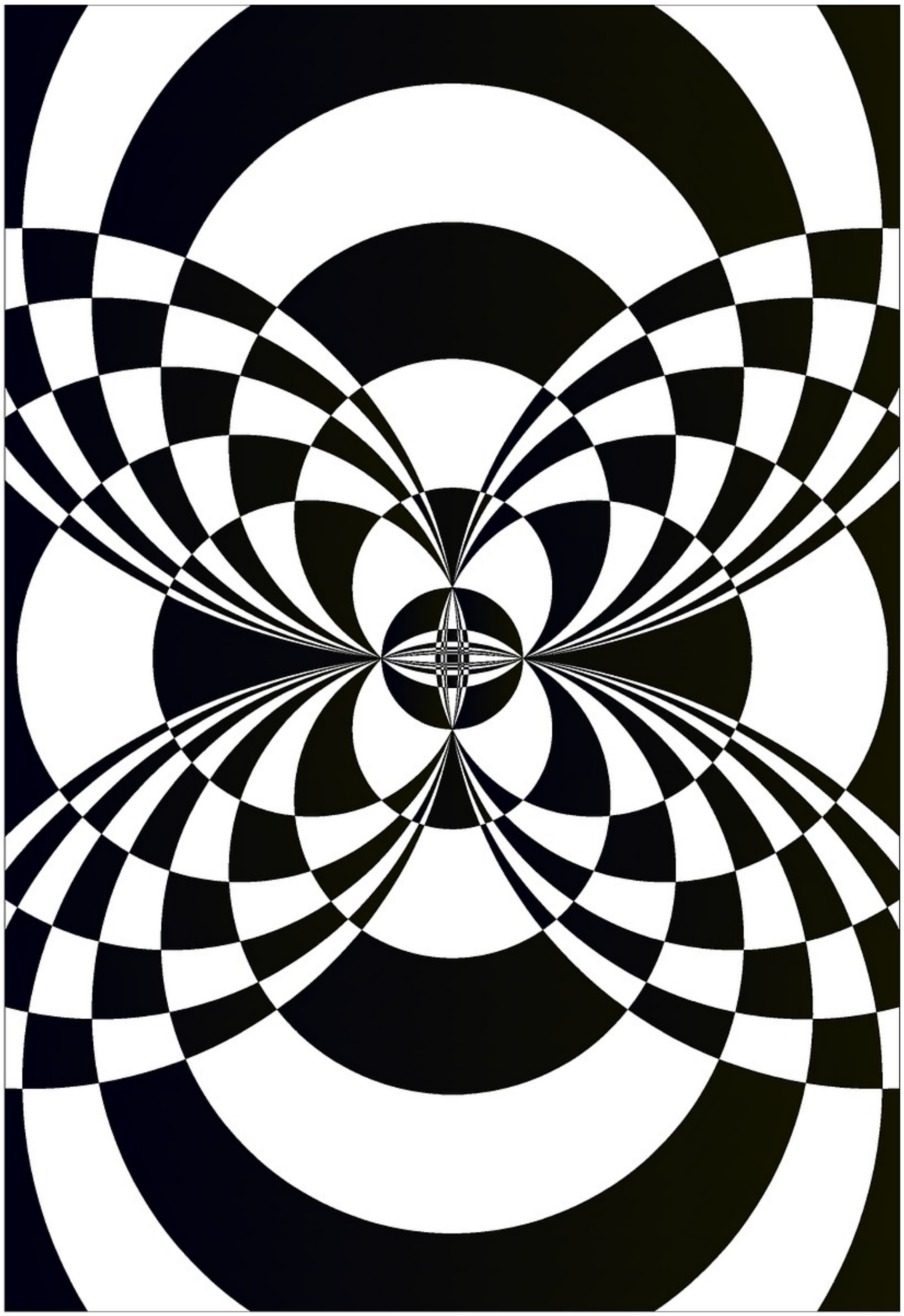
The Russian psychologist A. L. Yarbus was one of the first people to measure eye movements (Yarbus, 1967). He found that people tend to look at regions of an image that contain high contrast and fine detail, and at areas of biological significance, such people or faces. When we make eye movements our peripheral vision picks out those areas and sends a message to the eyes to make a motion so that we look at those regions next. Artists seem to have figured this out. The French Impressionist painter Pierre-August Renoir (1841-1919), in his painting *Madame Henriot*, paints the face region with details and at high contrast while leaving the rest of her body and the background relatively fuzzy and featureless. This ensures that our eyes move to her face and exaggerates its importance.

People also fixate changes to features, a change in color or shape for example, and abrupt onsets, such as when something appears or moves (Yantis & Hillstrom, 1994). If a region or object differs in some way from what is around it, for example in color, orientation or shape, it will attract fixations. Luminance contrast does as well (Krieger, Rentschler, Hauske, Schill, & Zetzsche 2000). Fuchs, Ansorge, Redies and Leder (2011) confirmed salience effects for viewing of photographs and for abstract and representational artwork. They computed the local feature contrasts for these images (differences in color, luminance and orientation) and found that these contrasts did attract eye-movements.

However, top-down expectations about what to look for also influence where we fixate (Cave, 1999). If you expect a lion will attack you from the bushes then you will look at those bushes. There is a tendency to fixate the center of a framed image, no matter what its content (Henderson, 2003). Faces also do a good job of grabbing our attention. If a picture contains a face, we look at it almost automatically, even if we have been instructed to look for something else (Cerf, Harel, Einhauser, & Koch, 2008). Within a face the eyes attract the most attention (Birmingham, Bischof, & Kingstone, 2009).

Op Art consists in many cases of alternating stripes of black and white (see Figure 6.14). Observers upon viewing these stimuli report illusory visual motion. That is they will perceive that the visual field is moving when it in fact is not. Kapoula, Lang, Vernet and Locher (2015) had 28 adults view a control stimulus and two Op Art paintings. The first was *Movements in Squares* by Bridget Riley. The second was *Rollers* by Akiyoshi Kitaoka. They were instructed to either fixate the center of the image or to explore the artwork freely with their eyes. Eye-movements and postural sway were measured. The two artworks induced significant body-sway as measured by an accelerometer and an increased effect of the illusion in the free viewing condition. They attribute the results to macro-saccades (large eye movements) in the free viewing condition and to small vergence drifts during fixations. The eyes normally rotate inward (convergence) when focusing on a near object or outward (divergence) when focusing on a far object. Vergence drifts are changes in these movements that may produce the illusory motion and that may also account for the forward and backward sway.

Figure 6.14. An example of op art. From Pixabay. Free for commercial use without attribution.



Mondrian's paintings are preferred in their original orientations that contain more vertical and horizontal orientated lines than when they are rotated into an oblique orientation turning these lines into diagonals (Latto, Brian, & Kelly, 2000). Plumhoff, Schirillo, and Winston (2009) examined this in an eye-movement study. They presented eight Mondrian paintings at either the preferred vertical-horizontal orientations or at oblique orientations while recording fixation duration and saccade length. There were larger saccade-distance oscillations for the pleasing vertical-horizontal images than for the oblique ones. These oscillations are alternations between saccades of different distances, so for example an alternation between making small and large eye movements. So there is a greater amount of both localized small eye-movements to details and larger global eye-movements across regions in the painting when they are liked.

Rembrandt painted many portraits, including over 90 of himself. In his later works he deliberately blurred the periphery of his portrait paintings, leaving the center portion of the face and the eyes clear. He did this to direct the viewer's gaze toward the eyes, the effect being that they stand out in even greater clarity. This effect is sometimes used in photography and is called depth of field. It is achieved by focusing at one object or scene at a given depth plane in the image. The areas in front of and behind this focal plane are blurred which attracts attention and gaze toward the clear region.

Many viewers seem to scan a painting from left to right, in some cases with a slight upward trend so starting at the lower left and then trending diagonally to the upper right. This would make objects on the left take on greater importance because they are looked at first. Early studies on this suggest left side objects are perceived as more salient, nearer to the observer and clearer (Adair & Bartley, 1958; Bartley & Thompson, 1959). These directional differences seem to be guided by reading practice. Readers who scan the page from right to left, as is the case for Hebrew and Arabic languages, show opposite preferences to English readers (Chokron & De Agostinic, 2000).

Left and Right Biases

The inferred direction of motion for objects in a scene also makes a difference. For objects at the center of a scene left-to-right direction readers (most English-speaking nations) prefer an object facing to the right that appears as if it will move right, consonant with the reading motion. In contrast right-to-left direction readers (Hebrew and Japanese) prefer the version where the car faces to the left, which is consonant with their reading motion. However, reading direction does not predict preference for landscape drawings that are weighted to one side or another, so there are other factors in addition to scanning direction that influence perception of direction.

Directional biases exist even in our imagination. When asked to draw a picture corresponding to a verb like "shooting" or "giving" most people will draw the picture so that the agent, the one doing the shooting or giving, is on the left, with the action moving in a leftwards direction (Chatterjee, Maher, & Heilman, 1995). There is also a preference for objects that face inwards toward the center of the picture rather than those that face outwards. For objects that don't point in any particular direction, such as frontal view of a person, the preference is for objects to be located at the center of the scene (Palmer, Gardner, & Wickens, 2008).

When it comes to paintings, there is no preference for the original version or a mirror image of it, when the two are shown side by side (Gordon & Gardner, 1974). When the participants in this study were asked to pick which of the two is the original, their performance is no better than chance. The occasion where they do prefer the original is when they are familiar with it (Ross, 1966). Again, we can conclude the directional biases are only one of many factors that affect preference for complex scenes.

Composition

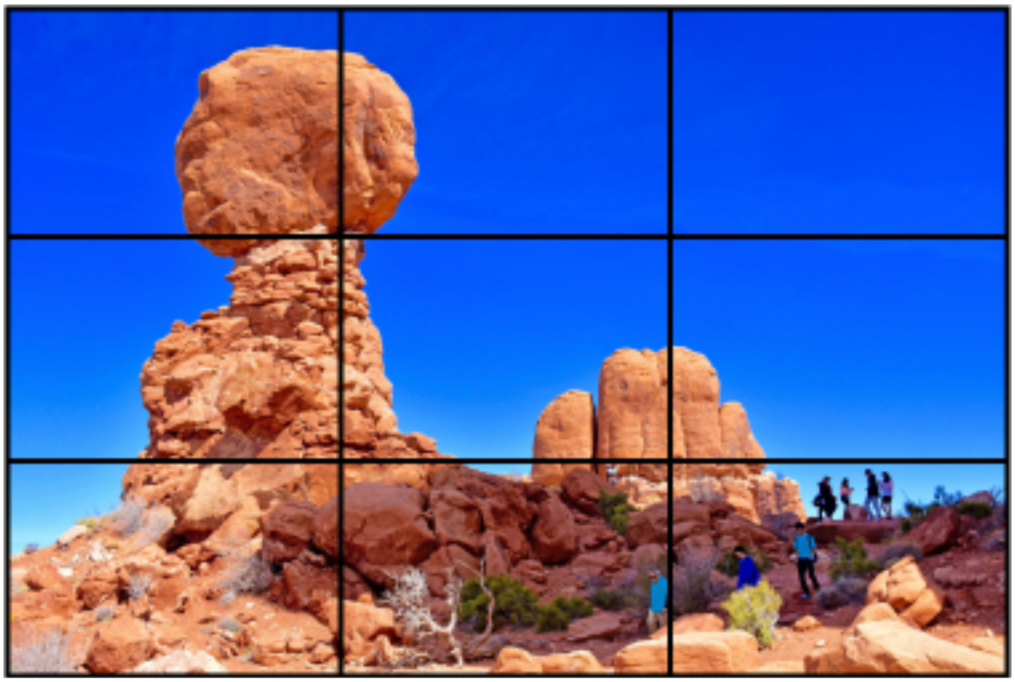
Classical Division of Space

The Rule of Thirds

One trick used by painters, photographers and cinematographers to position elements in a painting is the rule of thirds. This involves dividing up the horizontal and vertical lengths of the canvas and then drawing lines. The four points where the lines meet then become focal points for the placement of important objects in the painting. Proponents of this technique argue that placing objects at these points creates more tension, energy and interest than having the objects centered. Placing objects directly in the center of paintings is considered too boring and is generally avoided.

Horizon lines or other linear elements should in this method fall along or near one of the guidelines. As in the placement of objects, the horizon line or prominent vertical elements like tree trunks should not fall along center lines. Objects not directly on the focal points can still be considered effective if they appear in close proximity to them. Figure 6.15 shows an example of an image composed using the rule of thirds with guidelines and focal points indicated.

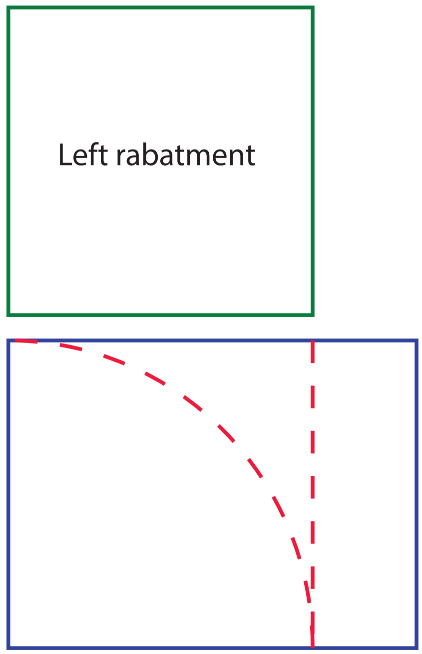
Figure 21. A photograph in which the major picture elements are at or near one-third dimension lengths and intersections.



Rabatment

Rabatment is another technique used as a compositional aid. In this method the length of the two smaller sides of a rectangle is used to form a guideline. To perform a rabatment for the left side, measure out the length of the smaller side starting from the left and then use this distance as the point for placing a vertical division. This forms the left rabatment. Applying this procedure from the right side creates the right rabatment (Figure 6.16). This procedure can be applied to rectangles of any proportion or orientation. Primary objects of interest should be placed within one of the two rabatment squares, with lesser elements allocated to the remaining smaller rectangular space.

Figure 6.16. A rectangular picture space (blue) in which the length is divided by the height (red) to form the left rabatment (green).



As is the case with the rule of thirds, this technique can be used for painting, photography or film, since these all employ rectangular frames. For rectangles with a 3:2 proportion as is found in 35 mm film photography, the rabatment corresponds exactly to the rule of thirds. If the dimensions of the rectangle are 2:1 then the rabatment falls along the midline and so this should be avoided. In cultures where reading is from left to right, attention may be focused inside the left rabatment or near the line it forms toward the right side of the rectangle. One of Rembrandt's self portraits shows the lit side of his studio and hence the primary area of focus on the left. The darker side to the right is of less significance and occupies the smaller rectangular region. The two areas are divided according the proportion of the rabatment.

The Power of the Center

Rudolf Arnheim, (1904-2007) the Harvard Professor and art researcher thought deeply about composition. He believed that objects in space exercise force over one another the way planets do in physics. He wrote a book titled *The Power of the Center* in which he expounds upon these ideas. In this section we will summarize some of the more important principles he mentions. Keep in mind that these are mostly theoretical ideas; not all have been tested experimentally.

According to Arnheim, the center is the most important point of every regular figure and artistic display. Sometimes the center is visible but sometimes it is only implied. By center, he means a place where forces issue and toward which forces converge. Single objects have centers but so do collections of objects. Two objects that are located some distance apart from one another will have a center that is somewhere in between them. An object's "heaviness" can then exert more attractive pull, bringing the center closer to itself. Objects that appear darker, denser, or more detailed are perceptually heavier. Of course in any complex scene there will be multiple objects, each exerting force upon each other. Linear objects will exert force in two directions, along their main axis. A vertical column will thus exert force upwards and downwards.

Arnheim summarizes some of his principles in several short statements. He states first that distance increases visual weight. This is actually the opposite of what we see in physics in which the mass of a body decreases with distance. In this case, he likens the effect to potential energy, or perhaps as a weight on the extended arm of a fulcrum. Distance also decreases attraction when perception is anchored in the attracted object. Finally, weight increases attraction. A heavier object will exert more attractive force on the objects that surround it.

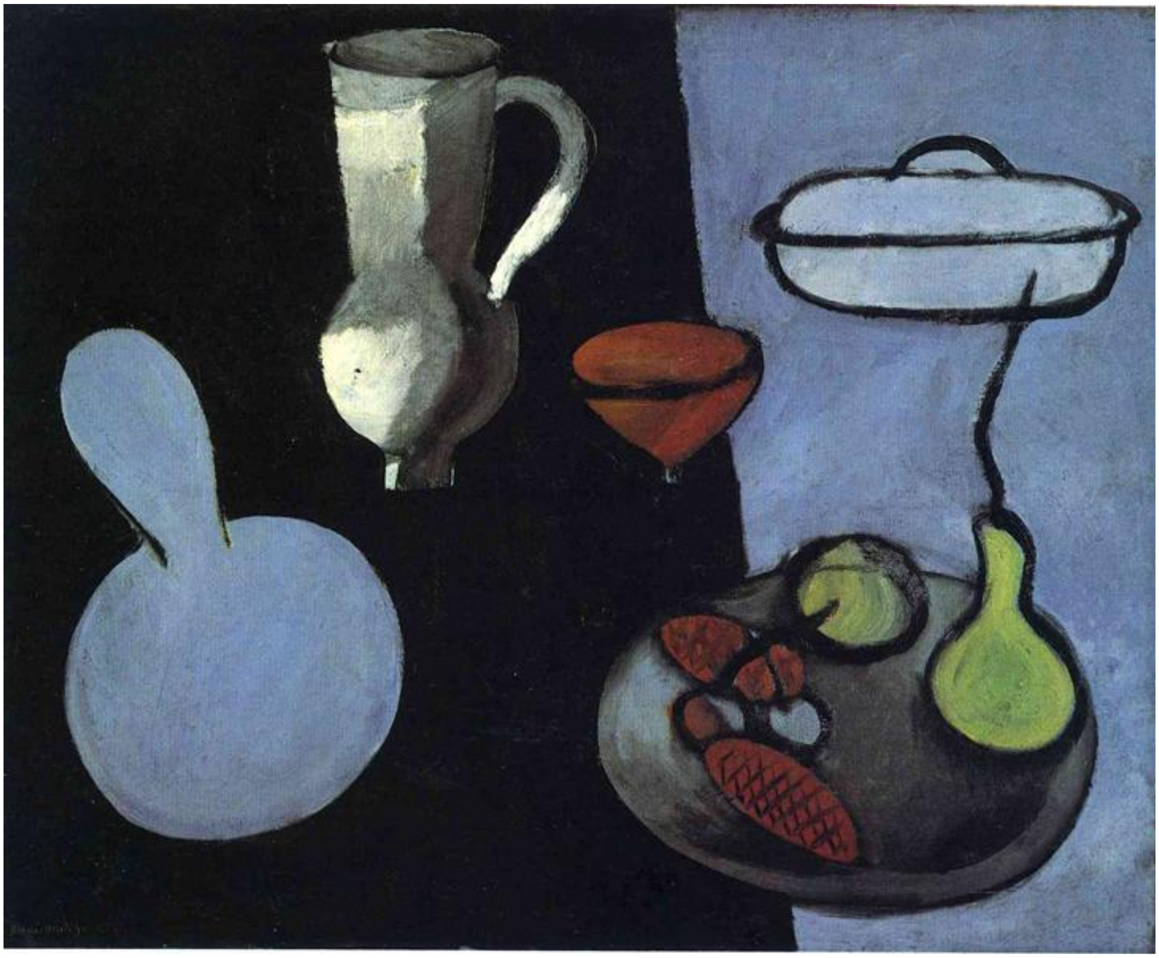
We can apply some of these principles to sculpture. Arnheim states that a sculpture is attracted to the ground by gravity. It will have its own center, determined by its own particular configuration of mass. This center, perhaps near the waist in a vertical human figure, serves as one focus. The head in some cases can serve as another. Heads are a focal point of attention and can serve to elevate a figure. This can be seen in Figure 6.17, *Perseus Holding the Head of the Medusa*, by Antonio Canova (1804-1808). The head of Perseus attracts our attention partially because of the vertical upward force flowing through his body. His gaze then brings us to the head of Medusa. However this makes the sculpture "lean" toward the head and to counterbalances this Canova places the short sword on the opposite side, balancing the configuration.

