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Redefining Reality:
The Intellectual Implications of Modern Science

Course Guidebook

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SUPPLEMENTAL MATERIAL

Redefining Reality: The Intellectual Implications of Modern Science

Scope:

In this series of 36 lectures, we examine the ways in which scientific and technological advances in the 20th and 21st centuries have forced us to re-envision what we believe to be real. Our views of reality derive from a number of sources—religious, cultural, political, and so on—but new theories and new tools can lead to conflicts with the picture of the universe we hold. In light of those conflicts, we are forced to develop a novel sense of what the world is truly like. This new sense of things that we derive from science and technology is not removed from the larger social context but is reflected and sometimes foreseen in the arts. In this course, we will look at both the ways in which science has reshaped our understanding of reality and the ways in which these changes have influenced the way we live, our interactions with one another, and the artifacts we create.

We will begin in the first two lectures by discussing what we mean by *reality*, where our traditional Western view of reality comes from, and the ways in which scientific and technological advances interact with our view of reality. On the one hand, science simply comes up with ways of organizing what we see. On the other hand, these organizational structures—what we call scientific theories—can be interpreted as disclosing aspects of reality itself. This interpretive project comes from science but is the work of philosophers. We examine the intersection of the scientific and philosophical projects closely.

In Lecture 3, we examine the state of mathematics at the dawn of the 20th century. With its absolute rigor, mathematics was long thought to be the bedrock of our intellectual framework. But at the beginning of the 20th century, when faced with bizarre results about the nature of infinity and non-Euclidean geometry, mathematicians found themselves in the uncomfortable position of doubting the entire basis for the mathematical program. Their struggle was the first domino, as the foundations of every science would come under scrutiny in the decades that followed.

First to be infected by this radical doubt and the need for complete reformulation were the physical sciences. In the period before the mathematical concerns began, physicists were equally complacent, assured that physics as a science was almost complete. We had Isaac Newton's theory that explained the working of gravitation and mechanics, the theory of motion. We had James Clerk Maxwell's theory that accounted for electrical, magnetic, and optical phenomena. It seemed that we could explain almost everything we see. But the two theories did not quite mesh. Scientists figured that we just needed someone clever to figure out how the pieces fit together. Someone clever appeared in the person of Albert Einstein, but instead of unifying the classical view of physics, he overturned it with his theories of special and general relativity and his proof of the existence of atoms. We will examine each of these and the theory of big bang cosmology that followed from Einstein's work in Lectures 4 through 7.

After Einstein, indeed because of another of his results—the explanation for the photoelectric effect, wherein light when focused on a piece of metal causes electrons to be emitted—the theory of quantum mechanics was developed and turned into quantum field theory. It is a strange picture of our world, in which reality is governed by probabilities that cannot be eliminated by additional knowledge. This leads to a discussion of chaos theory and systems theory, which likewise show us to be living in an intricate and sometimes unexpectedly complex world. We will explore these advances in Lectures 8 through 10 before turning to the recent discovery of dark matter and dark energy in Lecture 11. This sets the stage for a discussion in Lecture 12 of the contemporary project at the heart of physics, the grand unified theory, which seeks a single coherent explanation for all physical phenomena.

But does this encompass all observable aspects of the universe? What about human consciousness? In Lecture 13, we will look at theories that try to explain human thought and the appearance of free will in terms of quantum mechanics. Are our minds reducible to our brains, and are our brains, because they are made up of nothing but atoms, completely open to an explanation on the basis of physical theory?

This question allows us to turn from the physical sciences to the human sciences. In Lectures 14 and 15, we look at the development of evolutionary theory and genetics as giving us accounts of who we are. But we then ask whether the biological aspects of humans constitute a complete description. Could there be elements of ourselves that are more than biological? We turn to developments in psychology in Lectures 16 through 21 to examine the ways in which we were forced to reconsider what it is to be human.

But perhaps this, too, is too small a lens. Perhaps we can understand human nature only by understanding how we interact with one another in groups. In addition to biological facts, culture shapes us, as well. In Lectures 22 through 26, we look at questions raised in sociology, economics, and anthropology: Are we competitive or cooperative by nature? Is race real? Is humanity progressing?

In Lectures 27 and 28, we turn to a larger view of life itself. Where did life on Earth come from? Are we unique? Are we alone? Could there be life elsewhere in the universe?