Figure 6.17. *Perseus Holding the Head of the Medusa*, by Antonio Canova, 1804-1808. Image in public domain. Sourced from Wikipedia.org.

Arnheim also applies these principles to painting. To begin, a frame around a picture separates it from the wall and from surrounding objects, creating its own insular space. We the viewer, independent of a painting or its content, can impose force upon a scene, simply by fixating or moving our eyes. We tend to scan an image from left to right and there is a tendency to perceive the area in the left corner of the visual field as the starting point. Pictures thus seem to be organized flowing in this direction. This bias may also occur because our right hemisphere, which is more spatial, processes information from the left visual field.

We can illustrate some of these ideas using *Gourds* painted in 1916 by Henri Matisse and shown in Figure 6.18. There is a downward gravitational pull on all of the objects but each of them also strives against this pull. The large blue gourd reaches upward with its neck; the pitcher has a handle and wide opening towards it's top; the red funnel widens as it goes up; the handle of the pan cover makes it seem ready to lift off; and the yellow gourd on the plate points upward like a chimney. The lack of a definite background makes all the objects seem as if they are floating like balloons. Only the objects on the plate are grounded because they rest on its surface. The objects also interact with one another and the frame. The white pitcher is attracted by the upper border and almost seems to hang from it. Larger objects here have greater weight. The volume of the large gourd and the pitcher seem to be mutually attracting one another because of their size. The smaller objects on the plate are attached to it by its larger size. There is also some attraction here due to similarity of color. The red objects are connected as a group. So are the yellow ones. The gourd in the left side seems to be the "home base" or starting point for the composition, which makes the pan in the upper right corner seem more distant.

Figure 6.18. *Gourds* by Henri Matisse, 1916. This painting illustrates many compositional ideas. See text for an explanation. Image in public domain, sourced from Wikiart.



Frames in some cases do not completely delimit their interiors from the space around them. Arnheim (1969) reports studies showing that the pictorial depth in one painting may appear shallow if viewed too close to another painting with greater depth. There are also movement effects in which one painting can enhance the motion of its neighbor. Frames developed in Europe around the fifteenth century because more people were starting to buy art. Prior to that point paintings were part of architectural settings, drawn as murals, for example to fill palace walls for wealth patrons. Round and circular frames because of their multiple radial symmetries produce a sense of stability. Rectangular frames allow for action to happen across their horizontal extent.

Interior painted objects cut off by a frame tend to perceptually continue. They are not fully completed, though. If a character's arm is cut off, we tend to see the arm as continuing, but we do not imagine the hand. Small cut offs do not affect the compositional balance but if there is a lot of information leading the viewer's eye outside the frame, it will. If the frame cuts off important information like a face however, the effect is startling and looks strange. Advertisers sometimes do this to attract viewer's attention on posters. Frames will enhance interior objects that are parallel to them, but contrast those that are at opposing orientations, as shown for the horizontal and vertically aligned rectangles inside the horizontal frame. Conversely, the interior content of a frame if strong enough can affect the perceived frame's extent. Vertical stripes inside a horizontal rectangle tend to make it look shorter. Horizontal stripes tend to make it look longer (Figure 6.19).

Figure 6.19. Which of these two rectangles looks longer? Why?

Contrapposto is an Italian term that translated means counterpose. It describes a human figure standing with most of their weight on one foot. This twists the arms and shoulders relative to the hips and the legs giving the figure a more dynamic appearance. A classic example of this is *The Spear Carrier* or *Doryphorus of Polyclitus*, dating to the fifth century B.C. Notice that this introduces a curvature into the standing figure that makes it look much more interesting than if he were standing straight upright. William Hogarth in the eighteenth century referred to this as "the line of beauty" as shown in an S-shaped curve inscribed within a pyramid. From a center point analysis, this offsets the center belonging to the head the head, the hips and the lower body so that they are no longer in a line.

We mentioned the rule of thirds and rabatment earlier as ways to divide space. Arnheim also discusses such divisions. If a space is cut exactly into two equal halves, they each have their own centers and now compete with each other for the viewer's attention. A good demonstration of this can be seen in Fra Angelico's *Annunciation*, painted in 1439-1445 (Figure 6.20). The composition is broken into halves by a frontal column that symbolically distinguishes the heavenly realm on the left with the angel Gabriel from the earthly realm of the Virgin Mary on the right. But the space behind the columns serves to partially bridge the two regions, as does the interaction between the two characters. Arnheim calls this type of bridge a "latch".

Figure 6.20. *Annunciation* by Fra Angelico, 1439-1445. The frontal column breaks the composition into a left space (the heavenly realm) and a right space (the Earthly realm). Image in the public domain. Sourced from Wikiart.org.

A balanced composition is harmonious and unified but if too balanced runs the risk of being boring. An unbalanced composition is dynamic and interesting but if too unbalanced appears lopsided or chaotic. The best outcome for a painting or other artwork then is the proper balance between these two forces. The simplest form of balance is between two sides in which we have two major objects with different weights to the left and right. Balance in this case is determined in much the same way as a scale with the weights in either pan. Alternatively we can use the analogy of a fulcrum. On a fulcrum a large weight on one side can be counterbalanced by a smaller weight that is farther from the center on the opposite side.

In paintings the situation is rarely so simple. There are usually far more than two objects and they are positioned not just to the left and right but all over the canvas. An example of a complex composition of this type is *Chastisement of Amor*/*Mars Chastising Cupid* (approximate date 1595), attributed to Bartolomeo Manfredi (Figure 6.21). Here we see three figures that swirl around a central pivot point, which is Mars grasping Cupid's hand. The circular organization keeps our attention circling around this center looking at the faces and bodies of the three characters and linking their roles together in the scene. Arnheim calls these two hands a "micro theme" because they symbolize the action taking place on the scale of the entire painting.

Figure 6.21. *Chastisement of Amor* attributed to Bartolomeo Manfredi, 1595. Image in public domain, sourced from Wikipedia.org.

Empirical Studies on Composition

As we saw previously the balance of elements in a painting has a strong effect on perceived beauty. A balanced composition is one in which the perceived weights of objects in an image are arranged so that they compensate one another about a center. The “weights” of elements are influenced by how big they are, what they look like, where they are located, as well as they way they seem to face or move (Locher, 1996; 2003). Forward-facing objects are preferred to be near the center of a display (Palmer, Gardner, & Wickens, 2008). Colors also can be balanced in a composition. For instance a small area of saturated color can balance a larger area of dull, unsaturated color (Locher, Overbeeke, & Stappers, 2005). In an experiment by these researchers they found that red was perceptually heavier than blue which was perceived as heavier than yellow. So not all colors carry the same perceptual weight. Some are more powerful than others and can dominate a composition.

It follows that if someone pays more attention to composition they will be better able to judge it. The amount of attention we pay to composition likely varies depending on the type of painting. Representational art that has recognizable objects like people and trees ought to draw attention toward the content and emotional aspects of the work. Abstract works ought to draw attention to the physical and structural features of the work. Attending to each of these qualities for that particular type of painting ought to improve one’s ability to detect the balance and composition of a painting. Locher (2003) tested this idea. He had 100 college students without training in the arts discriminate between original reproductions of representational and abstract paintings and less well-balanced versions. These alternate versions had pictorial elements moved to disrupt the balance across the painting’s center. Identification of the originals was greatest for the abstract works and when the observers focused on their compositional style, based on written comments they also provided. It was also high for representational works when they focused on the picture’s content and realism.

Nodine, Locher, and Krupinski (1993) recorded the eye movements of adults without art training when they evaluated paintings for harmony and beauty. The images used were reproductions of paintings by well-known artists like Cezanne, Mondrian, and Seurat along with versions of these that were manipulated to be less balanced. Average coverage of the picture field was 72% for the original balanced images but only 53% for the less balanced versions. The distribution of the fixations across the originals showed that observers spent more time looking at the elements that went into balancing the figure. This was not the case for the less balanced paintings. They conclude that balanced compositions “engage” viewers more, causing them to look throughout larger regions of the painting and to look at the elements in the painting that determine the balance.

Stephen Palmer and his colleagues have performed an extensive set of experiments investigating spatial composition. This refers to the arrangement of objects in a scene. Specifically they are interested in the placement of objects within a rectangular frame so that viewers will judge them to be aesthetically pleasing. They avoid content issues, i.e., differences that might arise because of the use of different objects, by using different compositions of the same object viewed from the same perspective. They avoid using real landscape paintings because these are complex and vary in many ways making them difficult to manipulate. Their observations are from “average” viewers rather than art sophisticates because these individuals would have received training in composition.

The first set of research studies described will be about the horizontal placement of a single object. As described above, Arnheim believed that central positions are powerful and that objects are best seen inside the central region of a space. Palmer and Guidi (2011), using a “goodness of fit” rating task supported this notion. They found that optimal places for object placement inside rectangles are at the center, the place where the vertical and horizontal symmetry axes of the frame intersect. These results support Arnheim’s theory.

This view on optimal placement is based on the external effect of the frame, but the objects inside the frame also exert an influence on optimal placement. Gibson (2014) believed that objects have perceptual affordances, meaning that people can infer their function from their appearance. Palmer extends this notion to the idea of an affordance space around an object. This specifies the local area around an object where it typically interacts with humans and other environmental objects. An affordance space implies that there a greater area in front of an object that is of functional interest to an observer than behind it and no difference between the left and right sides, at least for reflectionally symmetric shapes. This in turn suggests that the best position for different views of the same object is that for its affordance space. These ideas have been supported in a number of studies using a variety of methodologies (Palmer, Gardner, & Wickens, 2008). Forward-facing objects are preferred in the center, right facing objects on the left and left facing objects on the right.

Palmer, Schloss, and Sammartino (2012) next examined ecological biases. These are expectations about where an object should be based on how we have interacted with or perceived them in everyday use. They looked at perceived vertical placement of a bowl on a surface and a light fixture affixed to a ceiling. Optimal perceived locations of the bowl were lower down while for the lighting fixture they were higher up. They also found a downward bias for a stingray, normally perceived swimming in water that is lower down, and an upward bias for the positioning of an eagle, typically seen flying higher up in a scene (Sammartino & Palmer, 2012).

Lighting, Art and Scene Perception

One would think that shadows are important cues in paintings. They can inform the observer about the location of global and local sources of illumination. A global source of illumination for example would light up an entire scene whereas a local source would only illuminate a subset of objects in the scene. For an interior scene of a room a global source would be an overhead light shining down on all the objects in the room, while a local source would be a desk light casting shadows just for objects on the desk. Shadows can also tell an observer where the objects that cast them are located. For example if a shadow is projected to the left of an object it implies that that the source of illumination is coming from the right.

Surprisingly, research shows that we ignore inconsistencies in shadowing in scenes and paintings (Casati, 2006; Cavanagh, 2005; Ostrovsky, Cavanagh, & Sinha, 2005). Many paintings, including those by the medieval artist Domenico Beccafumi will have shadows for objects cast in one direction and shadows for other objects cast in a different direction, inconsistent with the location of the single global illuminant, the sun in this case. Shadows can also be left out altogether and in many cases not noticed. This is true for other paintings by Giovani Bellini, Andre Derain and Paul Gaguin (Mather, 2014). Why is this? The visual system is apparently quite flexible in the way it uses shadows, perhaps because they vary so much in natural scenes. The direction in which shadows are projected will change when the lighting sources changes. This happens slowly when the sun moves across the sky (for instance the moving shadow of a sundial). But it can also change more quickly when local illumination sources change as is the case for a person carrying a lantern or moving a flashlight. Shadows also change when the object themselves move or have parts that move.

This does not mean that the visual system discounts shadows completely. Boyaci, Doerschner, and Maloney (2006) had participants judge the spatial distribution of light sources in complex rendered three-dimensional scenes. The cues available were cast shadows, surface shading and specular highlights. Surface shading refers to the change in lighting gradation on an object. Specular highlights are the glint of light on reflective surfaces. In their first experiment each of these cues was used in isolation and all were employed by participants to perform the task. The highlights and cast shadows were used by more than half of the observers. In a second experiment observers used all three cues in combination when they were available to estimate the light source. So shadows as well as other information in isolation or in combination can be used.

Gerhard and Maloney (2010) created a three-dimensional scene with bumps lit up by diffuse and concentrated light sources. These were viewed stereoscopically while the location of the light source changed quickly in one of four directions. The performance of all of the observers was above chance. They created a model based on shape and shading to predict the types of errors that were made. The results show that the shading on objects and qualities of the shapes themselves were utilized to perform the task. This work shows that in the absence of obvious shadow information shape and shading cues can be used to estimate the location of a light source.

Most paintings tend to be lit from above and to the left. Sun and Perona (1988) found that 77% of 225 portrait and landscape master paintings were lit from the left. Other studies have also obtained a leftward bias for Byzantine and Italian Renaissance paintings. The same is true for full-page advertisements in magazines. Advertisements with leftward lighting are also preferred (Hutchison, Thomas, & Elias, 2011). An upward bias is most likely the result of our experience with the sun, which with few exceptions comes from above us (Mcmanus, Buckman, & Woolley, 2004). The left-side bias is more difficult to explain. McDine, Livingston, Thomas and Elias (2011) tested the up and to the left bias while controlling for other cues like posing, ground line, shadows and reflections. He had 42 participants move a “virtual flashlight” across the surface of abstract images presented on a computer monitor.

The participants were instructed to light the painting in the way that was most pleasant to them. On average the flashlights were focused in the top left quadrant.

The color of light can affect our aesthetic and emotional evaluations of a scene. Odabasioglu and Olgunturk (2015) had observers judge interior spaces on several qualities under red, green, and white chromatic lighting. The spaces were judged equally pleasing for all three colors. White lighting was considered as more useful, spacious, clear, and luminous, as was green lighting. Both of these colors were also judged as equally comfortable. The red and green lighting were perceived as more aesthetic than white lighting. Based on these results we can conclude that colored rooms, lit up in cool or warm lighting are considered more beautiful than those under white, neutral lighting. Red lighting seems to be a color that people might not want to work under.

Lighting conditions also affect how we judge portraits. Sakuta, Kanazawa, and Yamaguchi (2014) varied the contrast (either high or low) and lighting location (left or right) of portraits. Likability and attractiveness were the same regardless of these manipulations. Low contrast portraits were perceived with more positive emotions while high contrast portraits were perceived with more negative emotions. The fact that lighting position had no effect is consistent with a discounting of shadows. The high contrast negative emotion finding is interesting. Faces of monsters like Frankenstein, vampires, zombies, etc. are often presented in high contrast. They also tend to be lit from below, which is contrary to the sun's normal direction and so might induce a sense of creepiness or unease.

Reflections and Mirrors in Art

Figure 6.21 shows the painting *The Toilet of Venus*, also called the Rokeby Venus, by the artist Diego Velasquez. In it one can see Venus staring at her face in the mirror. However, given the angle of the mirror it is impossible for the viewer to see her face. The viewer instead would be seeing parts of the scene to the right of where Venus is laying. If the mirror were rotated to allow the viewer to see Venus in the mirror, Venus would now see the viewer in the mirror instead of herself. Bertamini, Latto, and Spooner (2003) have dubbed this the Venus Effect. A survey of 40 mirrors in paintings shows that about one-third incorporate the Venus effect. But we must ask ourselves, is the artist making a mistake or is he or she doing this deliberately? One contention is that Velasquez placed the mirror at this angle so that Venus is looking at the observer looking at her, i.e., to imply that she is vain or enjoying others looking at her in the nude.

Figure 6.21. *The Toilet of Venus* by Diego Velasquez, 1647-1651. It is impossible for both the viewer of the painting and Venus to see her reflection given the angle of the mirror, yet people don't typically notice this. Public domain image from Wikipedia.org.

Bertamini, Lawson, Jones, and Winters (2010) show that the Venus effect is not specific to paintings. It has been demonstrated for photographs and real life conditions. Observers generally believe that a person can see themselves when they are near a mirror even when their face is not visible in the mirror. When approaching a mirror from the side people expect to see their reflection in the mirror earlier than they actually do. This effect is true when the observer moves horizontally and when the mirror is placed on the floor or the ceiling. It does not hold when the observer moves vertically (Bertamini, Spooner, & Hecht, 2003).

Cavanagh, Chao and Wang (2008) make another interesting observation about mirrors in paintings. As we move about in relation to a mirror in the real world what we see changes. Looking at a mirror straight on, an object that is to one's left that is hidden becomes revealed if the observer moves to the right of the mirror. Conversely, an object that is hidden to our right becomes revealed if we move to the left under these circumstances. The reflection in a mirror in a painting of course cannot change. Yet, this is something we either do not notice or notice but does not disturb us when appreciating a painting.

Why are people so poor when it comes to reasoning about mirrors? It may have to do with mirrors being an evolutionarily recent development. Mirrors are a technology created by humans and have only been around for the last few hundred or thousand years. Aside from a reflection in calm waters, it would have been rare for our early ancestors to see their face staring back at them. We thus haven't evolved perceptually to deal with this situation. There are also other factors difficult to determine. The angle of inclination of a mirror relative to the observer is impossible to know if we cannot see its edges and there can be objects in the mirror not visible by direct line of sight. As a result, the visual system seems to be very tolerant of mirrors, the same way it is for shadows and linear perspective.

Complexity

The research on complexity and visual arts is mixed with regards to results. Berlyne (1971) found that complex paintings were preferred over simple ones. However Zajonc, Shaver, Tavris and Van Kreveld (1972) found the opposite. Brickman, Redfield, Harrison and Crandall (1972) obtained both effects depending upon whether initial responses were favorable or unfavorable. One of the problems with this research is that it is difficult to define what complexity is. To overcome this problem Cutting (2003) had participants themselves judge the perceived complexity of French Impressionist paintings. He found that complexity judgments were not correlated with preferences or recognizabilty. In that study he discovered that the participants were in part determining complexity by counting the number of objects, such as people and trees, in the paintings

Cupchik and Berlyne (1979) had subjects view paintings and other patterned stimuli that varied both in complexity and orderliness. They were presented at 50, 500 and 5,000 ms. The observers could discriminate complex and orderly images in the shortest duration condition (50 ms), where they were only able to view them in a single glance. This suggests that the ability to judge complexity is an automatic and preattentive process and does not rely on eye movements. Information about complexity thus can be extracted from holistic or global stimulus properties and does not appear to rely upon an analysis of details.

Cupchik and Gebotys (1988) showed subjects slides of paintings varying in complexity for 18, 36, and 72 seconds. The subjects were asked to estimate how long the slides appeared and to rate them on various verbal scales. They overestimated the duration of more complex images, in accordance with the idea of "filled time", related to perceptual and cognitive activity (Fraisse, 1963). In an earlier study, subjects viewed paintings by Manet, Monet and Degas (Cupchik, 1976/1977). They underestimated exposure duration for very orderly paintings, in accordance with the idea of "empty time", related to ease of perceiving the structure in the images. In summary, intense processing of complex paintings makes time appear to pass more slowly while ease of processing simple paintings makes time subjectively pass more quickly.

Effects of Familiarity – Mere Exposure and Processing Fluency

We tend to like stimuli that are familiar to us. This is known as the mere exposure effect and has been shown to be true for a wide variety of stimuli, including faces, words, music, pictures and abstract patterns (Bornstein, 1989). Mere exposure works for meaningless items like polygons, ideographs, nonsense words, syllables, or sounds. But it also works for meaningful stimuli like photographs of objects or people, or even music (Szpunar, Schellenberg, & Pliner, 2004). There may be an evolutionary basis for this effect, as familiar items are not harmful. Novel stimuli however can be.

The mere exposure effect can be explained in terms of processing fluency, which is the relative speed or ease by which a picture or other stimulus is processed (Chenier & Winkielman, 2009). The processing fluency account assumes that in addition to knowing what we are looking at (the semantic content), we also have access to how fast or easy it was to process the item. An object that is processed easily is said to have high fluency. High fluency can signal a number of things including the likelihood of achieving a goal, decreased threat, and greater degree of harmony, i.e., lower conflict within the perceptual or cognitive system. As such, high fluency has been said to give rise to a "warm glow" or good feelings that can in turn produce higher aesthetic judgments (Reber, Schwarz, & Winkielman, 2004).

Let's examine next studies of mere exposure and art. Brickman, Redfield and Harrison (1972) used abstract paintings. If the observers initially rated these paintings as neutral, they liked them more with repeated exposure. If however they initially rated them as negative, they ended up liking them less the more often they were presented. We will now present in detail a study looking at familiarity and representational paintings.

Cutting (2003) was interested in whether people prefer French Impressionist paintings they had seen more often. As his stimulus set he used paintings by eight major artists within this genre. He determined frequency of occurrence based on the number of times these images appeared in an extensive university library book collection. Images were presented in pairs to undergraduates, older adults, and children. Recognition rates were low among the college students at only 3% but higher for the adults at 19%. The older participants preferred the most frequently occurring image of each pair on 59% of all trials, commensurate with the size of the mere exposure effect for other stimuli in the literature. Children showed no preference for the most frequent image. This finding for the children makes sense, as they have been less frequently exposed to paintings. Images from the D'Orsay museum in Paris were not preferred more. Neither were paintings from a prominent collection by Caillebotte. Instead, frequency of occurrence in any form, whether that be a t-shirt, coffee mug, calendar or poster seems to predict preference best.

Cutting (2003) next looked at prototypicality. A prototype is a representative example of a category, usually based on the most frequently occurring items in the category. Our prototype of a bird will thus be closer to a robin than to an ostrich. He had 21 undergraduates in a class on perception view a sequence of 138 French impressionist paintings. They rated them on a scale of one to seven as to how representative they each were of impressionism, what is called a style-typical judgment. Surprisingly, the prototypicality judgments were not correlated with either image frequency or recognition. They were also not correlated with preference or complexity judgments. These results suggest that what people consider representative for this particular style of painting does not correspond to how often they occur. The most prototypical images were by Sisley who is considered one of the less important impressionists. The next most prototypical artists were Monet, Pissarro and Renoir. After that were Degas and Cezanne. The lease prototypical were Manet and Caillebotte.

One hypothesis used to explain preference in art is that "better" paintings get reproduced more often and people simply like better art, not art that is seen more often (Cheetham, 2002). To test this idea Cutting (2003) presented the least frequent French impressionist images from the literature to students. They were presented with greater frequency, singly and without comment as part of a lecture course in perception. Preference for this group of students was now for these images, showing that it is frequency of occurrence and not quality that predicts liking.

Processing fluency has been found to cause positive affect. In the theory, high fluency is a signal that things are familiar and that cognitive processes are running smoothly. In contrast, difficulty of ongoing processing signals that things are not going well. The former situation informs a person that they can continue to do things as they are doing them, applying well-practiced skills. The latter situation tells an individual that something is going wrong and that they need to focus their attention and apply analytical problem solving skills. There are other factors that help to explain the positive affect of processing fluency. One of these is subjective experience. We tend to incorporate our own psychological state into judgments of beauty. The assumption here is that if we feel good when looking at a painting we are more likely to say we like it. Another factor is expectation and attribution. We may be pleasantly surprised if we encounter a new song, and are able to process its structure based on a previously acquired schema, but less so if its structure is unfamiliar.

One might question the processing fluency theory when it comes to abstract art. Because this art is difficult to understand or process, it should be disliked. But level of understanding depends on the observer's prior knowledge. If a person knows something about the style and the artist who produced the work, they will process it more easily. In cognitive terms they have developed a schema for the work, a structural and informational description of it that is held in memory. When they look at the painting this schema is activated. A match between the stimulus input and the schema would occur. This match is more fluent than when an observer has no prior information to judge the work. In that case they may need to search through memory, trying to match the painting against other information like memories of similar paintings. This search is more extensive and may not produce any satisfactory match with which to interpret the work. The result is disfluency, lowered affect and decreased aesthetic ratings. We can refer to this process as semantic coherence.

Artists may deliberately manipulate fluency in order to achieve a desired effect. J. M. W. Turner, in his painting *Snow Storm* paints a scene that is difficult to process (Figure 6.22). One can vaguely make out a shape at the center of the wind and snow that resembles a ship with a pale sun and possible coastline behind it. But this ambiguity reinforces the chaos and fear that a sailor might experience with a snowstorm at sea. Similarly, disfluency in paintings by Robert Pepperell can express uncertainty. Those by George Baselitz can express meaninglessness. These examples show that artists don't always want people to experience their work as beautiful but wish to convey other messages. Difficulty in interpreting their work may be intentional and a desired part of this process.

Figure 6.22. *Snow Storm* by J. M. W. Turner, 1842. We normally like visual images that are easy to process according to fluency theory. This painting by Turner though is difficult to process, invoking a feeling of chaos and fear. This was probably the artist's intent. Public domain image from Wikimedia commons.

Prototype Theory

In prototype theory people prefer objects that are prototypical (Martindale & More, 1988). A prototype is a good example of its category. For example a robin is a better example of the category bird than is a penguin. Farkas (2002) presented surrealist paintings varying in typicality of surrealism as an artistic style. The participants in this study viewed the paintings many times, building up a prototype in their minds that formed a representative painting of the set they viewed. At the end of this presentation they rated how much they liked the paintings. Those they liked the most were typical examples of the set. Since these were new paintings both the familiarity and novelty of the images was controlled for.

Visual Dissonance

Solso (1999) points out a very important psychological principle that can sometimes play out in art. This is visual dissonance. This is defined as a state of psychological tension caused when one experiences a disparity between what one expects and what one actually sees. If we have an unfulfilled expectation, the viewer will try to resolve it, because this state of tension does not feel good. Tension is an aversive state and is to be avoided or resolved. This idea is known as dissonance reduction.

There are three ways to reduce visual dissonance. The first is to reduce the importance of one of the dissonant elements. The second is to reinterpret one or both elements. The third is to change one of the dissonant elements. Solso (1999) illustrates each of these with an example of a painting by Rene Magritte, titled *Not to Be Reproduced*. The image, shown is of a man looking at his reflection in the mirror. The reflection is startling however because it is not his face staring back at him as should normally be the case. The mirror instead shows the man's backside. This should induce a state of dissonance in the observer because it violates our expectation of what mirrors do.

The first method of dissonance reduction is to simply say to oneself that the painting is not important. A person might say to themselves, "Oh, this is just a stupid painting" and move on. The second method of reinterpretation might have our observer realizing there is symbolic content to the image. One might think, "Ah, the man is so ashamed of something he has done, that he cannot face himself". The message of the painting might thus be one of shame or failure to confront our nature. The third method of change might have the observer change their idea of mirrors. Instead of believing that mirrors can only reflect the front side of objects, one could now accommodate this schema to include the idea that they can reflect the backside of objects as well, under certain circumstances.

Emotion, Beauty and Art

Gerald Cupchik's Research

Interest seems to be more of a cognitive aspect of art as it involves thinking about the content matter. Pleasure on the other hand, is believed to be more of an emotional aspect of art as it involves positive affect. Cupchik and Gebotys (1990) explored some of the differences between these two. They had subjects rate twelve paintings on six verbal scales such as uninteresting-interesting, displeasing-pleasing, and simple-complex. They then performed comparison judgments on the stimuli under two instructional sets. In the interest set the participants were encouraged to adopt an intellectual viewpoint emphasizing an objective analysis. In the pleasing instructional set they were encouraged to relate the paintings subjectively and personally.

An analysis showed several dimensions underlying the responses. For the interest set responses indicated a search for knowledge and meaning, especially for complex paintings. Unfamiliar paintings were also found to be more interesting. For the pleasing instructional set there was a dimension that on one end of the continuum involved paintings that were less emotional. These depicted social interactions that were simple and warm. At the other end of this continuum were paintings that were complex, cold and emotionally intense and that embodied negative themes like social isolation and aggression. A second dimension for the pleasing instructional set was labeled aesthetic affectance. This is pleasure that comes from meaningfully interpreting complex and challenging materials. This work shows that it is difficulty to disentangle cognitive and emotional responses to artwork because they are sometimes driven by the same stimulus factor. Complex paintings encourage a search for knowledge (a cognitive response) but they also produce an associated pleasure (an emotional response).

Cupchik and Lazlo (1994) had people read excerpts from short stories that focused on action or experience. They measured reading time and gathered verbal ratings of the texts. Surprising and action-oriented excerpts were read quickly, while the experience excerpts were read more slowly. One interpretation of these results is that surprising texts were overly arousing and so readers passed through them quickly. Experience-oriented readings that encouraged connections with personal episodes might then have produced lower levels of arousal that encouraged further interpretation, slowing reading times.

Art can induce emotional states in us whether we want them to or not in the lab, but we also seek out art in real life to produce emotions based on need (Cupchik, 1995). In this later case we use art to intentionally modulate our state of pleasure or arousal. For example, a person who is lonely and seeking romantic companionship may desire sentimental pleasure by reading a Harlequin romance novel or by watching a romantic comedy. Someone who is bored might choose to increase his or her level of arousal by seeing an action or horror film. So the strength of the art and the need of the individual interact, causing someone to either seek out or avoid art of particular emotional character.

If a person experiences art that is very personally moving and negative (a drama that reminds them of their father's death) they might turn away from the work because it generates too much anxiety or sadness. Under these circumstances the viewer might decide to focus attention on neutral, stylistic aspects of the art such as color or composition in a painting or the use of alliteration in the case of literature. This intellectualization or defensive attentional shift has received support in the literature. Cupchik and Wroblewski-Raya (1998) presented paintings of solitary figures to subjects that were either gregarious or lonely. When told to imagine themselves as the figure in the painting, the lonely students preferred stylistic features to subject matter.

Appraisals and Art Emotions

According to appraisal theory how we evaluate an object or event (an appraisal) determines how we later feel about it (Scherer, Schorr, & Johnstone, 2001). In this theory the emotion we experience to a stimulus is a consequence of how we think about it in terms of our goals. If we encounter an event we appraise whether it further or hinders the goal, whether it can be managed and why it happened. For example if you believe that art is designed to make you think and you see a painting that makes you think then you will experience more positive emotions like satisfaction or happiness. This will motivate you to understand the work and think about it further. In contrast if you think that the goal of art is to make you feel good and you encounter an artwork that you don't understand then you may experience a negative emotion like confusion or anger. This could motivate you to move on to a new painting or leave the museum. Appraisals are subjective. They are based on our expectations, goals, values, beliefs and knowledge. These are going to differ between individuals.

Ludden, Schifferstein, and Hekkert (2008) studied the role of surprise in how people experience consumer products. They created several products designed to violate people's expectations because their visual and tactile properties conflicted. For example, they made a cubic stool that looked like concrete but was soft and cushy to touch. These generated surprise in the participants that in turn motivated them to explore the objects. This exploration then produced other emotions like enjoyment and interest. In appraisal theory these subjects appraised the products as new, unexpected and unfamiliar. This then caused them to appraise their own ability to understand them. If they thought they could, what is called coping potential, they then would explore them further. If they could not understand them they might feel confusion or frustration that could motivate them to avoid the product.

Silvia and Berg (2011) showed film clips to experts in motion picture media who were faculty and graduate students in media studies and to novices. The experts found the movies much more interesting and less confusing, most likely because they appraised they would find them interesting and then appraised that they would be able to understand them, i.e., they probably had greater coping potential. Silvia (2010) obtained similar findings for a complex poem. When information about the poem was supplied it was easier to understand and caused a decrease in confusion and an increase in interest in line with people's appraisals of comprehensibility.

Positive and Negative Emotions

Positive emotions like happiness or contentment in appraisal theory originate from people's concerns, goals, and values. Demir, Desmet, and Hekkert (2009) determined that people have a wide range of goals when it comes to purchase of consumer goods. These can be abstract, like safety and social acceptance. Alternatively they can be concrete, like how easy a product is to operate. When a product satisfied these goals people reported feeling happy, satisfied and content. Parsons (1987) evaluated the goals and values that many people have for art. Some think that art should depict reality and that the extent to which it does this determines the quality of the work. Others think that art can be abstract. After further thought and experience with art, new values and goals can develop. One such expectation is that art should express emotion and that art that evokes emotions is a better form of art. Encountering art of whatever type that meets one's appraisal of it produces positive emotions, but this can change over time.

Artists often seek to trigger negative emotions like contempt, anger and disgust in viewers of their work. Silvia and Brown (2007) showed college students a variety of photographs and paintings including some that were provocative and homoerotic. Anger was associated with appraising a work as incompatible with one's values and as intentionally offensive. Disgust was associated with appraising a work as incongruent with one's values and as inherently unpleasant. They later found that hostile emotions connected with controversial photos produced negative attitudes (a person thinking that a work shouldn't be shown) and behaviors like rejecting an offer to take a free postcard of the work.

Bringing it All Together – Psychology I Chapter Summary

The psychological study of aesthetics is quite broad and includes the study of stimulus characteristics, the person, and the environment. It has old roots but is now becoming an increasingly popular research area. Experiments utilize both real world stimuli with ecological validity as well as simplified patterns to isolate component variables. Empirical aesthetics historically has had many antecedent perspectives and influences ranging from the Gestalt movement to the neurocognitive and evolutionary approaches.

Artists have either consciously or subconsciously utilized many principles of visual perception. These include the use of contrast to enhance a focal point and the use of color theory to place pleasing combinations of colors together. There has been lots of work looking at color to see what individual colors people prefer and what pairs and triplets of color go well together.

Linear perspective is an example of how to introduce depth into a painting and has been used by artists since the Renaissance. Artists also sometime violate the rules of perspective but these typically go unnoticed because it is difficult to compare separate regions of a painting to one another. Artists also use monocular cues like occlusion, relative height, familiar size, shadows, relative size, atmospheric perspective, and texture gradients to induce a sense of three-dimensionality in their paintings.

A sense of motion can be introduced in 2-D artwork and sculpture through the use of suggestive body poses, what is called representational momentum. These have been found to activate the part of the brain that responds to visual motion even when there is no actual movement present. Implied motion can be created also by superimposing a series of still shots to portray an ongoing action. Other techniques used to achieve this effect include forward lean, motion blur and motion streaks.

We are better at recognizing objects when they appear at orientations that provide maximum information and even draw objects from memory that are closer to such viewpoints. We also draw, imagine and view objects at certain preferential sizes. Mice for instance are usually represented at a proportionally smaller size than are elephants.

We often fail to notice large changes to visual scenes, what is called change blindness. To take in an entire scene we make multiple eye movements or saccades to different regions. Artists make more saccades when drawing than non-artists as would be expected if they had to take in more details. When looking at paintings we tend to first scan across it generally to look for regions of interest. This is followed by shorter saccades with longer fixations at those regions. We also tend to look at areas of detail and semantic significance such as the interior of faces and areas of color, luminance, and orientation contrast.

There are many "rules" of composition used in art instruction. These include the positioning of objects at one-third divisions of a canvas and at the distance of the height of the canvas, what is called rabatment. Arnheim thought the center of a canvas and of groups of objects in a scene were of great importance. He believed that objects attract one another as is the case in physics and has illustrated his principles using a variety of different paintings and sculptures.

Balance is also an important principle in composition. Two objects balance one another about an implied center. Observers spend more time looking at balancing elements in a picture. The arrangement of objects in a scene, called spatial composition, also affects perception of a scene. Participants in studies prefer to place a single object at the center of a rectangular frame. Objects that we normally see lower down in a scene are placed lower in a frame and objects that are normally higher up are positioned higher.

Most paintings tend to be lit from above and to the left. Scenes that are illuminated in colored light are judged more aesthetic than those lit up by white light. Low contrast portraits are judged more positively than those in high contrast. We tend to ignore inconsistencies of shadows in paintings. We also fail to notice mirror violations. Mirrors in a number of paintings show a subject's face when physically this should not be possible, yet observers do not notice this discrepancy. Mirrors are a recent invention and we may not have evolved to perceive them accurately.

We tend to like stimuli that are familiar to us. Repeated exposure to a stimulus increases our liking for it, what is called the mere exposure effect. This effect can be explained in terms of processing fluency. Stimuli that are processed more easily are judged more positively, probably because they take less effort. One study has shown that viewers like French Impressionist paintings the greater their likelihood of appearance in books.

According to appraisal theory how we evaluate something determines how we later feel about it. Products that violate our expectation generate surprise and encourage further exploration but only if we think we can understand them. When products satisfy our goals we report feeling happy and satisfied. Images that are incongruent with our values are judged unpleasant, for example when artwork is provocative, or intentionally offensive.

Chapter 7 - Psychology and the Other Arts

Psychology II – Beyond the Visual World

There is a lot of terminology in music, so this chapter provides at the outset a glossary of basic musical terms. Music researchers have studied melody perception, "groove", and how those are affected by expectation. What makes for a likeable song? Research on the topic shows that our musical preferences can start before we are born, based on what we hear while still in the womb. Adult music preferences are affected by many factors such as familiarity, pitch and memory associations. Literature unfortunately, is one of those under-studied areas in science, but that is changing. We look in this chapter at what readers get out of a text, reading, and "flow" states. Film is a very difficult art to study because it is so complex and involves complex collaborations between many people. Nevertheless, we will feature several studies based on database analysis of film characteristics and how those can be used to predict award-winning films. Psychology is also about learning, social, and cultural factors. All of these affect our aesthetic preferences. How does knowledge about art affect the way we perceive it? How do people with greater art experience judge art? How does our perception of art change over the lifespan?

The Psychology of Music

Basic Musical Terms

Music has a language all its own and in order to understand some of what we will be discussing in this section we need to get some basic definitions straight. In the music glossary we provide a list of musical terms. If you are unfamiliar with them we recommend you go to the glossary now and take a few moments to study them. If you are familiar with these terms or want to refer back to them later you can skip the music glossary or use it as a reference.

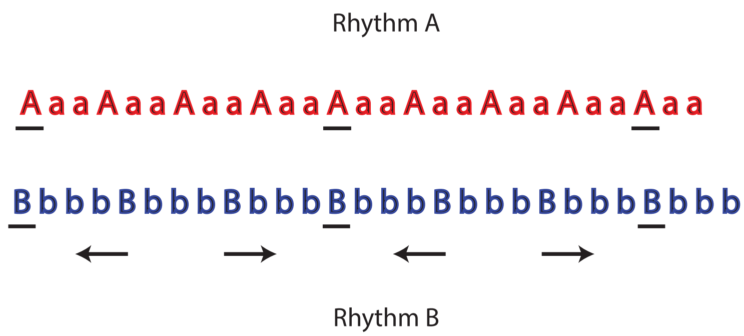
Rhythm Perception

In an old but classic psychology study Bolton (1894) played the simplest rhythm possible. It was just a sequence of identical sounds equally spaced in time. This type of sound has no rhythm. Nevertheless, the listeners reported hearing the sounds in groups of two, three, or four. The first element of a group was heard as being accentuated or stressed, with the remaining elements unstressed. A phenomenon similar to this can occur in a train that is passing over railroad tracks. Instead of hearing clack, clack, clack… we hear CLACK, clack, CLACK, clack… or possibly CLACK, clack, clack, CLACK, clack, clack… Garner (1974) also discovered some interesting findings in rhythm perception. He played simple repeating sound sequences in which the note durations were constant but the spacing between them varied. In these cases, listeners heard the rhythm as starting on the first element of the longest run of notes, what is called the run principle. They also heard the rhythm starting on the element following the longest spacing between notes, called the gap principle. It is as if the auditory system needs a starting point to organize the rhythm and the simplest way to do this is at the beginning of the largest group of notes or after the longest period of silence. Boker and Kubovy (1998) provide an updated, information theoretic account of this process.

A simple repeating rhythm is boring. One way musicians can make music more interesting is to introduce syncopation. This is a violation of expected rhythm. For example, a musician can accent a note that has not yet been accented in the musical piece. Alternatively, they fail to play a note when it is expected. Classical music composers like Bach, Beethoven, and Mozart used syncopation in some of their works. It is also commonly employed in jazz, reggae, and ska music.

Auditory polyrhythms are the simultaneous playing of different rhythms and can be found in the music of countries in West Africa. For example a bass or larger drum could play out one rhythm with an accented beat structure while another, higher pitched drum could play out a different rhythm with a different beat structure. These types of rhythms are more complex to listen to and can demonstrate some interesting properties of the auditory system. Handel and Oshinsky (1981) created syncopated auditory polyrhythms in the lab. An example of one such stimulus would be playing a three-note group sequence with the accent on the first element and a four-note group sequence, also with the accent on the first note. If the two rhythms are played at the outset with the two stressed notes of each sequence coinciding, they will shift in and out of coincidence, only lining up after every five groups in the three group sequence (see Figure 7.1). In between these coincidences they don't line up. The brain apparently doesn't like this and "forces" the accented note of the four group sequence to shift in time either forwards or backwards to line up with the three-group accent. This is apparently a simplification of the auditory input, making the two streams easier process.