The final section of the course turns from questions about the nature of reality raised by scientific advances to those that result from technological developments. According to Benjamin Franklin, the only two things in life that are certain are death and taxes. Having considered taxes in an earlier lecture, we now ask: What about death? New advances in medical technology are leading us to reconsider what death is and whether it is necessary. Could we become immortal? Would that be desirable? Advances in technology also lead us to question birth and life. What does it mean to be a parent if seven different people might contribute to bringing a new life into the world? What about the use of genetic engineering and cloning? Has the human being become a blank canvas for us to construct however we choose? These are the topics of Lectures 29 through 33.

In the end, we wonder: Are humans necessary anymore? Instead of thinking about ways in which we can use technology to change ourselves, has technology itself become human? Is artificial intelligence something we should fear or welcome? We consider these questions in Lecture 34. If our technology is not itself human, what about the virtual realities it can create for us? The development of the Internet has given rise to cyberspace, a new location for human life. We interact, we create, and we find ourselves existing in a social world that exists parallel to the so-called "real life" we lead. Is the virtual online world as real as the material world? We consider this question in Lecture 35.

In our last lecture, we look at the ways in which the online world can lead us to predict and manipulate the material world in terms of our digital footprints. Data analytics allows someone to predict our actions with a higher degree of accuracy than we can, and we are the ones who choose our actions. Based on a range of factors, researchers can use big data to tell us what we will buy, what we will eat, and where we will sleep well before we have been confronted with these decisions. Has our technology eliminated our humanity? Is there anything left of the way we thought reality was shaped? These are the provocative questions we will ask in this course. ■

Metaphysics and the Nature of Science

Lecture 1

The study of reality is what philosophers call metaphysics. Although philosophers have traditionally discussed metaphysical questions from a purely conceptual standpoint, advances in science have forced a reevaluation of some traditional metaphysical views. In this lecture, we'll consider the example of the discovery of the germ theory of illness. The discovery of harmful bacteria causing disease forced us to reassess how the human body works and how it relates to the surrounding world. We'll also see the connection between scientific theories and our pictures of reality in the work of historian and philosopher Thomas Kuhn, whose concept of a paradigm illustrates the idea that every scientific theory contains a worldview within it.

Metaphysics: The Study of Reality

- René Descartes, known as the father of modern philosophy, began his intellectual odyssey with this question: How do we know that there is a reality outside our own minds? We each know that we have experiences, and we can be sure of these experiences; therefore, each of us can be sure that we exist. But how do we know that the internal experiences we have correspond to objects outside our minds?

- You can see, smell, touch, and taste a loaf of bread, but those experiences are in your mind, not out in the world. How, then, do you know that there even is a world out there, and if there is, how do you know that it resembles the world of your internal experience? If all of your experiences are in your mind, how do you know that the thing giving you the bread experiences is, in fact, bread?

- Perhaps, Descartes considers, you are merely dreaming or there is an evil demon artificially feeding experiences into your mind, creating a false universe that you wrongly believe is real. Descartes ultimately rejects this hypothesis, in part because there are surprising regularities in our experiences that are beyond our ability to control or create. When we keep careful track of our observations, intricate patterns emerge that can be generalized to systems we had never previously known or imagined.

- The study of these patterns of observations is science. We look at patterns and create theories to explain their appearance. These theories, in turn, posit mechanisms that are supposed to be in the world and are responsible for creating the patterns. We can use those theories not only to explain what we have already seen but to predict new observations we have yet to make. If those predictions come true, we take it as evidence that the mechanisms in the theory are likely an actual part of the real world.

- In this way, we use our best scientific theories to define reality. When we have new theories that replace our old ones, we not only gain new understandings about how our observations relate to each other, but we conceive of the world itself in new and strange ways. This is where science and philosophy meet. Scientists give us new accounts of how the universe works, and philosophers unpack those theories to see what they tell us about what is real.

- In this course, we will look at the ways we have been forced to re-understand reality in the face of science in the 20th and 21st centuries and how that relates to other intellectual endeavors.

The Germ Theory of Illness

- According to Descartes, we are made up of two parts, a body and a mind. The body is mechanical and runs according to the laws of physics. The mind (for Descartes, the soul) is non-material and is where the will resides. For centuries, medical science was based entirely on this picture of the human body as a machine.