Figure 7.1. A three-note rhythm and a four-note rhythm with a stress on the first note of each group. Listeners perceive the stressed elements as aligning in time even though they don't.



Melody

Melody is that sequence of notes that defines a musical piece. One of the very interesting aspects of melody is that it does not rely on absolute frequencies. One can take a melody such as *Yankee Doodle Dandee* and transpose it so it is played in a different key or with different notes. When this is done we have no trouble recognizing it as the same song. This suggests that the auditory system represents melody based on the differences between notes rather than any individual notes in particular. Researchers have also performed tempo transpositions by playing a song at half or double speed or created melody and tempo changes simultaneously and listeners will still continue to recognize it.

Auditory Stream Segregation

In music there are often multiple instruments playing at the same time. In a rock band for instance, there is typically a drummer who creates the rhythm, a bass guitar and one or more lead guitars in addition to singers and perhaps a keyboard player. We hear all of the instruments together as a single sound but if we concentrate we can pick out individual instruments. The way in which we segregate such sounds is called auditory stream segregation (Bregman, 1994). Individual instruments usually sound different based on timbre and are easy to pick apart when they are at different pitches. If the pitches are too similar they will blend together and form a single stream. Sometimes this happens during a rock music performance. The lead guitarist may lower the pitch of his or her notes to match that of the base guitar. In this case the two may become indistinguishable and form a single stream. In this fashion instruments can blend together or move apart, creating interesting effects during the performance.

Music and Memory

There have been a large number of studies looking at the effect music has on memory. Here we will summarize a few of these studies with regard to working memory, verbal and visual memory, and autobiographical memory. Liu et al. (2015) interrupted tasks in young adults with breaks involving eyes-open resting, listening to music, and playing the video game ‘Angry Birds’. The video game led to a decline in task performance in working memory compared to the other two conditions, suggesting that taking a musical break from studying does not necessarily lead to a decline in working memory ability.

Roden, Grube, Bongard, and Kreutz (2014) presented one group of primary school-aged children a music education program and another group a natural science training control program and found working memory improvements in the music program compared to the control group. Other studies have found that musical schooling produces a slight mild effect on the positive recall of tones, while it produces no effect for verbal material (Benassi-Werke et al., 2012). However, Ho, Cheung, and Chan (2003) found that music training improves verbal but not visual memory. Yang, Lu, Gong, and Yao (2016) found that tonal music was more distracting than atonal music on a visual working memory task. Atonal music is that which lacks a tonal center. Most western classical music is tonal and organized around a center. Another study looking at distraction found that working memory performance was better with instrumental music compared to equivalent music accompanied with speech but that it was not better than either silence or speech alone. Familiarity with song lyrics in that study had little effect on performance (Alley & Greene, 2008).

Autobiographical memories are those for personally experienced events as opposed to factual semantic information. Janata, Tomic, and Rakowski (2007) played participants a large sample of popular music and found that on average thirty percent of the songs evoked autobiographical memories. The majority of the songs also evoked mostly positive, strongly felt positive emotions. The third most common emotion reported was nostalgia. Belfi, Karlan, and Tranel (2016) found that autobiographical memories were more strongly evoked by music than by faces, confirming the commonly held intuition that songs we heard in our past can powerfully transport us back to those times. It is believed that songs heard during our adolescence and early adulthood will trigger personal event memories more than from times later in our life. However, this was not the finding of a recent study that showed songs across five decades of our life were good at triggering autobiographical memories (Platz, Kopiez, Hasselhorn, & Wolf, 2015). There is a strong connection between music and emotion, especially for a feeling of nostalgia. Barrett et al. (2010) had participants listen to excerpts of popular music and had them rate how nostalgic each made them feel. The feeling of nostalgia was stronger the more salient, arousing and familiar the song was. In one study participants who experienced nostalgic feelings while this type of music was played recalled memories from their elementary school days more quickly and made fewer memory errors.

Next we will describe memory for music itself. Deffler and Halpern (2011) found that young adults were better at tune recognition than older adults while there was no difference between these two age groups for fact recognition. Changes to timbre and tempo both impair explicit memory for tunes while tempo changes only affected implicit memory for tunes (Halpern & Mullensiefen, 2008). Although older adults show lower overall memory for music there is no difference between memory for music in younger and older adults based on positive vs. negative emotional types of tunes (Alonso, Dellacherie, & Samson, 2015). There is evidence, however, of better memory for music that is more highly arousing . Schellenberg, Stalinski, and Marks (2014) found recognition for melodies presented only twice was worse when changes were made to key and tempo compared to untransformed music. Their results imply that surface features of melodies can be remembered when strong mental traces are not present. Surface features in this case refer to pitch level or key, tempo, and timbre. These features are not necessary for identifying melodies, while relational characteristics between successive tones in pitch and duration are. For more information on this subject see Halpern and Bartlett (2010) who provide a review of the literature on memory for melodies.

Are musicians better than nonmusicians at remembering music? One would think so. Cohen, Evans, Horowitz, and Wolfe (2011) found that musicians have superior auditory recognition memory for both musical and nonmusical stimuli compared to nonmusicians. However, this finding did not generalize to visual stimuli. Jakobson, Lewycky, Kilgour, and Stoesz (2008) found that musicians showed better immediate and delayed recall of word lists. They also, in contrast to the former study, found superior learning of visual designs. Lu and Greenwald (2016) found that adults with formal musical training were better able to extract lexical tone information from print compared to adults without such training. Adult musicians who begin training before the age of seven years did better on a visuomotor task than those who started their training later in life. The results imply that there is a 'sensitive' period in development that produces long-lasting changes in cognitive ability. There is an advantage for long-term verbal memory and for verbal working memory span in musicians, perhaps linked to enhanced verbal rehearsal mechanisms. Ramachandra and Meighan (2012) showed a positive effect for musical training on domain-general central executive tasks. The central executive is that part of working memory that plans and organizes operations. Finally, a study in children shows that participation in an enhanced music curriculum produced improvements in visual as well as auditory memory (Dege, Wehrum, Stark, & Schwarzer, 2011). So in the end, most of these studies show that musical training, especially early on, can produce benefits not just in music- or verbal-related domains but in visual domains as well.

Musical Aesthetics

Development

Believe it or not our music preferences start before we are born. Lamont (2001) found that children recognize and prefer music they were exposed to while in the womb. This means that the auditory system of a fetus is sufficiently developed to develop a memory for music by the age of twenty weeks after conception. In this experiment moms played a piece of music over and again during the last three months of pregnancy. The pieces played spanned a wide variety of genres and included examples from classical, reggae, world beat and top 40. After birth these moms could not play any of the pieces for a period of one year. Then in the lab these pieces were played to the babies along with another control piece of music matched in terms of tempo and style. The babies tended to look longer at a speaker that played the music they were exposed to prenatally. This does not mean that our musical preferences are completely determined by what our moms like, but that this is merely one among a number of influences.

This and other studies have found that babies tend to like faster upbeat music. They also demonstrate preference for consonance over dissonance. The ability to appreciate dissonant music thus appears to be a learned taste that is acquired later in life. Neurons in primary auditory cortex of both humans and monkeys synchronize their firing rates in response to dissonant chords but not to consonant ones. This suggests that there is a neural mechanism for this process but why this should lead to preference is currently unknown.

Children first begin to like the music of their culture (music they are familiar with) around the age of two years. Children also start off preferring simple songs with clear melodic themes and chord sequences that resolve in a predictable way. Following this they begin to like music that is more complex and challenging. Early in life we may also acquire specific musical tastes based on exposure. Hearing jazz often enough in later childhood can set the stage for liking as an adult.

At about the age of 10 or 11 years children begin to show serious interest in music. This is true even for children that didn't show interest in music prior to this point in development. The music we tend to be nostalgic for and like in many cases for the rest of our lives is the music we listened to from this time onward into the teenage years. Marketers are keenly aware of this fact as evidenced by music stations corresponding to different decades, including the '70's (disco), '80's (new wave), 90's (grunge) and others. We also have good recall for songs of this era from our childhoods. The teenage years are emotional and it may be that we associate strong emotions with songs heard during this period making them more memorable. Music also serves a form of social bonding and so we tend to listen to the same music our friends do when we are teenagers.

Taste for new music can be acquired at any stage in our lives but most people have developed their tastes by the age of 18-20 years. Part of this may be because we generally become less open to new experiences as we grow older. There may also be a "critical period" for musical taste. A critical period is a time during which we need to be exposed to something in order to learn it fully. There is a critical period for language acquisition. Children not exposed to language by their early teens never develop adult level language competency. Part of the reason for this is neural maturation. Neurons are still sprouting and forming connections throughout adolescence. This growth slows down after the teenage years.

Adult Musical Preference

Some of our musical preferences are determined by chance: where we lived or went to school, the friends we had and what music they listened to, etc. (Levitin, 2006). But internal personality traits certainly play a role. We have seen that for the visual arts individuals who score high on the trait of openness are more likely to prefer abstract or other novel forms of art. It is thus also likely that more open people will like new forms of music. People who understand more about art show preference for more complex forms than do naïve viewers. So individuals with greater understanding of music would probably be more willing to listen to more complex forms. Most people tend to prefer stimuli of moderate complexity but training and expertise must be taken into account. What is complex for one person may be stimulating and exciting to another.

In general music that is too simple is boring and music that is too complex is confusing. What makes music more familiar and less complex is knowledge. As we learn about music either by reading or repeated listening, we begin to develop a schema for it. Recall that a schema is an organized body of knowledge. A musical schema acts like a template, structuring what we hear and making it easier to understand. A schema for a symphony might be the fact that it contains four movements along with a melodic theme that repeats. Having this knowledge makes what we hear more comprehensible. This in turn can lead to greater liking.

There are certain features of music that affect preference. Music with a high dynamic range (the difference between the softest and loudest parts) may be unacceptable to someone who wants to be in a calm mood. Similarly, this individual may not prefer music with a wide emotional range. We select music that fits our mood. If we are going to the gym we will be biased toward high energy, fast tempo and louder music, perhaps choosing songs from the rock band Guns and Roses. If we want to chill out after work we will more likely prefer softer, slower, more sedate music, perhaps choosing songs by Enya in the new age category.

Levitin (2006) outlines several other features of music that can affect preference. One is pitch. Some people may not like the low thumping bass in hip-hop music. Others may not like the high pitch of a violin or viola in a symphonic piece. This could be due in part to learned associations, both positive and negative, to different instruments. Rhythm is another factor. Some musical styles have very complex rhythms like Latin music that may be difficult to identify for a new listener. In addition there is safety. Safe music is that where we trust the composer and musician. We surrender ourselves to them and allow them to manipulate our emotions. In many cases this surrender allows us to connect deeply with what the song represents, whether that an emotion, political message or spiritual state.

Strong Musical Experiences

The humanist psychologist Abraham Maslow (1976) found that people reported peak experiences most often through music or sex. His criteria for a peak experience had several features. These included: a state of total attention or absorption, disorientation in time and space, an ego transcending experience, (meaning a fusion of the perceiver and the perceived), and feelings of wonder, reverence and humility. These peak experiences were good and desirable, never evil, and were sometimes described as sacred. Panzarella (1980) also studied reports of peak experiences to music and identified several factors. These were: renewal-ecstasy, an altered world perception, motor-sensory ecstasy, physical and intentional physical acts, withdrawal-ecstasy, a loss of contact with the environment, and fusion-emotional ecstasy, a merging with the aesthetic object. The fact that music can produce such reactions in people testifies to its power.

However the most extensive study of such reactions comes from Gabrielsson and Lindstrom Wik (2003) who over a period of many years collected data on the subject from a very large sample of 950 Swedish citizens. They did not wish to impose any preconceptions on the participants and so asked them to describe in their own words “the strongest, most intense experience of music that you have ever had”. They then collected personal and demographic data from each individual through interviews and written reports. The people in the study came from a wide variety of backgrounds and had many different musical preferences. The sample was well represented with regard to gender, age, occupation and musical background. One half of the participants were musical amateurs. The other half was comprised about equally of music professionals and nonmusicans.

The responses were similar to those described by Maslow and Panzarella as well as to Csikszentmihalyi's (1990) concept of "flow", in which a person becomes positively immersed in some action. A summary of the responses yielded several categories. The general features were of a unique, fantastic and incredible experience, of which in some cases words were insufficient to describe. There were physiological reactions like chills. Perceptual responses were not just auditory and included visual, tactile and synesthetic experiences. Cognitively, there were reports of loss of control, changed attitude, and associations with prior memories and thoughts. Emotions were intense and mostly positive. There was also a category of existential aspects where people reported feelings of transcendence and religiosity.

Music of all sorts could trigger these responses and included classical, sacred and religious music, folk, jazz, rock, pop, dance and others. Classical and sacred made up the top two highest examples. Within classical, it was most often triggered by the composers Bach, Beethoven, Mozart and Schubert. In most cases, the music causing the strong experience was in a genre that was familiar and preferred. Only two percent of the responses were negative and of these the feelings were due mostly to non-musical factors. For instance, the music had become associated with negative events like death of a loved one, divorce, unhappy love, war, illness, etc.

Features other than the genre of music could also produce these strong experiences. Examples include performance qualities and special instruments. Factors specific to the person or situation were also responsible. These were state of mind, previous experience, education, personality, being alone or with others, at home or abroad, etc. So the experience was dependent on the right combination of circumstances, described as "the right music for the right person at the right moment". The authors stress that these results are for their sample only and that the results may change if a different sample were tested.

The Role of Expectation

Expectation, Violation and Groove

Listening to music causes us to generate a prediction or expectation about what will happen next. We can anticipate meter and melody in some cases after listening to a song for only a few seconds, especially if we are familiar with it. This is because many aspects of songs are repetitive. In numerous rock songs the drums play out a basic beat while the bass guitar plays a repeating riff. These elements of music provide a framework or skeleton across which other instruments can play. In rock music the lead guitar has more freedom to perform melodic variations and solos, but these are usually linked to the framework established by the drums and bass guitar. Obviously songs vary in their degree of repetitiveness. Techno music is very repetitive while improvisational jazz can be nearly impossible to anticipate. None of these styles of music are inherently good or bad. They are simply different. Learning to like a particular style of music means listening to it enough so that you can form accurate expectations about what will occur.

Composers know that we form predictions about what will happen next in a song and use this to manipulate our emotions. In Western classical music a cadence is a chord sequence that sets up an expectation and then closes with a satisfying conclusion. A deceptive cadence is one that repeats enough to allow the listener to anticipate the satisfying conclusion, but instead ends with an unexpected chord. This chord is still within the key but leaves the listener feeling unsatisfied or surprised. It creates tension and suspends at least temporarily our sense of rest or peace. The composer Haydn frequently made use of the deceptive cadence. Violation of expectation can occur not just for melody, but also for timbre and rhythm as well. In electric blues it is standard for the band to build up momentum and then stop suddenly while the lead guitarist or singer continue on.

The classical composer Schonberg is known for having eliminated expectation altogether. He composed music using scales that lacked a tonic note. As such there is never any feeling of resolution or rest for these works. Listening to this music one gets the feeling of constant unease or of being "adrift". These scales are sometimes used in movie soundtracks to accompany dream sequences or in underwater or outer space scenes to convey weightlessness (Levitin, 2006).

Levitin (2006) discusses an aspect of music related to aesthetics, which is groove. He defines it as that aspect of a song that captures your attention and that engages you completely. While listening to "groovy" music time seems to stand still and the listener doesn't want the song to end. Groove also has momentum in that it drives a song forward. It is similar to a book that you can't put down. Groove is more in the way a piece is performed than in the notation on paper. Examples of songs that have groove are *Super Freak* by Rick James, *Sledgehammer* by Peter Gabriel and *Ohio* by the Pretenders. All of these songs are groovy in different ways, so there is no set method or algorithm for how to perform it.

However songs with groove do have one feature in common and that is subtle violation of expectation. It involves playing a song so that it is mostly the same but different in small ways. An example is a drummer who changes the tempo slightly. When and how these changes are made are often at the discretion of the drummer who implements them based on what else is happening in the song, like points of melodic variation. Drums that have this quality are said to "breath" and are in contrast to songs with constant and precise drumbeats, i.e., those made with a drum machine or synthesizer. This is not to say that songs made with a drum machine are not danceable or good: they are, just for different reasons.

A Model of Expectation for Music

Deliege (2006) describes a model for how we anticipate structure in music. The model involves first abstracting cues based on similarities and differences. These cues are then used to build a schema, or internal representation of musical structure that is used to anticipate what might come next. Music naturally contains regularities, for instance a note with a particular frequency and duration may continue for several beats before changing. This may then be followed by a series of notes with a higher pitch and shorter duration that repeat a different number of times. The auditory system in this case would group each of these notes into separate categories based on their within-group similarities and between-group differences. These two groups may then repeat a given number of times to form an even larger group, meaning that a hierarchical schema would be formed. The basis of the grouping could be the Gestalt laws of proximity and similarity (Lerdahl & Jackendoff, 1983).

In Deliege's theory the cues are emergent structures that produce auditory figure-ground segregation, separating organized musical movements into "objects" that can form schemas and memory representations. This implies that some aspects of a musical piece are processed, perhaps entering conscious awareness, while other notes are not, forming a background against which perception takes place. Deliege likens this process to a form of "natural selection" where by some aspects of the music "survive" and others do not. The emergent structures that survive are then used to create predictions about what notes, chords, melodies, or other sorts of musical structure will occur next.

These ideas have been tested in several experiments. In one, the *Sequenza VI for viola* by Luciano Bero was used (Deliege, 1989). Two expert composers were first asked to indicate where the segmented boundaries of groups in the piece occurred. A group of musicians and non-musicians were then asked to perform the same task. Surprisingly, there was good agreement on how the piece was segmented for both types of subjects. The results suggest that determining boundaries of musical groups is an automatic process and is not affected by training.

In another study participants were asked to recognize motifs (a melodic sequence of notes) in the *Allegro Assai of the Sonata for violin solo* in C major by Bach. The listeners heard the piece played in full. They were then played the motifs and asked to evaluate the frequency of appearance of the motifs in a subsequent playing. Musicians and non-musicians were both fairly accurate at recognizing them. In a second experiment the subjects had to memorize the motif. They were repeated eight times as practice. Then they were asked to recognize different variations of the motifs presented three times at random. The accuracy of response for non-musicians was 90% and for musicians it was near 100%. A similar study was carried out with 9- to 11-year old children (Deliege & Dupont, 1994). Performance was 75% for the non-musicians and 90% for the musicians. These results show that the ability to extract motifs from music and recognize them an automatic, perhaps innate process.

The Psychology of Reading and Literature

What do Readers Get from a Text?

Vipond and Hunt (1984) used a questionnaire to study 150 student readers of a John Updike short story, "A & P". It was hypothesized that the students would understand the story in terms of points. A point is when a reader begins to work out an interpretation of a story, such as an understanding of its theme. The results showed though that only 5% of readers engaged in a point-based reading. The majority however adopted a story-driven approach in which they were centered on the plot and what events were occurring in the story.

Miall and Kuiken (1999) also studied how reading takes place. They had thirty participants read a short story and them make comments about it. The most frequent type of comment (33.6%) was related to explaining a character, for example, wondering why a character in the story had done something. The second most frequent comments were about quotations from the text (21.5%). This suggested the readers were savoring the quality of the writing and thinking about how to interpret certain passages. Following this were comments about local meanings in the text (10.1%), for instance wondering why a particular character had done something. Other examples of comments were related to the reader's emotions, instances of surprise, or writing style. Only 2.1% of the comments were related to points or more literary interpretations of the text such as metaphorical analysis.

Experimental Methods for Investigating Reading

Mial (2006) provides a nice overview of the different methods used in scientific literary analysis. He divides these into four categories. The first involves a manipulation of a text to isolate a particular effect. For example, Hunt and Vipond (1986) presented readers with an original version of a short story containing stylistic and emotional evaluations and an alternate version in which those evaluations were rephrased in neutral terms: "they camped around the room" vs. "they sat around the room. The readers were much more likely to notice and recall the original phrases.

The second major method employed involves the use of an intact, unmodified text. Miall and Kuiken (1994) analyzed a series of short stories in terms of foregrounding. Foregrounding in a text refers to stylistic elements like alliteration and metaphor that are likely to elicit feeling: "dark and twisted branches…" They rank ordered the various texts in terms of the amount of foregrounding. They found that readers spent more time reading texts higher in foregrounding and these textual elements were rated higher in emotion and in how striking they were. This was true regardless of the amount of literary experience the readers had, implying response to foregrounding may be natural and automatic.

The third methodology uses a comparison of two or more texts. Seilman and Larsen (1989) presented a short story with a non-literary expository text, an essay on population growth. The readers made check marks in the margins when a passage reminded them of a personal experience. They were then given a questionnaire about their comments. It was found that readers were able to recall 95% of the marked experiences. The literary text evoked twice as many "actor-perspective" reminders. These were moments about agency or character-based personal events. The expository text elicited more "receiver" markings. These were notes related to things read or heard about. A literary text therefore resonates with an individual's autobiographical experiences.

In the fourth method, readers think aloud about a text while reading it or afterward reading. These comments are then transcribed and analyzed. Andringa (1990) had readers "think out loud" in response to a Schiller short story. The participants in the study ranged from beginning undergraduate literature students to professors. Less experienced readers tending to react with an emotion, causing them to perform an evaluation and then an argument. The think out loud method has the advantage that it generates categories of response that are "natural kinds" and not assumptions brought to the study by the researchers. Examples of these natural kinds include reading resistance, emotional engagement, story-line uncertainty and aesthetic coherence (Kuiken & Miall, 2001).

Issues for the Empirical Study of Literature

Miall (2006) summarizes five issues facing the scientific study of literature. The first is to define what is literary. A question we can ask here is whether "high" literature evokes a different mode of reading than expository readings. The second is to delimit what is literary. This is to understand how literature relates to other forms of language such as media and advertising. There are many questions here as well. How do people choose what to read? What types of media do they choose? In what way are their responses to them different from alternate media like film or video games?

A third issue involves normative assumptions researchers bring to their work. What types of questions should be pursued? Is it more important to look at metaphor or character identification? Concepts from literary theory may bias researchers and turn them away from more significant psychological phenomena. A fourth issue is whether or not researchers should study historical documents or collect data from more contemporary sources. For example, there are three centuries worth of working class memoirs in which reading effects are described (Rose, 2001). Finally, there is the issue of how to apply the findings of scientific literary research. Should the findings be implemented in the teaching of literature?

Reading and Flow

The concept of flow as articulated by Csikszentmihalyi (1990) is an activity that demands a considerable investment of mental energy, but brings little or no conventional reward. Instead, the activity serves as its own reward. Flow is the state of mind that occurs when the challenge of the activity is commensurate with the individual's ability level. If the activity is too difficult or the skill level is too low, then frustration will result. If the activity is too easy or the skill level is too high, then boredom will result. Flow can occur during nearly any activity but engaging with the arts is one of the more frequent categories.

Reading seems a good candidate for the flow experience, as the reader is submerged in the experience, identifies with the protagonists and loses sense of self and time. These are all reported aspects of flow. Reading is believed to change the focus of attention from self to the world of the book. This redirection shields the reader from other demands, whether those are internal and psychological or external, from the environment. This may contribute to the positive affect of the experience.

Van Peer, Mentjes and Auracher (2007) report two studies investigating flow and reading. In the first, the authors wanted to understand some of the general features of reading and flow. They submitted a questionnaire to 150 Germans, mostly young and urban. The results showed that overall women read more often than men. Men read newspapers, journals and informative books more than women. Reading was found to produce higher self-reported states of flow than all other activities: more than sports, a good conversation, driving a car, listening to music, and even more than sex! Readers with frequent flow experienced more intense levels of reading involvement. Also, those who experienced flow in daily life also experienced it more often while reading.

In a second study these authors recruited 50 individuals and asked them to read Bernhard Schlink's novel *The Reader* (*Der Vorleser*, in German). They chose this book because of its popular appeal and because its language and style made it accessible to readers of all levels. The participants were stopped after reading five segments of the novel and asked questions about the experience. When flow was high, readers wanted to continue reading. Conversely, when readers wanted to continue reading their reported level of flow was high. Flow also correlated with reading delight. This delight was not related to the content of the novel, which had a somber and negative ending. Flow must therefore be ascribed to the psychological mechanisms the reader brings to the novel.

Film Aesthetics

Film or cinema has been studied from an aesthetic perspective as well as an approach based on popular culture and norms, investigating topics like sexist stereotypes and gender roles. The sheer complexity of film has served as a barrier. It is a highly collaborative art form with contributions and interactions among a wide variety of specialists like screenplay authors, directors, producers, and actors. Also, films can be on average about two hours long so watching any large number of films for analysis is a very time consuming endeavor.

One methodological approach to get around this is to statistically analyze existing datasets on film. Fortunately this information is widely available in the form of sites like the *Internet Movie Database* and *Metacritic*. Simonton (2004) has adopted this approach. In one study he analyzed 1,132 films released between 1975 and 2002. The sample consisted of English language feature-length films that had received at least one award or nomination in a major achievement category from one of seven established sources like the Academy of Motion Motion Picture Arts and Sciences. A series of measures was defined for categories such as picture, screenplay, direction, male and female leads, cinematography, costume design, score, song and so on. All of the awards categories yielded a consensus and the Oscars provided the best single indicator of overall agreement across all categories. Awards bestowed by the seven rating organizations corresponded with more specialized awards granted by guilds and societies. The awards also correlated positively with later movie guide ratings. However the predictive validity of the honors bestowed by the critics was poor in comparison.

Simonton (2004) next performed a second study of 1,327 English-language narrative feature films released between 1968 and 1999. This time the films were judged based on awards received from organizations such as the British Academy of Film and Television Arts across a wide variety of categories. A factor analysis revealed four clusters. These were dramatic (direction, screenplay, acting categories, and film editing), visual (art direction, cinematography, makeup, and costume design), technical (visual effects, sound effects editing, and sound), and musical (score and song). The dramatic cluster was the most important, followed by visual, technical, and musical. Movies that scored highest on dramatic and visual qualities had the greatest likelihood of getting best picture awards, but of these two dramatic was far more important with an effect size ten times larger. The technical and musical clusters had no influence over best picture awards.

In a follow-up study Simonton (2005) examined the effect of budget, box office, and aesthetic success. A motivating question was whether “blockbuster” films tend to garner awards, given their popularity. Another was if a film’s production budget was related to awards because producers with large budgets may be able to “buy” the best directors and actors. The results showed that production costs were positively related to box office success but they had no correlation with best picture awards and were even negatively correlated with critical acclaim by film reviews and movie guide ratings. Simonton concludes that big budgets go to paying for special effects that then attract moviegoers. But these effects do not influence those who vote for movie awards or write film reviews. There thus appear to be two kinds of film. The first are “art” films that center on drama, the second are popular “entertainment” films. In this study there was very little overlap between the films with the highest budgets and the films with the best critic evaluations (*The Lord of the Rings, Part 1* being the exception). Some of the most critically acclaimed films, like *In the Bedroom*, had the smallest production costs.

Simonton next looked at gender differences in awards. Female actors have shorter careers, earn less money, and play in less desirable roles than their male counterparts (Markson & Taylor, 1993). Does this translate into the number of awards that they receive? The dataset was derived from 2,157 films that received Oscar nominations between 1936 and 2000. There was a significant gender difference. Male actors are far more likely to be in films that receive best picture awards than female actors. This difference held for both leading and supporting actor categories. The gap is best illustrated using Meryl Streep. She claimed more Oscar acting nominations than any other woman in the history of the Academy Awards. However, only a small number of those nominations were for films also nominated for best picture. This gender difference may originate in cultural expectations. Male roles may be more strongly associated with “great” stories than female roles. It is true that best-selling novels tend to have central male characters. “Great films” may be expected to include “great” male actors because these films are consonant with what is an “epic” prototype.

Personality Differences and Aesthetics

Feist and Brady (2004) found that participants in their study preferred realistic to abstract art. This effect was greatest for people low on the openness to experience dimension. Those who scored higher in openness liked every style of art presented, which included realistic, abstract, and more ambiguous forms of art. This preference increased as the art became more abstract. Also students in the study who were more tolerant of political liberalism and drug use preferred abstract art the most. No demographic variables including age, gender, race, income, political and religious affiliation of parents and class and major in school, were associated with preference for abstract art.

Learning about Art

Aesthetic Fluency

Our knowledge and reactions to art are not static. They change dynamically based on new experiences and the development of our cognitive faculties. Both Parsons (1987) and Housen (2005) provide five stage models of how our relation to art changes over time. These models start in childhood and end with a stage in adulthood reached only with broad experience in the arts. Table 7.1 provides a comparison of their two stages. Both are connected to Piaget's (1952) theory of cognitive development, meaning that our ability to appreciate art is based to some degree on having a particular underlying cognitive capacity. Both of these theories attempt to explain how we interpret, understand, and appreciate art.

There is a lot that one can learn about art. It has a history, vocabulary, a list of great artists and artworks, multiple styles, techniques and more. Our capacity to understand and use such knowledge is called aesthetic fluency (Smith & Smith, 2006). It is what we have learned about art, accumulated over years of experience. This experience can take many forms. It can include looking at art in museums or online, taking classes in art history or appreciation, reading books or having conversations. It is for instance, knowing what Pre-Raphaelite is and being able to recognize an example.

Table 7.1. A comparison of Parson's and Housen's development models of art appreciation. From Smith and Smith (2006).

Stage	Parsons	Housen
Stage 1	Favoritism: This stage is associated with young children; paintings exist for pleasure.	Accountive: The viewer creates a narrative of the art. Evaluation is based on what the viewer likes.
Stage 2	Beauty and Realism: Paintings exist to represent things and should be attractive.	Constructive: Personal judgments of whether works of art look like they are supposed to.
Stage 3	Expressiveness: The expressiveness of the painting as it is personally understood is more important than beauty.	Classifying: Works described in art historical terms, using a school, genre, or period as a basis.
Stage 4	Style and Form: Medium,	Interpretative: Personal

	style and form are important. The work of art exists in public and in an artistic tradition.	feelings and meanings guide interpretation of the work.
Stage 5	Autonomy: The individual can transcend traditional and cultural limitations on interpretation of the work.	Re-Creative: Personal meaning combines with broader understandings and concerns.

Smith and Smith surveyed 400 people who visited the Metropolitan Museum of Art. Their attempt was to better understand aesthetic fluency. Individuals were asked how much they knew about a list of artists and art ideas ranging from Egyptian funerary stelae to Isamu Noguchi. Each of the visitors was asked to rate their degree of understanding for each of these concepts on a scale that ran from zero to four. Along with this they collected a variety of demographic information from each participant including questions about their educational attainment and frequency of museum visitation.

The ratings showed that the data existed in three main groups. The topic people knew most about was impressionism. Following this people were about equally knowledgeable about abstract expressionism, and the artists Alessandro Botticelli, John Singer Sargent, and Mary Cassatt. The areas the participants knew least about were Egyptian funerary stelae, Gian Lorenzo Bernini, Fauvism, Isamu Noguchi and Chinese Scrolls. The results also showed that aesthetic fluency was most strongly influenced by museum visitation, followed by training in art history, and then age. There was no relation between general education and fluency. Based on these results the author's conclude that developmental level (as shown in Table 7.1) determines an overall approach and level of sophistication in experiencing art. Level of aesthetic fluency then provides a cognitive and knowledge base to engage in discourse that facilitates understanding. They also relate the growth of aesthetic fluency to vocabulary acquisition: a process that occurs gradually and broadly across the different areas of art.

Art Experience and Training

The nativist fallacy in the study of affective psychology is that objects and events in the environment directly cause our feelings. In this view the stimulus is all-powerful. The complexity, symmetry, or colors of a stimulus create a feeling in us. Studying these properties and manipulating them will therefore allow us to understand why people experience beauty or joy. Silvia (2012) provides two reasons why the stimulus cannot be the only factor however. The first is that the meaning of an aesthetic object changes over time. This is in large part due to culture. The way people reacted to a Clark Gable movie in the 1930's is not the same as how we would react to it now. Cultural values and knowledge continually alter our perceptions of art. The second reason has to do with individual differences. Each one of us independent of culture has our own values, knowledge and beliefs. The way you react to an abstract painting may be quite different from the way your friend your spouse does.

Cooper and Silvia (2009) examined people's hostile feelings toward art by asking a sample of 200 people what they thought of Andres Serrano's photograph *Piss Christ*, probably the most controversial work of art ever created. Piss Christ is a 1987 photograph showing a small plastic crucifix submerged in a glass of Serrano's own urine. Lots of individuals in this sample reported being very angry at this work, perhaps because they were Christians who perceived this as an attack on their religion. However there were quite a few people who reported not being very angry at all. These may have been people with an understanding of contemporary art. This study demonstrates that it is not enough to study the stimulus; we must also study the different types of people who experience art. Silvia (2012) believes that an aesthetic psychology should study more than just mild aesthetic reactions to stimuli, it should open up to include all of our emotional states including shame, disgust, anger, sadness and pride. This is especially true in contemporary art where the intent of the artist is to induce these emotions in the observer.

Artistically sophisticated people have a greater tendency to find complex artworks more pleasing and interesting than do more naïve viewers. There have been a variety of explanations for this effect, including the processing fluency model (Reber, Schwartz, & Winkielman, 2004), schema theory (Axelsson, 2007), and appraisal theory (Silvia, 2005). Given that experts have training and knowledge, they should feel that they are better equipped to understand and appreciate challenging artworks. They should expect to find features interesting in these works that novices cannot. In other words, their appraisals of art will differ from that of novices. An appraisal, as we describe in the section on emotion is how we evaluate something. These expert appraisals tend to generate more positive emotions and they induce greater exploration and thought about the work. Novices appraise art differently. They expect art to make them happy or pleased and when this does not occur they will be more likely to be upset or angry (Parsons, 1987). If a novice does not expect to understand art then when they encounter art they don't understand they will be less likely to explore or make sense of it (Silvia & Berg, 2011).

Many of the studies on expertise have divided participants into two categories, expert and novice or sophisticated and naïve. These categories were based on the amount of formal schooling in art. In fact many people learn about art on their own by through books, the Internet and attending art events at galleries and museums. In order to capture art experience more accurately Smith and Smith (2006) created the Aesthetic Fluency Scale (AFS). This assesses the amount of art knowledge one has through both formal and informal educational processes and expresses it as a continuous amount. Interestingly, university student's scores on the AFS correlate with their score on the openness to experience personality dimension from the Big Five personality test. People who score high on the AFS though were not found to score higher on a measure of fluid intelligence (Silvia, 2007).

Adults without art training will sometimes look at abstract art and conclude that it does not require talent. The phrase "My kid could have done that" has been heard in response to viewing such art. Alvarez, Winner, Hawley-Dolan, and Snapper

(2015) presented abstract art and art by children and animals to adult viewers without extensive art backgrounds. They found that average duration of fixations, total fixation time and the degree to which they looked around all areas of the paintings were greater for the images created by the artists. There was also greater pupil dilation in response to the artist images. When asked to judge the quality of the images the participants consistently picked the works by artists, even when there was no difference in preference between the three categories. So even though adults may not like such work they are capable of discriminating it from similar work by nonartists.

Art Training and Eye Movements

Kristjanson and Antes (1989) examined artist and nonartists who were exposed to familiar and unfamiliar paintings. Both groups fixated the centers of interest in the painting longer and more often than the areas of noninterest. This was especially true during early and late viewing periods. The artists spent more time looking at the familiar paintings whereas the nonartists looked more at unfamiliar paintings. This last effect probably reflects top down knowledge vs. novelty. The artists may have known more about the familiar paintings that drove increased looking time. The nonartists may have sought out more information in paintings they knew less about.

Locher, Krupinski, and Schaefer (2015) had art sophisticates and art naïve observers view paintings that were labeled as authentic, copies or fakes while recording eye-movements. Those who had more art experience showed the longest initial fixation durations. These long dwell times reflect greater visual attention to and interest in certain pictorial features of an artwork. These initial fixations are probably used to develop a "gist" or general understanding of the painting that helps develop an emotional "gut feeling" on whether it is fake or not. Naïve subjects showed greater maximum duration of fixations. This suggests they spent more time attending to the pictorial content, i.e., the various objects in the painting.

Art Training and Perceived Balance

We defined a balanced composition as one in which pictorial elements are balanced about a center. Locher et al. (1996) were interested in differences in perceiving balance between those with and without artistic training. They presented reproductions of 20th century paintings varying in style along with a reconstructed version that was less balanced. Less-balanced works had pictorial elements moved so that they did not balance about a center. The subjects in this study included adults with no formal art training, university faculty who taught courses in design theory, and museum professionals. For each image the observers were asked to indicate the location of the balance point, to assign "weights" to the pictorial elements and regions that contributed to the perceived balance point, and then rate each picture in terms of its overall balance. They found all three types of subjects were in good agreement as to these measures.

In another study Locher, Stappers, and Overbeeke (1999) used compositions in which a major element of the balance structure was removed. The resulting space was filled in to match the background. There were again three groups of subjects: those who had no art training, those who were novices in design and those who where design experts. The task was to place the removed element back into the position of the original composition by the artist. All three groups placed the element back at the proper position intended by the artist. So the amount of art training that one has does not appear to affect one's ability to accurately estimate where major picture elements should be in order to produce a balanced composition.

Arnheim (1974) proposed that balance "hits" the viewer's eye first. He thought it was so important that it would be the first thing a viewer is aware of when looking at a painting, even before awareness of subject matter. A study by Locher and Nagy (1996) addressed this question. The stimuli they used were color and black-and-white reproductions or original paintings and less-balanced versions. Art-trained participants and those with no training in the arts were participants. They rated the compositions for balance at short exposure durations of 100 ms. that would only permit a single glance, and at a longer duration of five seconds that would allow multiple fixations and saccades. Both the naïve and expert groups could reliably tell the difference between the originals and the unbalanced versions and they were able to do so very quickly, at the short exposure condition. The researchers conclude that the visual system processes balance very quickly, using holistic or global information (that from across the entire image, rather than just one part). This happens preattentively, before we can even bring conscious awareness into play. This ability seems to be natural or "hardwired" and does not depend upon training in the arts.

Artistic Development

For some time there has been the idea that children possess a valued aspect of artistic skill that becomes lost as they grow older. This may be based in the Rousseauian notion of the "noble savage" as applied to the child: that creativity and fluency is greatest before the imprint of civilization. At the start of the modern art movement this idea received some popularization due to support from artists like Dubuffet, Klee, Picasso, and Miro (Fineberg, 1997). A quote by Picasso is well known. He said, "I drew like Raphael, but it has taken me a whole lifetime to learn to draw like children".

Gardner (1980) and Gardner and Winner (1982) proposed a U-shaped model of aesthetic growth to describe the change in art ability starting at five years of age and extending until adulthood. In their analysis, young children are more expressively fluid in the way they produce art of all types, including visual arts, language, and music. This gradually decays as they are taught a more literal approach to art during the school-age years. Those that decide to pursue the arts later may then gradually reacquire these skills. Davis (1997) tested this hypothesis by looking at the visual arts of children aged 5, 8, 11, and 14 years old with and without art training to adults who were artists or non-artists. She found a decline in expressive development. This decline persisted in adults who did not pursue artistic training. They were found to have the expressive skills of the 11-year old group. Those who pursued the arts showed a gradual rise and returned to earlier childhood peak.

Environmental and Social Factors Affecting Art Perception

Titles and Names

Millis (2001) had participants view illustrations and photographs with three types of title, either no title at all, a merely descriptive title (Bar Scene), or a metaphorical title (Prohibition). They were asked to describe their aesthetic experience to the art works, whether for example they enjoyed or were interested in the works. He found that only the metaphorical titles led to greater aesthetic experiences, presumably because those titles would elicit additional schematic information that would allow for more elaborative processing. In other words, the participants would bring to bear additional information in memory that would allow them to interpret and think about the work. The effect held for more experienced art viewers but only for representational and not abstract works.