- In the 1840s, Ignaz Semmelweis was an Austrian doctor working in the First Maternity Ward at Vienna General Hospital.

  - Semmelweis noticed that the incidence of childbed or puerperal fever was quite high in his ward and, schooled in Descartes's machine view of the body, considered a number of causes for the illness that accorded with that picture.

  - But when another doctor died from childbed fever after being accidentally cut with a scalpel during an autopsy, Semmelweis considered the possibility that the doctors themselves were a vehicle for the ailment.

  - He then demanded that people working on his ward clean their smocks and wash their hands with a chlorine solution before assisting with a birth. Childbed fever cases fell dramatically. Semmelweis had identified the cause of the illness: a type of bacteria present in both dead and infected tissue.

  - This idea, however, was widely rejected. The human was thought to be a machine, and all problems with the machine could only be caused by parts of the machine malfunctioning. The idea that there were tiny animals inside us making us sick seemed silly.

- After Frenchman Louis Pasteur's work, the germ theory of illness became accepted, and we had to change our picture of reality. We were no longer "ghosts in a machine" but castles surrounded by hostile one-celled barbarians. Blood was no longer thought of as oil or hydraulic fluid flowing through our veins; white blood cells were now thought of as armed guards doing battle with tiny invaders. This was a completely different foundation from which to understand human physiology and health.

- In the century that followed Semmelweis, this standpoint led to vaccines that eradicated diseases from smallpox to polio and to new ways of life. Cleanliness was not just next to godliness but the source of continued life itself.

- Not long after the work of Semmelweis and Pasteur, we find the writings of Jules Verne and H. G. Wells, who posited new worlds at the bottom of the ocean, on the Moon, and back in time. It was a period of great discoveries, and the uncertainty associated with seeing that the world contains things we had never seen before was jarring. The entire genre of science fiction grew out of—and was informed by—the need to redefine reality with our scientific advances.

Kuhn's View of Scientific Theories

- In his 1962 book *The Structure of Scientific Revolutions*, Thomas Kuhn notes that when we think of the archetype of the scientist, the people who come to mind are Newton, Darwin, and Einstein. But science as it is done on a daily basis by working scientists is not at all like what those towering figures did. Newton, Darwin, and Einstein are revolutionary scientists whose work is different in kind from what Kuhn calls "normal science." Normal science is quite the opposite of revolutionary.

- Normal scientists work within a paradigm that tells them what counts as a legitimate scientific question, what tools they can use to answer such questions, and what counts as a legitimate answer. In other words, normal science occurs when someone poses a question deemed meaningful by the paradigm and uses the tools prescribed by the paradigm to find an answer that is acceptable within the paradigm.

- Scientists do not question the paradigm. They teach their students how to act according to it, and challenging it is considered a challenge to rationality itself. Rationality, Kuhn argues, exists only within the paradigm. Because the paradigm tells us what is real and how it works, to question it is to question the structure of the world itself; according to those within the paradigm, that leads to nonsense.

- Occasionally, however, anomalies pop up. There are questions the paradigm accepts as legitimate, but when the proper tools are applied, the answer fails to be one the paradigm recognizes. The first reaction is to assume that the normal scientist made an error, but sometimes, even after checking the calculations, the anomaly remains unanswered.

- The unanswered anomalies, according to Kuhn, are ignored for as long as possible, until there are enough of them or they are so significant that they can no longer be discounted. At this point, the scientific community is thrust into a crisis and is forced to reevaluate the paradigm. If the crisis is severe enough, some will consider the unthinkable: using a different paradigm, a new set of basic concepts, a new structure to reality itself.

- These people are seen as nonscientific by those in the community because scientific thought is defined by the paradigm. But if the normal science within the new paradigm starts to look good, some will leave the old way for the new. If a critical mass adopts the new paradigm, the result is a scientific revolution. In the same way that a political revolution completely changes the system of government—that is, one legislative reality is replaced with another—so, too, does a scientific revolution replace one reality with another. Scientific revolutions, according to Kuhn, force us to redefine reality.

Researchers are now seeing relations between microbiome imbalance and a number of diseases, such as Crohn's disease, asthma, and even forms of cancer.

Moving Past the Fortress Body

- The revolution that Semmelweis began seems to have triumphed. Bacteria are outside invaders whose penetration into the interlocked systems of the body must be stopped. But there is also a new paradigm emerging, one in which our bodies are no longer seen as metaphorical castles with bacteria as the bad guys.