Palmer, Schloss, and Sammartino (2012) investigated how titles can affect the optimal positioning of an object. They presented images of a horse running against a blurred background. The horse was shown as occupying several locations across the horizontal extent of the frame. When the participants received a title implying the horse was losing a race, with the title “Dead last”, the preferred location was near the left, facing inwards placing the horse in a losing position. When the title was “Frontrunner” the preferred location was to the right facing out of the frame, suggesting a winning position. The center position was chosen most often with the use of a neutral title of “Racehorse”. So titles can be powerful enough to override our normal default preferred location for objects as being in the center.

The amount of time it takes to view a painting affects how it is understood. Leder, Carbon, & Ripsas (2006) showed abstract and representative paintings to participants under long viewing conditions (90 seconds) with elaborative and descriptive titles. They found that the elaborative titles increased observers understanding of abstract paintings but not their appreciation. Under short viewing conditions (1 second) descriptive titles increased understanding more than elaborative titles but at medium viewing times (10 seconds) elaborative titles increased understanding more than descriptive titles did. Thus it seems to take an observer at least 10 seconds to assign meaning to a painting beyond mere description.

Knowing who created an artwork also makes a huge difference in how it is interpreted. If a painting is authenticated as having been created by a famous or well-known artist its value will skyrocket. If that same painting is instead deemed to be by a forger it can be worth less than nothing. Both situations have occurred numerous times in history. An American named Teri Horton purchased a drip painting that appeared to be by Jackson Pollock for $5 at a thrift shop in California. Upon investigation, it was rumored to be an original and later was put on sale for

$50 million, although nobody bought it. In the 1940s a Dutch artist Han van Meegeren, painted numerous fake Vermeer paintings. These were accepted by many dealers and experts as real and sold for large sums. Later, when he was exposed as the person who forged them, their value plummeted.

Picture Format and Location

Locher, Smith, and Smith (2001) were interested in whether picture format affects viewer's perception of artworks. They had participants view paintings by Chardin, Christus, Giotto, Rembrandt, van Eyck and Vermeer in three formats: in the the New York Metropolitan Museum of Art, in slide-projected images and viewed on a computer screen. Individuals who were art sophisticates consistently rated the paintings across all formats as more complex, varied, asymmetrical and contrasting than did unsophisticated observers. The works were rated significantly more pleasant, interesting, and surprising when viewed in the original than in either type of reproduced format. So there is nothing "like the real thing" when it comes to viewing paintings. They are universally preferred in a museum or gallery setting. In another study with a different methodology, participants viewed artworks in a museum, as a postcard, on a computer screen or counterbalanced in all three conditions (Hubard, 2007). All of the students who saw the work in three formats preferred the original museum viewing condition to the reproduced conditions. The reasons they gave were that the size, clarity of detail and the fact they were seeing an original made them think they had seen something unique and valued.

We have already seen that people like art more when viewed in museums than when seen in other formats like on a postcard or computer. But museums aren't for everyone. Unfortunately the social status of museums makes some people feel like they belong and others feel excluded (Chang, 2006). People who don't visit museums report feeling that they are formal, formidable places that are for the upper class only. They also feel that people who frequent museums are knowledgeable and dress up when they visit. So non-visitors feel they lack the understanding to appreciate museum art and that they might not fit in with regular museumgoers. It turns out that these assumptions are actually true. Museumgoers are professionals, mostly Caucasian, central city residents with above average educations.

The majority of adult visitors to a museum (as high as 85%) go with a partner, friend or family member (Ballantyne & Packer, 2005). Those who attend on their own have a higher need for cognition than those who attend in groups, are more likely to use audio guides, spend more time reading labels and show a greater desire for learning. Nearly one half of those attending museums as couples report not talking to one another while viewing the art. The reasons for going to museums differ. In one study, those going to a museum with an ancient art collection reported doing so in part to learn about history while those attending a contemporary art exhibition went for the pleasure of viewing the artworks (Mastandrea, Bartoli, & Bove, 2007).

Culture

In the Visual Aesthetic Sensitivity Test 42 pairs of designs were generated with one of each pair considered to be more aesthetic based on the unanimous choices of eight artists (Eysenck, 1983; Gotz, Borisy, Lynn and Eysenck, 1979). This test was administered to people from various cultures. Children who viewed them responded similarly showing that at a young age at least there are similar standards for aesthetic judgment (Iwawaki, Eysenck, & Gotz, 1979). However, there were some notable differences. Japanese children between the ages of 11 and 14 scored higher than British children, but British college students did better than Japanese students implying that education makes a difference. In another study children from Hong Kong and adults from China received lower scores than the Japanese and British, even when they were equated in terms of socioeconomic status (Chan, Eysenck, & Gotz, 1980). We must take these results with a grain of salt however because the test itself was created using western cultural standards.

Cultural beliefs also affect how we interpret situations. In an experiment, researchers showed a video of four fish swimming to Chinese and American viewers (Hong et al., 2000; Morris & Peng, 1994). At one point four of the fish in the video stop and the one in front continues on. When asked to interpret what they had seen the Americans said the fish in front was a leader and showing the other four fish where to go. The Chinese viewers instead saw the four fish as kicking the other fish out of the group. These differences reflect cultural values. In the U.S., independence and individualism are valued highly. In China social harmony and collectivism are instead primary values.

Differences in the appreciation of art also vary by social class. Bourdieu (1985) observed that members of the same social class usually share similar tastes for music. He explains this by saying that the members of a social class learn what the taste of their class should be. The upper classes are supposedly socialized to develop “refined” taste for art and other consumer goods. Some pride is taken in this taste, as it is part of what separates one from other classes. These people would exhibit a disdain even for stereotyped high art like *The Blue Danube* because it is overly popularized. These upper classes thus deliberately choose art that is unfamiliar and hard to process without exposure or training. This goes against the mere exposure effect and processing fluency accounts. The pleasure these upper classes receive may not be so much from actual liking of the art but in the pride it produces. This is discussed further in the section on clothes and fashion.

Postmodern Aesthetics: Modern Art Culture

The postmodern period in art that developed in the late 20th century saw the development of conceptual art, meant to be devoid of aesthetic quality. This art instead was to demonstrate ideas only and not beauty. A good example of this is the work by Joseph Kosuth, titled *One and Three Chairs*, from 1965. The exhibit had a dictionary definition of a chair next to a photograph of a chair next to a real chair. Each time the work was installed a new chair and photo could be chosen. The goal in concept art is to get the observer to think. In this case, one would be motivated to think abstractly about what a chair is. The idea takes precedence over the actual physical form of the work.

Performance art is presented to an audience as fine art and involves a performer or more than one performer acting out. It can be scripted or unscripted, live or by media and take place for any length of time. Traditional theater, dance, and music are by this definition a subset of performance art, but a much more general version of it began in the 1960s and can be considered part of the postmodern movement. Performing artists often challenge their audience to think in about the unconventional. Carolee Schneemann in her early piece titled Interior Scroll performed actions mostly naked designed to raise questions about the female body.

Another feature of the postmodern period is disgusting art. The British artist James R. Ford's 2004 work titled *Bogey Ball* is created from his nose mucus that he had been collecting in a cup for two years. It went on sale for £10,000. The American photographer Andres Serrano is notorious for his shocking photos of cow's heads, corpses and concoctions made of urine, semen and excrement. Serrano received National Endowment of the Arts (NEA) funding to create it his work *Piss Christ*, described previously. The exhibition created such a stir that several politicians threatened to eliminate and/or reduce funding to the NEA.

What is the point of this so-called "shock art"? In many cases it is to make the audience aware of certain social taboos and practices. Marina Abramovi in her 1974 Rhythm 0 piece had people perform minor sexual assaults on her, slice her clothes with razor blades, cut her throat and suck her blood. This example of performance art can be considered a commentary on rape and violence perpetrated against women, perhaps on how it was tolerated or not prosecuted fully at the time.

So the postmodern period can be characterized historically as moving away from art as beauty toward art that makes us think and to art that disgusts. However, there may be a trend now back toward beauty. Arthur Danto in his book Abuse of Beauty introduces the idea of internal beauty. What he means by this is that art can present beauty in a conceptual way in terms of the message it is trying to get across, in addition to a purely sensory form of beauty. Two examples are May Lin's Vietnam Veteran's Memorial and Motherwell's Elegies. One question that arises from this work is whether the most beautiful art is that which portrays beauty at all three levels: sensory, knowledge (concept) and emotional.

Anthropological Conceptions of Beauty and Art

Wahburn (2006) describes how Western conceptions of aesthetics can be misapplied to other cultures. In Western culture, the term aesthetics did not originate until after the Renaissance, when art was commissioned and collected outside of a purely religious context. Thus what may have been judged "beautiful" prior to this period in the West may have been different. Anthropologists focus not on the form of art but more on how artworks are used as part of a culture or society.

For example Melanesian aesthetics is about the capacity to accomplish tasks. Beauty for them is about the process of making and using objects, not just in the object's form (Gell, 1998). For Nilotic speakers of the southern Sudan, beauty focuses on cattle. Beautiful cattle have a glossy sheen, properly shaped horns and fat bodies. These cattle are beautiful not just because they are essential for their survival or because they will bring a good price on the market, but because they are a "feast for the eyes". (Coote, 1992). The Yalngu are an aboriginal people from northern Australia. One form of beauty for them is the brilliance and light associated with ancestral power. The paintings they create possess this power when the paint pigments are crosshatched to produce a shimmering quality. These are inscribed upon boards and bodies as part of a ritual practice.

Washburn (2006) has studied the Hopi Indians of the American southwest. The focus of her research has been on how beauty in that culture is an expression of their spiritual beliefs. Nearly all of what the Hopi do is a reflection of their cosmology and is expressed not just in ritual dance and pottery decoration but in the practices of daily living. In Hopi belief spirits called katsinas observe the people and if they are found worthy, reward them with clouds delivering rain that then brings corn for food. Their appreciation of beauty is seen in their songs, which praise the patterning on butterflies and the colors of flowering plants, both associated with rain. But it is also seen in the actions that bring these events, in the behaviors like planting that are rewarded by the katsinas.

The Hopi ideals that appear in their songs and actions also seem to appear metaphorically in the patterning of ceramics, textiles, and basketry (Washburn, 2006). The same is true of their ancestral peoples, the Huichol in Mexico. The interlocking and reciprocal roles between the Hopi and the katsinas may be reflected in the two-fold rotational symmetry pattern that is found on their artwork such as Sityaki polychrome ceramic design. This bifold pattern is seen more than any other point symmetry type in their art. To sum up the anthropological approach, then one must focus not only on the stimulus but also on the beliefs and practices associated with it.

Bringing it All Together – Psychology II Chapter Summary

We tend to accentuate and group simple rhythms perceiving them as starting on the first element of the longest run of notes or the first note that follows the longest gap. Musical objects can be thought of as streams that play out over time. If these streams are sufficiently different in pitch or timbre they will separate and be heard individually, what is called auditory stream segregation.

The research on music and memory is mixed. Some research shows that music can interfere with a memory task if it is listened to concurrently. Music can elicit autobiographical memories and feelings of nostalgia. Young adults appear to be better than older adults at tune recognition. Musicians are better at auditory recognition than non-musicians as well as on some visual tasks.

Children are better able to recognize and prefer music they were exposed to while in the womb, showing that we have some prenatal musical processing capacity. Babies prefer faster and more upbeat music. Older children prefer songs with a clear melody that resolve in predictable ways. Preference for more complex music appears after this. A serious interest in music occurs at around age 10. Music we have nostalgia for starts from this time onwards. Although we can learn to like new music, stylistic preferences are somewhat fixed prior to the age of 20.

Music that is too simple is considered boring. Music that is too complex can be confusing. Learning about music allows us to understand and better appreciate new forms. A number of factors can affect adult musical preference. These include dynamic range, current mood state, pitch, and rhythm. Peak experiences that are emotionally transcendent can occur while listening to music. This attests to the power that music has over us. Peak experiences can be triggered by any musical style. Contributing factors are the genre, performance, mood, education, and previous experience of the listener. Peak experiences thus seem to happen for a specific song, individual, and moment.

All music has repeating elements which enable prediction and hence anticipation. Violations of expectation create surprise and can make a song interesting. Groove is that aspect of a song that captures interest and is emotionally engaging. Groove can be generated in the way a song is performed as much as in its melodic or rhythmic structure. Groovy songs create subtle violations of expectation.

Readers tend to center on the plot and sequence of events that occur in a story while reading. They also focus on characters, particular quotations of text, local meaning, and emotions. Experimental methods for investigating reading are relatively new but already an established set of methodologies exists. Some of the central issues in the empirical study of literature are on the nature and types of literature itself, how it relates to other forms of language, what elements should be studied, and how to apply findings. Reading produces a state of flow more than most other types of activities. Flow is part of a reader's immersion in a text and makes readers want to continue.

In one study of the statistical analysis of films, it was found that movies that scored highest on dramatic and visual qualities had the greatest likelihood of receiving best picture awards. Production costs were positively associated with box office success but not correlated with awards. In fact they were negatively correlated with film reviews and movie guide ratings. This suggests two types of film. The first are "art" films based on drama. The second are popular "entertainment" films with big budgets and elaborate special effects.

Individuals who score higher on the trait of openness are more willing to like abstract and other forms of ambiguous art. So are people who are tolerant of political liberalism and drug use. Our ability to appreciate art is based to some extent on our cognitive capabilities. Art knowledge or aesthetic fluency is most strongly influenced by museum visitation, art training, and age. Educational attainment in one study was not correlated with fluency. Culture and individual differences can affect our art judgments independently of an art stimulus.

Illustrations and photographs with metaphorical titles lead to greater aesthetic experience probably because they bring conceptual knowledge to bear on the work. Elaborative titles increase observers understanding of abstract paintings but not their appreciation. Paintings are also judged better when viewed in a museum context compared to alternative media. Culture and social class affect our judgments of art.

The postmodern period de-emphasizes the role of beauty in aesthetics. In concept art, the goal is to make the observer think about some idea. Performance artists often challenge the audience to consider the unconventional. Some postmodern art is deliberately intended to disgust, so called “shock” art. Different cultures also have different purposes for art. Melanesian aesthetics is purely functional and focuses on the making and using of objects rather than on their form.

Chapter 8 - Creativity and Conclusions

A New Beginning

There are a number of underserved research areas in empirical aesthetics. Prime among these are an understanding of how each of the specific arts get created. How do painters paint? How do musicians compose? We know in some cases the steps they go through because these are taught as part of art instruction. But what is needed is a deeper understanding, one that involves information processing models and a description of the neural events that underlie such activities. Future research will undoubtedly begin to unravel these mysteries.

We start this chapter with a general description of the psychology of creativity. Then we give examples of how visual art is created and studied along with a discussion of personality differences. The chapter finishes with a summary of several models of art creation and experience. Finally we draw some overall conclusions based on the content of this book.

The Psychology of Creativity

Creativity is a very important trait. It facilitates problem solving of all sorts. It has enabled us as a species to adapt to our environment. We may even owe our continued existence to it. Creativity allows us to transform our environment by imagining what is possible and then solving problems to achieve it. It gives birth to art, but the fine arts are by no means are the only creative field. Creativity exists in all endeavors and is necessary in the fields of science, engineering and technology. It may even be critical for emotional well being (Tiedt, 1976; Torrance & Safter, 1999).

We all use the term creative and seem to recognize someone who is but what exactly do we mean by this term? According to Jeffrey (1999), creativity is the novel arrangement of existing elements. Notice that by this definition nothing totally new can come into existence, because all novel creations involve the assembly of things that are already here. For instance, a painter will arrange existing colors in a unique way to create a painting. A musician will bring together existing notes and chords into a novel sequence. Jeffrey also states that this creation must not be a copy or duplication. He also adds the criterion that it must be considered good or beautiful by an observer or judge. This last part would be considered overly restrictive by modern art standards, depending on one's view, art can inform, disgust, or promote a political view.

Creativity involves rule following and rule-breaking. The former is more important when learning an art for the first time as a student. The latter is more important later in life as an accomplished artist. One can certainly create great art by following existing rules, but this art is ultimately imitative of existing forms and so is not new itself. In order to make a creative contribution to the field one must learn to break the rules, but to break them in interesting and aesthetic ways. An accomplished artist knows how to do this. They know what rules can be broken to introduce a new and worthwhile sort of effect. Breaking rules at random or in a way that doesn't involve understanding what they do won't result in good novel art.

There are two types of creativity (Jeffrey, 1999). In aesthetic creativity, the beauty or goodness of a work is judged subjectively according to an observer's own values. This is an emotional evaluation and is primary in the arts. An example would be judging the goodness of a painting or symphony or film. In analytic creativity, a work's goodness is judged objectively based on a predetermined set of criteria. This is a cognitive evaluation and is primary in science and engineering. An example would be judging how good a car is based on its fuel consumption or how good a bridge is based on its load bearing capacity.

Personality and Creativity

Feist (2010) summarizes his theory of personality and creativity. He sees it as a process that starts with genetics and epigenetics, which are genes and how genes get expressed, both during development (including prenatal) and during normal adult functioning. These affect brain characteristics, which in turn affect four types of traits. These four are cognitive, social, motivational-affective, and clinical traits. These traits then influence creative thoughts and behavior.

Cognitive traits deal with how people process information. The single most important of these is openness. This refers to how imaginative and curious people are. There is a strong linkage between openness and creativity, as we mention elsewhere in this book. The relation between these two variables though is often mediated by intrinsic motivation, which is the drive to do something for internal reasons like the need to self-express, rather than external reasons like money or fame. In fact when people are rewarded to do something, they generally create things judged less creative (Amabile, 1996). George and Zhou (2001) report that creative behavior is highest when participants are given tasks that are open and undefined, suggesting that open creative people may not functional optimally in closed work environments with narrow task demands.

There are a number of social personality traits that correlate with creativity. These are norm-doubting, nonconformity, independence, introversion, aloofness, hostility, coldness, and dominance/self-confidence/arrogance. Highly creative individuals are not social and outgoing but are independent, confident, and assertive (Feist, 1999). They also score high in self-efficacy, which is the belief that one is capable of doing something. This belief in all likelihood gives them the confidence to continue in spite of setbacks. There is also a strong negative relation between creativity and authoritarianism.

Motivational traits are those defined by the desire to persist and be successful in activities, things like being driven, ambitious, and impulsive. Creative artists, scientists, and businesspeople have these traits (Adelson, 2003). There is an interesting psychoanalytic take on motivation, which is the unconscious fear of death and the desire to overcome our limited lifespans (Arndt et al., 1999). This is the need to create a legacy by leaving behind us something to mark our passage through the universe like paintings, poems, and scientific articles.

Clinical traits are those related to psychological disorders. Creative thought and behavior are related to psychoticism. Individuals who score high on this trait are cold, aloof, eccentric, hostile, egocentric, and impulsive (Eysenck, 1990). There is a relationship also between schizotypal personality disorder and creativity (Martindale, 2007). One feature of the schizotypal personality is a lack of latent inhibition, the ability to selectively attend to the most relevant sensory experience and tune out irrelevant information. This may help to explain the ideational fluency of creative people, which is why they are capable of generating a wide array of loosely connected thoughts. Creative artists, more than scientists have elevated schizotypy scores.

Visual Art Creation and Personality Differences

Machotka (2003) reports an interesting study in which she looked at personality differences in artistic creativity. Participants were instructed on the use of Adobe Photoshop, asked to choose a landscape photograph they liked, and to then create a work of art from it using the software. The researchers took notes and made careful observations of the process. Afterward the participants completed a questionnaire on the creative process, their intentions, the meaning of the image and their previous art experience. They were also interviewed from a psychodynamic perspective in terms of their emotional motivations, relationship with their parents and romantic partners, ideas for the future and other topics.

Cluster analysis was performed on the data and yielded seven clusters that represented the ways in which their personalities affected their art works. The first cluster was titled *Narrative informality and compensatory longings*. These individuals had no concern for organization, composition, or texture. They had childhoods characterized by loss and illness and had dedicated their lives to helping others. This was psychodynamically interpreted as reparative wishes. The second cluster was named *Inhibited, disconnected forms and downcast angry lives*. Their images were all disconnected from each other and emotionally downcast and negative. This group seemed to have a seething anger and inconsistent relationships with others. Their childhoods were spent with a cold, or distant or demanding father.