- As scientists have started looking at the interaction between medications and the digestive system, they have discovered about 100 trillion bacteria that naturally live in the gut and play crucial roles in the body's ability to function properly. These bacteria break down certain chemicals in our food to new forms that the body can use and create an environment that allows for the immune system to work properly. This ecosystem inside of our bodies, called the *microbiome*, is essential to good health. Bacteria are not evil invaders; some of them are our partners.

- Some bacteria are harmful, and they need to be stopped to cure some ailments, but our weapons—antibiotics—have also been eliminating the bacteria populating the microbiome. We have been harming ourselves by not realizing that we are not just ourselves. We are not individuals but walking communities.

- Interestingly, this redefinition of the idea of a person follows a pattern that we will see repeated throughout this course.
    - We begin with a scientific theory that sees things as atomic individuals; these independent entities are studied closely.

    - Soon, we realize that we cannot understand reality entirely by looking at the pieces; rather, we need to see the pieces in relation to one another. Thus, we begin to look at a more complicated reality in which there is interaction between elements.

    - Eventually, we find that what we have is not a set of individual atomic entities but a complex interrelated system, a web of interdependence.

Suggested Reading

Carter, *Childbed Fever*.

Descartes, *Discourse on Method*.

Kuhn, *The Structure of Scientific Revolutions*.

Suggested Viewing

Fantastic Voyage.

The Matrix.

Questions to Consider

1. We don't believe everything we see. For example, we look in a circus mirror and see ourselves as taller or shorter. How do we determine when what we see is real and when it is a false observation?

2. Kuhn argues that because rationality is defined within a paradigm, there can never be a good reason to radically change your views about the fundamental elements of reality. Is he right?

Defining Reality

Lecture 2

Before we can begin the process of redefining reality, we need to explore the origins of our original definition of it. We begin with the classical Greeks to see how their picture of the world based on the notion of teleology shaped science moving forward. The Greeks gave us a coherent account of astronomy, physics, chemistry, and biology that became entrenched in Western thought and remained largely unchallenged until the Enlightenment and the Scientific Revolution. In the Enlightenment view, humans are rational beings in a rational world that proceeds with mathematical precision according to absolute laws that the human mind can discover. The hallmark of this project is Isaac Newton's laws of motion and law of universal gravitation.

The Ancient Greek Worldview

- The worldview of the ancient Greeks was based on the concept of *teleology*. This is the view that all change is goal directed, that everything happens because of an end that is trying to be achieved. The universe, the Greeks believed, was well ordered and striving for a goal, namely, perfection. When a thing is perfect, it has reached its goal and will never again change, but until then, it will seek a higher state on its way to the goal.

- This teleological view led Plato to express the famous picture of reality set out in his allegory of the cave in *The Republic*. This view contends that there are two worlds: the material world and the realm of ideas.
    - The material world is ever changing, which means that it will never be perfect; it is always corrupted and corruptible.

    - The realm of ideas, however, is different. All material things are part of a species. What defines that species is a set of essential properties. To have real knowledge of a thing is to understand this essence, or form, as Plato called it.

    - Wisdom comes from rejecting the imperfect representations of the forms—material things—and embracing the immaterial forms—the perfect, unchanging ideas of things.

- Like Plato, Aristotle was a teleological thinker. For him, reality strives toward a goal, a perfect, unchanging state. Aristotle also put forth a version of Plato's forms: All things are part of a species, and species are defined by essential characteristics. But where Plato put these idealized essences in a world of their own, separated from our world, Aristotle held that they are simply part of the soul of each thing; they are the thing's potentiality trying to become actualized.

- This essentialism served as the basis for Aristotle's theories of chemistry and physics. For Aristotle, all material things are composed of the four basic elements: earth, air, fire, and water. Each of these four elements has an essence that includes a natural place, the place in the universe where it was meant to be.
    - When Aristotle said that earth is at the center of the universe, he was not making an astronomical claim that the planet Earth is at the center of space. Rather, he was simply making the true claim that dirt falls straight down.

    - The Greeks knew that the Earth is round. If dirt goes straight down no matter where you are when you drop it, then it is always moving toward the middle of the sphere. When Aristotle said that earth is at the center of the universe, he meant that soil will seek its natural resting place and will remain there; that place is at the center of the universe.