The third cluster of individuals, *Bold, flowing process and the direct expression of emotion*, created images that were spontaneous, original, and fluid. This group seemed to have little control over the expression of their emotions and translated their emotional energy into vigorous graphic gestures. The fourth cluster created images that were highly controlled and so were named *Dense paintings and relentless control*. There was little evidence of the “painter’s hand” in these works. They were cut up, assembled and multiplied in set ways using the software tools. This group seemed to have an emotional distance from others while at the same time treating love as an absolute.

Cluster five created overly organized images that were subdivided and expressed a preoccupation with balance and order. Their pictures were formal and timid, performed in a disconnected manner. This group was named *Imposed order, inhibition, and the acceptance of parental standards*. They all described themselves as meticulous, precise, tidy and perfectionistic, as well as being self-critical. Group six consisted entirely of artists. They showed a tendency to integrate in their images. One subject, for example, attempted to integrate fluid organic shapes with more rigid angular lines. This cluster was named *Consistent style and need to integrate*. The final cluster was number seven. They drew pictures that avoided representation and narration. Their space was lacking in depth and characterized by the use of mechanical devices like filter rather than hands-on methods. Their pictures were abstract in nature. This group seemed to have vague boundaries between themselves and others and relationships of psychological distance. They could have been best described by the term *Emotional vagueness*.

The Investment Theory of Creativity

Sternberg and Lubart (1991, 1995) formulate the investment theory of creativity. Their studies support a description of creative people "buying low and selling high". By this they mean taking on an underappreciated idea and then pursuing it in the face of resistance until it is successful at which point they move on to another novel idea. Creativity in their theory involves the confluence of six related resources. The first are intellectual skills. These are synthetic (seeing problems in new ways), analytic (recognizing which ideas are worth pursuing), and practical-contextual (persuading others). Notice the similarities between these and the three-stage model proposed by Chavez-Eakle (1999). The second is knowledge, which includes learning a sufficient amount in the chosen field. Third are thinking styles, which are preferred ways of using skills. Fourth is personality. Creativity correlates with willingness to overcome obstacles but at the same time taking sensible risks, self-efficacy and tolerance of ambiguity. Fifth is motivation, particularly task-focused motivation. Sixth is an environment that is supportive and rewarding. In the investment model creativity is a decision that an individual makes. Sternberg (2001) and elsewhere have proposed multiple decisions by which one can develop creativity. These are listed in Table 8.1.

Table 8.1. Ways in which one can develop creativity as a decision. After Sternberg (2006).

	Method	**Description**
1.	Redefine problems	Thinking "outside the box"
2.	Question & analyze assumptions	Don't assume or take everything for granted
3.	Sell ideas	Creative ideas must be sold. Other people need to be convinced of their merit
4.	Idea generation	"Brainstorming"
5.	Knowledge boundaries	Learn the literature and familiarize oneself with what others have already done in the field
6.	Identify & surmount obstacles	Persevere in the face of obstacles
7.	Sensible risk-taking	Don't take unnecessary risks
8.	Tolerance of ambiguity	Know that everything cannot be "black and white"

9.	Self-efficacy	Believe in what you are doing
10.	Fit with desire	Do what you love
11.	Delay gratification	Learning to delay rewards
12.	Role model creativity	Teachers and authority figures can develop creativity in others by serving as role models
13.	Cross-fertilize ideas	Think across disciplines
14.	Time for creative thinking	Allow time for incubation and thought. Solutions don't always occur instantaneously
15.	Reward creativity	Teachers and supervisors need to reward creativity in their students
16.	Allow mistakes	Realize that mistakes will happen and allow for them
17.	Responsibility	Take responsibility for both successes and failures
18.	Collaboration	Encourage creative collaboration
19.	Other points of view	Imagine things form other people's point of view. Especially important for children
20.	Person-environment fit	Creativity is often a fit to an environment. What is rewarded in one context might not in another

Other Theories of Creativity

Kozbelt, Beghetto, and Runco (2010) provide a summary overview of ten theories of creativity. There are too many of these theories developed over too many years to be able to do them justice here. Instead we refer the reader to Table 8.2. This lists the type of theory, its primary assertion, key concepts and examples of major studies. Most of these theories have been around for at least several decades. They have considerable research support and span multiple levels of analysis and methodologies. There are other more narrow theories of creativity that focus on a particular subtopic, such as creativity and its relation to mental illness, to personality, to its biological underpinnings, to enhancement through educational intervention, and cultural differences, but these are not mentioned.

Table 8.2. Theories of creativity. After Kozbelt, Beghetto, and Runco (2010).

Category	**Primary Assertion**	**Key Concepts**	**Major Studies and Examples**
Developmental	Creativity develops over time; mediated by an interaction between the person and the environment	Place and family structures Role of play Longitudinal process Multivariate influences	Helson (1999) Subotnik & Arnold (1996)
Psychometric	Creativity can be measured with reliability and validity; differs from related concepts like IQ; domain-specific nature	Statistical reliability and validity Thresholds Domain-specificity	Guilford (1968) Wallach & Kogan (1965)
Economic	Creative ideation and	Macro-level factors	Rubenson & Runco

	behavior is influenced by "market forces" and cost-benefit analyses	Market influences Investment decisions	(1995) Florida (2002) Sternberg & Lubart (1995)
Stage & Componential Process	Creative expression proceeds through a series of stages; the process can have linear and recursive elements	Preparation stages Incubation and insight Verification and evaluation Component mechanisms	Wallas (1926) Runco & Chand (1995) Amabile (1999)
Cognitive	Thought processes involved in creative people and in accomplishments	Remote association Divergent/convergent thinking Metaphorical thinking Metacognitive processes	Mednick (1962) Guilford (1968) Finke, Ward, & Smith (1992)
Problem solving and expertise-based	Creative solutions to ill-defined problems result from rational processes that rely on general cognitive processes and domain expertise	Ill-defined problems Cognitive, computational approach Problem representation and heuristics	Ericsson (1999) Simon (1989) Weisberg (2006)
Problem Finding	Creative people proactively engage in a subjective and exploratory process of identifying problems to be solved	Subjective creative processes Exploratory behaviors On-line discovery	Getzels & Csikszentmihalyi (1976) Runco (1994)
Evolutionary (Darwinian)	Eminent creativity results from the evolutionary-like processes of blind generation and selective retention	Chance-configuration Blind generation of ideas Seective retention of ideas Equal-odds rule Social judgment and chance	Campbell (1960) Simonton (1997)
Typological	Creators vary along key individual differences, which are related to both macro- and micro-level factors and can be classified using typologies	Individual differences Categories of creators Seekers vs. finders Integrate multiple levels of analysis	Galenson (2006) Kozbelt (2008)
Systems	Creativity results from a complex system of interacting and interrelated factors	Evolving systems Domain and field Gatekeepers Collaborative creativity Chaos and complexity	Gruber (1981) Csikszentmihalyi (1988) Sawyer (2006)

The Creation of Visual Art

Our discussion of creativity thus far has been abstract. In the following section we remedy this by examining the steps in the creation of a painting. The steps here are specific to the creation of one type of visual art and do not necessarily apply to other types of art. Music composition for instance, may involve a completely different set of steps. The steps and rules for composing art within a given medium are flexible and in some cases can be violated to produce a particular result. A laudable research goal would be to analyze these across different types of art to see which aspects are universal/domain general and which are particular/domain specific.

Order of Operations

There are numerous books on painting instruction that have been written over the past century. In recent years it seems several new books come out each for one of the painting mediums of oil, acrylic, watercolor and pastels. Despite the difference in these mediums there are a surprising number of commonalities in the procedures. The rules of composition, the use of value, color, and temperature, ways to implement compelling depth, and so on are much the same regardless of medium. In this section we will review some of these procedures and then comment on them (Albala, 2009; Kessler, 1992; Payne, 2005).

Table 8.3 shows the rough sequence of operations most painters go through. We are assuming the painter has already chosen his scene or is working off of a photograph. The first and most important step is to form a set of maps. There are three types. A value map shows the arrangement of dark and lights shapes on the canvas. A color map shows where the different colors will go. There can be multiple color maps, one for each layer in the painting. At a minimum we will assume the artist utilizes two layers. The first is the under painting and the second is the over painting. The artist is ready to begin once these maps are determined; usually by performing several study sketches beforehand. He or she will then sketch in the masses. The masses are the largest collection of shapes in the image. Each mass typically has a different value and color attached to it. Once the under painting is completed the values of smaller shapes in the image are defined. At this point the artist will continue to apply colors/values to further refine the shapes. Only at the end are details applied.

Table 8.3. Order of operations for painting. This is a general sequence and is not followed strictly by all painters.

1. Maps – determine value, color and temperature maps for multiple layers. Values are lights and darks. Colors refer to the hues of the pigment (red, orange, yellow… etc.). Temperature refers to warm and cool colors. Warm colors are red, orange and yellow. Cool colors are green, blue, and violet. These maps are prepared as sketches prior to painting.
2. Masses - Sketch in the largest shapes in the scene.
3. Under painting - Apply primary layer of pigments if desired with proper values. Work on one layer at a time.
4. Darks and Lights - add in the darks, then the half-tones, and then lights in this order. Try not to use more than four or five values in total.

5. General order of operations - big to small, back to front, dark to light and loose to tight.
6. Coverage - work all over the canvas, not in just one area.
7. Strokes - Use appropriate stroke direction and type. Stroke size can be altered by the use of large or small brushes or by using the edge or tip of a pastel stick.
8. Shapes - simplify them if necessary.
9. Push and pull edges - some edges need softening, others hardening based on their distance from the viewer. There should not be spaces between objects. Edges can be lost-and-found.
10. Work on the details – these can be things like individual leaves on trees or blades of grass.
11. Stop early - try not to "noodle" or create "mud". Mud refers to gray areas created when too many colors are added in the same region because opposing colors cancel each other out.

It is important to maintain the proper order of operations while painting. These are rules for which actions should be performed before others. One should work 1) back to front, 2) dark to light, and 3) big to small. Working back to front means starting with the sky, then painting the clouds on top of the sky, then painting the background, mid-ground and foreground. This is done because the edges of objects painted later can overlap with those painted earlier, as would be the case for objects in depth in the real world. Painting dark to light (or light to dark as is also sometimes done) allows the artist to determine the range of values in the painting (how much darker some shapes should be compared to others). Working big to small means starting with large areas and shapes then getting progressively more detailed as one goes along. If a mistake is made, it is always easier to correct it at the larger level, with fewer changes at successively smaller scales necessary.

The global to local nature of painting in which large areas are created before small ones is actually the reverse order that the visual system uses. When processing a scene, the visual system extracts small features, essentially oriented line segments. These are then assembled into larger features like angles. These are in turn organized into even larger features such as the eyes and nose that might make up the mental representation of a face. In painting one works in the reverse direction, putting in the larger groups first, then working on the details within those groups before moving on to even smaller details. The reason is that the visual system doesn't "know" what it is looking at. It must tediously build a representation from the ground up. The painter has the full benefit of a visual system that can identify areas, objects, and other visual features. This enables he or she to start big and work downward which allows for maximum flexibility and economy should a design change be necessary.

Aesthetic Rules

In addition to order of operations, numerous authors suggest the use of compositional and aesthetic rules. These are intended to make the arrangement of shapes, surfaces and textures on the canvas look harmonious. As was the case with orders of operation, there is considerable agreement on what these are. Table 8.4 provides a listing and short description for each. Many research questions can be derived from these rules. One could vary the amount of symmetry or depth in a paint to see how that affects perceived beauty. One could also vary the orientation of major lines to see if diagonals make a painting more exciting or interesting. Are paintings without a focal point less aesthetic? Are more colorful paintings or ones with more saturated colors judged higher in beauty? Although some research on these topics has begun there are many paradigms and lifetimes worth of work to be done here.

Table 8.4. Aesthetic rules for representational painting. Not presented in order of importance or procedural sequence.

1. Space. Divide space into proper sections based on the golden ratio, rule of thirds, rabatment or other methods.
2. Symmetry. Although symmetry looks good for logos and tile patterns, it is to be avoided in paintings because it makes the scene look too simple and lacking in dynamism. Offset objects so they do not balance across the center of the canvas. Introduce irregularities in arrangement, so that for instance a row of trees is not equally spaced.
3. Depth. For realistic paintings introduce depth by using the monocular depth cues discussed in the psychology chapter. In particular, utilize atmospheric perspective by making farther objects lighter, more blurred, and bluer. Warm colors “advance”, cool colors “recede”.
4. Lines**.** This refers to the major lines used in a composition. Diagonal lines are more interesting and dynamic than vertical and horizontal ones. They introduce more energy. S-curve lines are flowing and graceful, circular lines give a sense of full and completeness. Lines that form a triangular shape give a sense of stability.
5. Focal point**.** Use lead-in lines direct the viewer’s eye to the focal point. Objects at the focal point should be higher in contrast. Optionally, regions in the periphery can be more blurred. Don’t overdetail the foreground.
6. Balance. Balance colors and objects across the center of the canvas but don’t have too much balance. See the suggestions by Arnheim on the power of the center. Never put an object in the middle of a scene.
7. Color. Amount of color to put into a painting is a personal choice, but often introducing color into shadows or other regions where it may not be as obvious in a real scene can enhance the image. Painting should be predominantly warm or cool.
8. Lightness. The sky is usually the lightest part of the canvas, followed by the ground and then the hills. Trees and shadows are the darkest. In general, values get darker the more vertical the surface is.
9. Simplicity. Simple compositions are generally better ones. Too many objects or too much texture can be distracting. Reduce clutter. Keep it Simple Stupid (K.I.S.S.).
10. Frames. Square frames are more calm and stable than rectangular ones. Vertical frames carry more energy. Frames should not pull attention away from the canvas. The color in a frame should match a minor color in the scene.

The field of graphic design can also contribute to our understanding of visual aesthetics. Lidwell, Holden, and Butler (2010) list 125 techniques that can be used to increase the appeal of a design or influence visual perception. Some of these have been researched extensively, like the Gestalt rules of grouping, but many have not. For example in area alignment, objects aligned by their areas are judged more appealing or easier to perceive than those aligned by their centers. The Japanese design principle of wabi-sabi has been applied to poetry, but less so to architectural and visual displays. Wabi-sabi invokes aesthetic ideals of impermanence, imperfection, and incompleteness. These descriptions can be operationalized and studied scientifically.

Bang (2016) provides another source of aesthetic design. She states that the upper half of a picture is a place of freedom, happiness, and power, and that objects placed in the top half feel more "spiritual". Conversely, the bottom half of a picture feels more threatened, heavier, sadder, or constrained. Objects placed in the bottom half also feel more grounded. She also states that larger objects appear stronger and that isolated objects appear lonely. These sorts of statements are easily amenable to testing. Much of the work in design can be understood in light of Gibson's affordances, in which we infer an object's functionality based on its appearance.

Techniques Used in the Study of Visual Art Creation

In this section we will look at the different methods that are used to study how art is created. Most of our knowledge about how visual artists create comes from two sources. Archival case studies involve the use of completed art works using different versions of a single painting. In real-life case studies, a variety of techniques are used to record the progressive completion of a work. X-ray analysis and other imaging techniques serve as an additional source of information. We describe examples of these methods in the sections that follow.

Archival Case Studies

An example of an archival case study is Weisberg's (2004) study of Picasso's painting *Guernica*. There are on record forty-five preliminary sketches for the painting and the canvas was photographed eight times throughout its completion. The first eleven sketches were divided between studies of the overall composition and structural organization and its relation to a central figure of a horse. Later on Picasso shifted his attention to the development of individual characters. Weisberg (2004) concludes that Picasso had the "skeleton" of the painting already conceived of in his mind prior to working and so the painting was the elaboration of this idea. He also mentions some of the influences on the work. These were three paintings by Goya as well as one of his own paintings that he had completed earlier, titled *Minotauromachy*. This demonstrates that he was drawing on his prior experiences and understanding of art.

Real-Life Case Studies

Miall and Tchalenko (2001) performed an in-depth real-life case study of the British portrait artist Humphrey Ocean as he completed several works. They used an eyetracker to record his eye movements, a sensor to record the movements of his pencil and a close-up video of the portraits as they were completed. For the first 35 seconds Ocean scanned the blank paper with only occasional looks at the model, suggesting an initial visualization of the composition. While drawing he employed a regular pattern of fixations on the model's face, each lasting 600-1,000 ms. During this period he drew features like the eyes, nose and lips. More complex features such as the hair seemed to require longer fixations. Ocean would repeatedly look back at a particular feature on the order of every five seconds, implying that was the rate needed to refresh his visual memory of that feature.

Yokochi and Okada (2005) also performed a real-life case study of the Chinese ink painter, named here as Mr. K. Their analysis showed that as Mr. K completed a picture, he would move back and forth frequently to view the entire work, adding a few lines here and there. This suggested that he formed the plans for the structural organization of the painting as he went along. In his case, he did begin with a completed image of the artwork in mind. Instead, he went through a cycle of structuring, evaluating the result, then more structuring based on the evaluation. This approach shows a global-to-local scheme in which the larger picture takes precedence.

Cohen (2005) performed an analysis of the drawing process of art and non-art students. They were asked to draw realistic images of male heads, seen in photographs. Eye movements were recorded. The results showed the art students made more visual alternations between the drawing and the stimulus compared to the non-art students. For both groups, increased looking times with the photographs were correlated with more accurate depictions. He makes several conclusions regarding the faster gaze alternations of the art students. First, this provides the visual system with a smaller amount of information that can be transferred to the drawing. Second, it helps to reduce memory distortions because it more rapidly refreshes the information. Third, it helps to reduce context effects of inattentional blindness and void viewing by focusing attention. This focused attention reduces the amount of the image that is "visible".

Much about the artistic process can be learned from the field of design, which includes fields like fashion, graphic design, product design, architecture and engineering. In these areas, concept design starts out with a sketch. These sketches help develop initial ideas that can be returned to later. They also provide cues for structural and functional problems with the product being developed. Sketching is a cyclical process that results in the emergence of new designs and has been likened in the industry to "visual thinking".

Tovey and Porter (2003) studied the drawing process of six automotive designers as they created concept sketches for a car. The process began with the use of structured lines and forms. As it evolved, certain lines were emphasized with darker strokes and form shading. Many designers use computer-aided design (CAD) programs that can be used to generate three-dimensional views. These programs impose more constraints on the design process than freehand sketching. As a result, some have come to criticize these systems, claiming that they actually suppress creativity.

Imaging Techniques

X-ray radiography and infrared reflectography are two techniques that reveal what are called *pentimenti*, images that come before the outermost layer of paint that is visible to the naked eye. These methods allow art researchers to delve into the underpaintings and trace the work's compositional history. One can see for example if one composition was tried but then abandoned. Alternatively, one can see the different stages of a single composition as it progresses, or see if certain colors or values were used but subsequently changed. The X-ray technique was first applied in the 1930s and has since been used to document painting "case histories" for thousands of major and lesser-known painters.

Research and Collaboration

Some artists as we have seen, come into a project with a more or less clear idea of what they want to do. Others have only a vague idea but develop it as they go through the design process. Also the studies reported here were done in the studio, not *en plein air*, as many painters prefer to work. Lighting conditions change quickly outside, so artists must work faster. It is not clear whether this increased speed changes the quality of the artistic process. The work by Machotka (2003) shows the importance of personality and how traits can affect artistic style. In addition to traits there are many personal, cultural and historical events that influence an artist's work. These have been documented extensively for many famous artists like Van Gogh, but there is little applied empirical work in this area.

How can we address these issues? More research needs to be done with real art stimuli: paintings, music, songs, poems and film in addition to the simplified and controlled patterns used in labs. This applies to the art process as well as the stimulus. We need to study art as it happens, in the field. What are the cognitive and neural processes underlying *plein air* painting or musical composition? The research on art has focused more on the perception and not the production side.

One way around these issues is greater collaboration between artists and scientists. C. P. Snow in his 1959 book *The Two Cultures and the Scientific Revolution* believed that intellectual life was split in two between the sciences and the humanities. Both have different methods and ways of seeing the world and people in these two areas do not comingle or understand one another. But science has advanced tremendously since then and has become more accepted and dominant in culture. People on the arts and humanities side are probably more willing to accept scientific scrutiny of their disciplines. Scientists are certainly now more willing to study art and beauty than ever before. We need more scientists in the studio and more artists in the lab.

We also need greater collaboration between the different disciplines studying aesthetics and art. This is in fact the point of this book. Each of these areas on their own has a lot to contribute but working in conjunction they could contribute even more. This model of collaboration has been fruitful in the cognitive sciences. There are barriers to this collaboration given different training and perspectives, but the rewards would be great.

Artistic Models

A theory is a general set of statements about some phenomenon used to derive hypotheses that can be tested. But theories don't often specify the temporal ordering of psychological states. They also usually don't specify the flow of information that occurs during perception, cognition and motor production. This is where models step in. A model is a representation of a system that captures some aspect of how it operates. Models are important because they provide us with a mechanistic description of some psychological process.

Models can be specific or general. The order of operations for the creation of visual art described above can be considered a specific model because it is about painting only. All of the remaining models described below are general models because they can be applied to all of the arts. General information-processing models that capture large aspects of a system are sometimes called cognitive architectures.

We can also distinguish between static and process models. Static models do not convey aspects of how a system changes over time, whereas dynamic models do (Friedenberg, 2009). Dynamic models are sometimes called process models. Process models can be depicted using flow diagrams. These are diagrams with boxes and arrows. The boxes represent computational units and the arrows represent the flow of information between units. In the first section of what follows we describe several general models of creativity. After this we outline several additional models that have been proposed to describe the overall art experience.

Models of Art Creation

Gestalt Models of creativity

The Gestalt psychologists came up with a six-stage process of creativity. This model was based on how animals solved problems. Kohler (1927) set up problem solving situations to apes. For example, he would place a banana hung from a hook on the ceiling. The banana was too high to reach by jumping from the floor, but enterprising chimps were able to use existing materials to get at it. They would pull crates underneath the banana, climb on top of the crates and then knock the banana off the hook holding a stick. Kohler noticed that the chimps attempted to solve the problem at first but then failed. It was only after an insight or "Aha!" moment that they were able to later obtain a solution.

Stage one in this model is interest. This would correspond to a hungry ape being motivated to solve the problem. Stage two was preparation. Here the chimp would make initial attempts at problem solving, but these would result in failure. The third stage consists of incubation. During this time Kohler believed the subconscious mind made attempts to solve the problem while the animal was busy doing something else. Eventually the subconscious mind would "figure it out" and this solution would bubble up into conscious awareness producing the "Aha!" moment called illumination. In stage five, called verification, the solution is tried and found to work. Finally during exploitation, one would apply the ideas in future situations or communicate them to others. Notice that this model applies equally to animals or humans.

Chavez-Eakle (1999) proposes another three stages model of the creative process. In his first stage there is an association and integration. Connections are made between ideas, images, sensations, etc. that are not normally associated. These disparate elements are then integrated. This stage can occur over an extended time period and corresponds roughly to the incubation stage in the Gestalt processing model. Processing here can be conscious or subconscious. In stage two there is an elaboration, a working of the associations and a building a product using the individual's particular skills. This stage is conscious and volitional. Finally in stage three there is a communication in which the creative product is shared with others. This can cause creative processes in them, so creativity in this model is contagious.

Some Other General Models of Visual Art Creation

Mace and Ward (2002) have identified four general phases in the creation of a visual artwork. These are 1) artwork conception, 2) idea development, 3) making the artwork, and 4) finishing the artwork. In phase one, the artist engages in various activities to get a basic concept of what it is they want to do. In phase two they may perform preliminary sketches to determine what idea works best. Once this is decided upon they start creating the work in phase three. At some point the artist decides the work is complete, in which case they will stop, or determine that some aspect of the work is non-viable, in which case they will revert back to an earlier stage. These stages are not static, and feedback loops between them can occur frequently.

Kozbelt and Seeley (2007) have developed the Visuomotor Skill Model of art creation in which there are two main sources of artistic skill. The first is specialized knowledge. This can be acquired through reading and art instruction. This knowledge is initially in declarative form, i.e., one that can be made verbally explicit. After time it is converted into procedural knowledge through practice. Procedural knowledge is for an action or behavior: it involves knowing how to do something. The second type of skill is motor planning, which is also developed through extensive practice. This skill is knowledge for how to control the arms and hand when drawing, for example. These two skills complement one another. Both influence the perception and conception of an artwork as it is developed. This model and the Mace and Ward (2002) model are both supported by the available empirical evidence.

Models of Art Experience

Berlyne's Arousal Model of Art Experience

D. E. Berlyne was a seminal figure in research on aesthetics. His theory of art experience focused on arousal. He believed that the objective, informational properties of aesthetic objects impinged on a person and influenced their level of arousal. This in turn motivated their action causing such behaviors as approaching, avoiding or exploring, and creating a subjective affective experience like interest, pleasure or discomfort. He introduced a set of cognitive variables called collative variables. These were psychological states like novelty, uncertainty, conflict, complexity and so on. All of the collative variables can be considered to be what happens when incoming information doesn't fit with expectation. The dependent measures in his work were self-reports of preference, especially how pleasant a stimulus was. He also measured the amount of time it took to experience a stimulus and physiological measures like arousal. Most of his participants were undergraduate student without extensive experience in the arts.

He formulated a model of the relationship between these variables. As a collative variable like complexity in a stimulus increases, a primary reward system activates. This reward system generates positive affect (good emotional states) and reinforces a behavior such as continued exploration of an object. Over time a second aversive system activates, generating negative affect (bad emotional states) that reinforce an avoidant behavior, motivating the individual to stop exploring. The reward system hits a limit but the aversive system does not. The two superimposed states then form an inverted-U shape over time. This shape describes how one is at first more and more interested in an artwork but then reaches a limit eventually losing interest.

Silvia (2012) provides a nice summary of Berlyne's work in a list of five points that we re-describe here:

1. The collative variables even though they may seem disparate are all inter-related. Factor analytic studies show that ratings of them independently load on the same factor. Manipulation of one set of these variables tends to affect ratings of the others.
2. The collative variables do a good job at predicting pleasing and interesting judgments. The inverted-U effect doesn't always appear. Sometimes the plot is linear and increasing.
3. Pleasantness and interesting responses are different. Interest predicted behavioral exploration measures like viewing and listening time.
4. There are effects of expertise. Experts prefer works that are more complex. This result has held up in contemporary research.
5. He failed to determine a complete psychobiology of aesthetic experience. His model of neural systems underlying reward is not supported by later research.

Berlyne's work impacted on modern aesthetic research both in terms of ideas and in scientific method. His predictions regarding complexity are still being applied today. One can now for instance measure the complexity of a stimulus and use it to predict interesting or beauty judgments. He set the stage for using art-like stimuli in experimental psychology and that one could make judgments of such stimuli. His views on developing an equation for aesthetic judgment are now seen as too simplified. But he solidified the view that art is a field that can be studied rigorously and opened the way for modern empirical aesthetics.

A Cognitive/Affective Model of the Aesthetic Process

Locher (2012) describes three factors that affect a person's judgment of art. First, there is the stimulus itself. This is the song, dance, sculpture, or painting that one experiences. A painting for example has visual features, a structural organization, a style and semantic content that can affect judgment. Second there is the observer him- or her-self with their personality, biases, and knowledge about art. Third, there is the context or setting in which the art is experienced. This could be the frame surrounding the painting, the room it is in or the museum or gallery in which it is being shown. Jacobsen (2006) provides and even more detailed listing of the factors that contribute to an aesthetic experience. These are listed in Table 8.5.

Table 8.5. Jacobsen's (2006) seven factors that contribute to an aesthetic experience.

Factor	**Description**
The Body	The physiology of the observer's brain and body
The Content	The structural qualities or content of the artifact (the art object)
The Person	The individual's personality and preferences
The Situation	The time and place in which the aesthetic experience occurs
Diachronia	Changes in aesthetic behavior over time from the perspective of evolutionary biology
Ipsichronia	The vantage point of comparisons within a given time segment with a focus on social processes, cultures, and sub-cultures
The Mind	As represented by contemporary psychological theories and models

The aesthetic experience with art takes place in two phases, as is believed to happen when anyone encounters a visual stimulus of any type (Locher, Krupinski, Melio-Thoms, & Nodine, 2007). After first exposure to an artwork, the viewer gets an overall impression or gist of the work. This includes a sense of the pictorial content, structural organization, and meaning. This is typically accompanied by an initial emotional response. The second phase consists of focused exploration of the image to obtain more information about it, satisfy curiosity and create an extended aesthetic response. Leder, Belke, Oeberst and Augustin (2004) have developed a multicomponent information-processing model of the cognitive processes that occur across these two stages.

Their model consists essentially of five stages. The first is perceptual analysis. This involves a processing of the stimulus and would include such things like grouping parts into wholes and determining whether a pattern is symmetric. The second stage of implicit memory involves subconscious processing of whether the image is familiar and draws on previous experience. In explicit classification one consciously determines the style of a painting, whether it is impressionist or cubist, for example. It also involves an understanding of the content like whether the painting is a landscape and what objects are in it. In the last two stages of cognitive mastering and evaluation one connects information from the painting to what one already knows. This can result in the recognition of the location or artist. Specific knowledge about the type of art, general factual information one already knows, interest, and personal taste contribute to classification and mastering. The output of the model is an aesthetic judgment, how beautiful one thinks the work is, and an aesthetic emotion, which is an affective state like happiness or gloom.

Continuing with our example of a painting from the visual arts we can examine the content in more detail. Let us suppose we are looking at a painting that is a portrait of Abraham Lincoln. We can think of the image as existing at three levels (Locher, 2012). The first consists of the low level features of the painting. This includes things like lines, texture, shape and color. At the second level would be a holistic representation. This could include objects and object parts such as the eyes and nose of Lincoln's face. At this level one can determine the complexity, contrast and balance present in the painting. In the final level are larger objects and their locations in the image. The overall composition can now be determined, assessing the location of Lincoln's face and body as well as other objects that might be in the background. Semantic processing relates to a meaningful description of the content so this would include recognition that it is Lincoln, knowledge that he was a past president of the United States, etc. Tinio and Leder (2009) describe the different image manipulation procedures that can occur at these three stages and that are important for aesthetics research. They are surface-level processes (sharpness, noise, grain, contrast, color fidelity and saturation), compositional-level processes (cropping, changes to complexity, symmetry and balance) and semantic-level processes (adding or changing of content or changing the locations of objects).

The I-SKE Model

Shimamura has produced a very nice model of the art experience. This model acknowledges that art is a multi-modal process involving perception, cognition and emotion. It also shows the perspective of the art producer and consumer. Shimamura's (2013) process model of how we experience art is called the I-SKE model. This is shown in Figure 8.1. It starts with the artist who has an intention of creating an artwork. The artist could be for example a woman who paints a picture of a tropical beach. She has the intention of creating the work so that others can experience it. The artwork would be the painting itself and the beholder would be an observer looking at the painting in a gallery after it has been completed and framed. Inside the beholder three processes can happen. Sensation corresponds to the process of seeing the painting. This would be for instance noting the turquoise blue of the water and the curve in the trunk of a palm tree. Knowledge corresponds to a conceptual understanding of what is happening in the painting. This would be an understanding that it is a beach, that it is a tropical scene, that one lays down on the sand to sunbathe or goes into the water to swim. Emotion stands for the emotional experience the observer has. In this case it could be a feeling of peace and tranquility. Table 8.6 shows a list of questions based on this model that you can ask yourself when experiencing an artwork at a museum.

Figure 8.1. The I-SKE model of art production and experience, after Shimamura (2012).

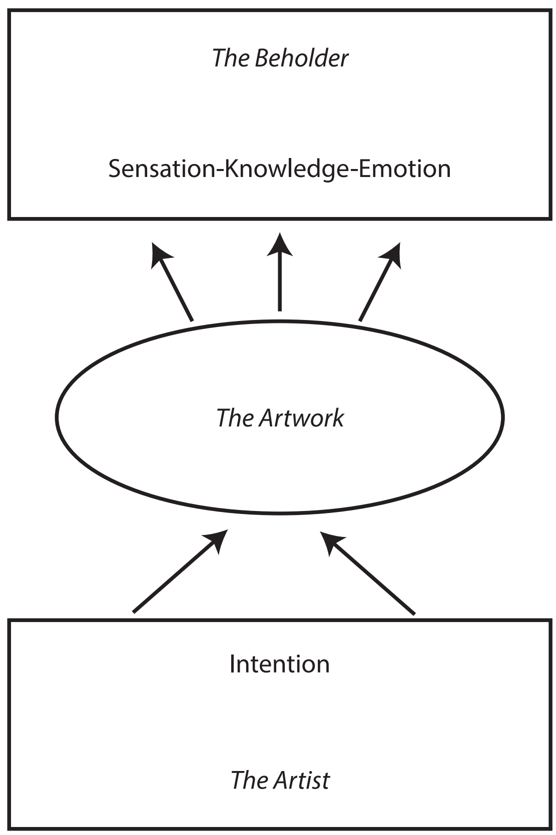


Table 8.6. I-SKE Question set. What to ask yourself at the museum. From Shimamura (2013).

Intention

What do I know about the artist?
What is the historical period or social context?
What is the artist trying to communicate?

Sensation

What is driving the pictorial composition (balance, tension, shapes, colors)?
How is realism represented (linear perspective, shading)?
Is there a grace or flow in the design (is there significant form)?
Where do my eyes move as I look?

Knowledge

What is the meaning or story behind the work?
Does it remind me of any prior experience or concepts?
Does it tell me something about art itself?
Do I find it interesting? Why?

Emotion

Does the artwork arouse me? Does it make me tense or relaxed?
What specific feelings are generated and how did the artist do this?
Do I like it or not? Why?

The End?

At this point we have reached the end. But really we are just at the beginning. It is only in the last few decades that the empirical study of aesthetics, art, and creativity has begun. Researchers of all stripes are now actively investigating symmetry, color theory, composition, and the sublime. We are seeing philosophers, evolutionary biologists, neuroscientists, and cognitive psychologists turning their attention to the study of topics like musical experience, dance perception, and film. Greater collaboration within and between disciplines is needed, as are the formulation of more detailed theories and models, but these will undoubtedly come with time. The future is exciting. We will probably learn more about these subjects in the next century than we have in the past thousand years. We will also likely see new forms of art emerge based on developing technologies and on the knowledge gained from understanding the artistic process. Onwards!

Bringing it All Together – Creativity and Conclusion Chapter Summary

Creativity helps us to solve problems and so is generally adaptive. From an evolutionary point of view it may have helped our species to survive. We find creativity not just in the arts but in all fields of human endeavor, including science, technology, engineering, and math. By one definition creativity is the novel arrangement of existing elements. Creative works follow rules but also break them. An audience almost always judges creative works by either aesthetic or analytic standards.

By one theory, creativity involves the expression of four traits, these being cognitive, social, motivational-affective, and clinical. Personality can affect the way visual art is generated. There are many theories of creativity, each which have research support as well as more specific theories concerning the relation of creativity to more narrow topics like mental illness and culture.

To illustrate the way one type of art is executed we have listed some of the generic steps used in the creation of paintings. Interestingly, the global-to-local nature of painting is the reverse of the local-to-global process of visual perception. In this sense painting can be seen as reverse engineering the neural processes of the visual system.

There are several types of methodology used in the study of artistic creation. These include archival case studies, real-life case studies and imaging techniques. In order to better understand the creative process more research is needed on specific real life works, for example on how poems, music, dance, and theater actually get composed. For this endeavor to proceed we need better collaboration between scientists and artists and between the different disciplines in each chapter of this book.

One way to better understand both creativity and aesthetic experience is to construct models of the sort used in the cognitive sciences. Models differ from theories in that they specify computational steps and a temporal ordering of events. Models can be both informational and neural. Each of these types of model can mutually inform the other. We described several general models of art creation and experience. These need further testing and elaboration to capture the great variety of behavior seen in the arts. If trends continue we will likely see a dramatic increase in our understanding of the arts as well as the emergence of new art forms.

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Appendix. Names and descriptions for each of the seventeen different wallpaper groups.

Group	Description
Group p1	This is the simplest symmetry group. It consists only of translations. There are neither reflections, glide-reflections, nor rotations. The two translation axes may be inclined at any angle to each other. Its lattice is parallelogrammatic, so a fundamental region for the symmetry group is the same as that for the translation group, namely, a parallelogram.
Group p2	This group differs only from the first group in that it contains 180° rotations, that is, rotations of order 2. As in all symmetry groups there are translations, but there neither reflections nor glide reflections. The two translations axes may be inclined at any angle to each other. The lattice is a parallelogrammatic. A fundamental region for the symmetry group is half of a parallelogram that is a fundamental region for the translation group.
Group pm	This is the first group that contains reflections. The axes of reflection are parallel to one axis of translation and perpendicular to the other axis of translation. The lattice is rectangular. There are neither rotations nor glide reflections. A fundamental region for the translation group is a rectangle, and one can be chosen that is split by an axis of reflection so that one of the half rectangles forms a fundamental region for the symmetry group.
Group pg	This is the first group that contains glide reflections. The direction of the glide reflection is parallel to one axis of translation and perpendicular to the other axis of translation. There are neither rotations nor reflections. The lattice is rectanglular, and a rectangular fundamental region for the translation group can be chosen that is split by an axis of a glide reflection so that one of the half rectangles forms a fundamental region for the symmetry group.
Group cm	This group contains reflections and glide reflections with parallel axes. There are no rotations in this group. The translations may be inclined at any angle to each other, but the axes of the reflections bisect the angle formed by the translations, so the fundamental region for the translation group is a rhombus. A fundamental region for the symmetry group is half the rhombus.Group pmm
Group pmm	This symmetry group contains perpendicular axes of reflection. There are no glide-reflections or rotations. The lattice is rectanglular, and a rectangle can be chosen for the fundamental region of the translation group so that a quarter-rectangle of it is a fundamental region for the symmetry group.
Group pmg	This group contains both a reflection and a rotation of order 2. The centers of rotations do not lie on the axes of reflection. The lattice is rectangular, and a quarter-rectangle of a fundamental region for the translation group is a fundamental region for the symmetry group
Group pgg	This group contains no reflections, but it has glide-reflections and half-turns. There are perpendicular axes for the glide reflections, and the centers of the rotations do not lie on these axes. Again, the lattice is rectangular, and a quarter-rectangle of a fundamental region for the translation group is a fundamental region for the symmetry group.
Group cmm	This group has perpendicular reflection axes, as does group 6(pmm), but it also has rotations of order 2. The centers of the rotations do not lie on the reflection axes. The lattice is rhomic, and a quarter of a fundamental region for the translation group is a fundamental region for the symmetry group.
Group p4	This is the first group with a 90° rotation, that is, a rotation of order 4. It also has rotations of order 2. The centers of the order-2 rotations are midway between the centers of the order-4 rotations. There are no reflections. The lattice is square, and again, a quarter of a fundamental region for the translation group is a fundamental region for the symmetry group.

Group p4m	This group differs from 10 (p4) in that it also has reflections. The axes of reflection are inclined to each other by 45° so that four axes of reflection pass through the centers of the order-4 rotations. In fact, all the rotation centers lie on the reflection axes. The lattice is square, and an eighth, a triangle, of a fundamental region for the translation group is a fundamental region for the symmetry group.
Group p4g	This group also contains reflections and rotations of orders 2 and 4. But the axes of reflection are perpendicular, and none of the rotation centers lie on the reflection axes. Again, the lattice is square, and an eighth of a square fundamental region of the translation group is a fundamental region for the symmetry group.
Group p3	This is the simplest group that contains a 120°-rotation, that is, a rotation of order 3, and the first one whose lattice is hexagonal.
Group p31m	This group is similar to the last in that it contains reflections and order-3 rotations. The axes of the reflections are again inclined at 60° to one another, but for this group all of the centers of rotation lie on the reflection axes. Again, the lattice is hexagonal.Group p3m1
Group p3M1	This group is similar to the last in that it contains reflections and order-3 rotations. The axes of the reflections are again inclined at 60° to one another, but for this group all of the centers of rotation lie on the reflection axes. Again, the lattice is hexagonal.
Group p6	This group contains 60° rotations, that is, rotations of order 6. It also contains rotations of orders 2 and 3, but no reflections. Its lattice is hexagonal.
Group p6m	This most complicated group has rotations of order 2, 3, and 6 as well as reflections. The axes of reflection meet at all the centers of rotation. At the centers of the order-6 rotations, six reflection axes meet and are inclined at 30° to one another. The lattice generator is hexagonal.