    - Water, too, moves straight down, but water's place is not at the center; instead, it sits on top of dirt. Thus, the natural place for water is in a sphere around the natural place of earth. Air, in turn, has a natural place above water, and fire seeks its natural place above the sphere of air.

- All the earthly elements have a natural place, and their natural state of motion is in a straight line to that place, where they then remain at rest. Motion is caused by an internal drive within the object based on its nature.

- The Greeks believed that all the objects close to Earth are made up of the four elements, but extraterrestrial objects—the Sun, Moon, and fixed stars—were made of a different kind of stuff, aether. Because aether is a more perfect element, objects made of it take on a perfect shape, the sphere. Thus, all the heavenly bodies are perfect spheres, and their trajectories are circles, the most perfect two-dimensional paths.

- The problem for Aristotle is that it was known from observation that simple circles did not account for the motions of heavenly bodies. The planets, for example, occasionally exhibit retrograde motions. Thus, Aristotle and others of his time tried to multiply the circles, giving us epicycles, or circles inside of circles.

- Claudius Ptolemy, writing in Alexandra in the 2nd century, finished this project, creating the greatest work of the ancient world, the *Almagest*. This book contains a complete account of the motions of all the objects in the night sky viewable without a telescope. To accurately describe their trajectories, Ptolemy relied on some intricate mathematical tools: epicycles, (multiple sets of circles inside circles), eccentricities (squished circles), and ecliptics (off-center circles). This was the state of science at the beginning of the Christian era.

- In the 5th century, Augustine found in Plato an intellectual foundation for Christianity. Plato's bifurcated world easily mapped onto Christian theology, with a sinful, diseased world and an eternal, perfect world of spirit.

- Thomas Aquinas later reshaped Aristotle to fit Christian belief. Aristotle, for example, has no creation event. The circular orbits of matter made from aether have been happening for an infinite time and will continue to do so. This would not do for Aquinas.

Thus, Aristotle's prime mover, the ultimate cause of the circular motion, became a first cause, the Creator God of the Old Testament. Ultimately, Aquinas's works became official church doctrine.

The Scientific Revolution

- The questioning of this Aristotelian worldview was the hallmark of the Scientific Revolution, and Nicolaus Copernicus was the first major figure to present a substantive challenge to it. Copernicus recognized that Ptolemy's description of the heavens, based on an Aristotelian view, could be greatly simplified by moving the Earth from the center of the universe and having it and the other planets orbit the Sun.

- Not having the Earth as the center of creation was a heretical denial of Aristotle and an insult to God's creation, but this view became increasingly popular among the educated. In his book *The Starry Messenger*, Galileo Galilei documented all the observations he made that contradicted Aristotle. For example, his detailed drawings of the mountains and craters of the Moon defied the Aristotelian view that the Moon is made of aether and, therefore, perfectly spherical.

- Johannes Kepler, a contemporary of Galileo, used the data of the Dutch astronomer Tycho Brahe to establish an account of planetary motion that rid astronomy of the epicycles. By trial and error, Kepler discovered that elliptical orbits with the Sun at one focus would perfectly fit observation. Kepler derived three numerical laws setting out not only the shape of the orbits but relations between the distance from the Sun and the period of revolution.

Galileo's work on Copernicanism caused him to be brought before the Inquisition twice; after his conviction, he turned his attention from astronomy to physics.

- Kepler's results were stunning, but no one knew why they would be true. Aristotle's circular orbits had a philosophical basis—their perfection. The church's adherence to the circles of modified Aristotelianism had a theological foundation. But the reason for elliptical orbits remained an open problem until Newton.

The Revolution of Newton

- Isaac Newton developed a simple theory with four basic laws: three laws of motion and the universal law of gravitation.
    - The first law of motion concerns any object that has no force applied to it. An object not subject to an external force will continue its state of motion at a constant speed in a straight line.

    - The second law of motion describes the behavior of an object that is subjected to an external force. The acceleration of such an object depends on two variables: the force acting on the object and its mass.

    - The third law applies to the force. For every action, there is an equal but opposite reaction.

    - These three simple laws explained a great deal, but they become incredibly powerful when combined with the law of universal gravitation. For any objects with mass, there will be an attraction between them along the line connecting their centers of mass. This attraction is proportional to the product of their masses and inversely proportional to the square of the distance between them.

- When these three laws of mechanics and the law of universal gravitation are used together, they provide an explanation for Kepler's elliptical orbits, as well as the tides, the motion of cannonballs, virtually everything in the world around us.

- Not only were Newton's laws successful in terms of explaining and predicting, but theoretically, they also undermined the foundation of Aristotle.

- Aristotle had said that an object's natural state of motion is at rest in its natural place. Newton has no natural places and says that an object's natural state of motion is in a straight line at a constant speed.

- Aristotle had said that objects move themselves, seeking their natural place. Newton says that an object cannot move itself.

- Aristotle had given completely different accounts for the motions of objects close to Earth and heavenly bodies. Newton's law of gravitation is universal; it applies to everything equally.

- Aristotle's worldview was enforced by the centralized power of the Catholic Church. Newton's worldview came not from authority but from simply observing, something anyone could do.

- Thus, Newton's success supercharged the Enlightenment. The picture of reality that emerged from the Enlightenment is one in which the universe is well ordered according to principles that are accessible to the human mind. This stands deeply opposed to the hierarchical structures found in religion and monarchical governments that were the holders of power at the time. The Enlightenment gave to all people the ability to understand the world.

Suggested Reading

Aquinas, *Summa Theologica*.

Aristotle, *Physics*.

Newton, *Mathematical Principles of Natural Philosophy*.

Toulmin and Goodfield, *The Fabric of the Heavens*.

Questions to Consider

1. The Enlightenment worldview tries to ground the scientific study of planets on the same basis as the scientific study of the economy. Are they similarly based, or do the physical sciences and the natural sciences have different starting points and different rules?

2. With the mandating of Aquinas's Aristotelianism, the church took an official position on science. Did it need to? Is a religious view always tied to a particular view of science? Is a particular scientific view always tied to a particular religious view?

Mathematics in Crisis

Lecture 3

For centuries, mathematics was considered to be the most stable and well-established field of human knowledge. Because its method used deductive reasoning, which gives results with absolute certainty, it was long believed that mathematical knowledge was beyond doubt. But at the end of the 19th century and the beginning of the 20th, several developments shook our faith in the inviolable nature of mathematical reasoning. The emergence of non-Euclidean geometry undermined absolute acceptance of the theory of space and shape that had reigned since classical Greece. Gregor Cantor's work on the nature of infinity forced us to rethink our sense of numbers. And Kurt Gödel's incompleteness theorem cast doubt on the possibility of a completely well-grounded notion of mathematical truth.

Euclidean and Non-Euclidean Geometry

- Since the 3rd century B.C., geometry had been synonymous with the name Euclid. He created a structure for the study based on a few simple and obvious propositions and used a strict means of reasoning to derive hundreds of complex theorems.

- Euclid divided basic truths into three groups.
    - First are definitions, which simply describe what is meant by basic geometric terms. A circle, for example, is the set of points in a plane some distance from a center point.

    - Euclid's axioms were basic truths that were not explicitly geometric. For example, equals added to equals yields equals.

    - The postulates are similar except that they are about purely geometric matters. For example, given any two points, we can draw a line between them. Given any line segment, we can continue the line as far as we want in either direction.

- Euclid's fifth postulate is different from the first four. It states that if two lines are approaching each other, they will eventually intersect. It's usually thought of in terms of an equivalent formulation: Consider a line and a point not on that line. One and only one line can be drawn through the point that will be parallel to the original line.

- This fifth postulate seemed less like the others and more like Euclid's theorems. If it were possible to derive the fifth postulate from the other four, Euclid's system would become even more elegant. For centuries, mathematicians sought proofs of the fifth postulate (the parallel postulate), but it was never found—because it does not exist.

- After mathematicians failed in their attempts to create a direct proof from the first four postulates to the parallel postulate, some had the idea to try an indirect proof. In this method, something is shown to be true by demonstrating that it can't be false.
  - The first step here is to assume the opposite, in this case, that the other four postulates are true and the fifth is false. Then, we derive a contradiction, that is, any sentence of the form "A and not A." Because either A or not A must be true and both cannot be, the contradiction "A and not A" must be false.

  - The existence of this contradiction shows that if the first four postulates are held to be true, then the denial of the fifth cannot be true. But if the denial of the fifth is false, then the fifth must be true. This would show that Euclid could be simplified.

- When mathematicians assumed the first four postulates and the negation of the fifth, they found strange results: There cannot exist triangles with the same angles but different sizes or the internal angles of triangles can add to less than 180 degrees. Such statements seemed as if they were false, but there was never a contradiction that had to be false.

- In the first half of the 19th century, the Russian mathematician Nikolay Lobachevsky and others realized that they had found something incredibly deep and troubling. They had in their hands a new geometry, a non-Euclidean geometry. But if there are two geometries, which one is true?

Cantor and Gödel

- If Euclid's geometry had come under question, at least numbers were thought to be well behaved; they obeyed certain undeniable first truths. Consider Euclid's fifth axiom: The whole is greater than the part. This seems trivial and obvious, but in the second half of the 19th century, German mathematician Georg Cantor showed that it is not the case.

- Cantor first realized that there is a way to compare the size of sets without counting. Two sets are of equal size if there exists a way to map the members of one onto the other so that each element of the first set corresponds to one and only one member of the second with none left over.

- Using this method, Cantor found that an infinite number + 1 yields the same number. That result seems strange, but it makes some sense to think that infinity cannot be made larger or smaller. However, Cantor's work went further.

- Cantor showed that adding the infinite set of rational numbers between 0 and 1 and the infinite set of irrational numbers between 0 and 1 yields a larger infinity. By mapping the rational numbers onto the real numbers, Cantor found that the set of real numbers has at least one number that cannot be in the set of rational numbers. Thus, some infinite subsets are the same size as the sets that include them, and some infinite sets are larger than others. In fact, there would be an infinite set of infinite numbers, and these obey different rules than finite numbers.

- Which number rules are true? The easy answer would be that there is one set of rules for finite numbers and another set of rules for infinite ones. That was the line mathematicians pursued until 1931, when the Austrian mathematician Kurt Gödel proved that we could not establish a complete set of rules for arithmetic.

- Gödel showed that we could use any set of possible rules to create sentences similar to the sentence "This sentence is false." If it is true, then it is false, but if it is false, then it is true.
    - Any attempt to create rules would allow such sentences as "This sentence is unprovable" to be proven; thus, we would have sentences that can be proved but are false. Alternatively, we could strengthen the rules to exclude these sentences, but then, because we can no longer prove the sentence "This sentence is unprovable," we would have true sentences that cannot be proved, making the system incomplete.

    - Any set of rules would either be unsound (include false sentences) or incomplete (not allow all true sentences to be proved).

The Arts and Mathematics

- Interestingly, the collapse of certainty in mathematics is reflected in a pair of notable works of fiction that came from Britain in the late 1800s: Lewis Carroll's *Alice's Adventures in Wonderland* and Edwin Abbott Abbott's *Flatland: A Romance of Many Dimensions*.

- *Alice in Wonderland* was written by Lewis Carroll, the pen name of Charles Lutwidge Dodgson, a mathematical logician at Oxford. Because of the ascent of non-Euclidean geometry and the attempts

In *Alice in Wonderland*, Lewis Carroll plays with the idea that following logic leads us to disappear down a rabbit hole, something that seemed possible given the paradoxes generated by mathematics.

to find a firm foundation for arithmetic in set theory, mathematicians had turned their attention to logic in hopes that an analysis of the nature of mathematical reasoning would yield the justification needed to keep mathematics as the basis of all that was certain.

- The heart of traditional logic is the law of the excluded middle: the claim that either a sentence or its negation, but not both, must be true. Either you have a brother or you do not. If you know that one claim is true, then you know the other is false. And if you know that one is false, then you know that the other is true.

- A paradox is a sentence, or set of sentences, that contradicts itself. That is, it must be true, but its truth implies its falsity. Because the law of the excluded middle holds that a sentence cannot be true and false, paradoxes present an affront to the basis of logic itself. Logicians were examining purported paradoxes generated by the logical system, which if authentic, would undermine the underpinning of our most rigorous form of thought.

- This is also what Dodgson was playing with in his famous work for children. When Alice follows the White Rabbit down the hole, Carroll wrote, "Either the well was very deep, or she fell very slowly, for she had plenty of time as she went down to look about her, and to wonder what was going to happen next."

- Recall that Newton's laws of motion had explained the finding of Galileo that all objects close to the surface of the Earth fall at exactly the same rate. If we take seriously the possibility that Alice is falling slowly, then we take seriously the possibility that the immutable laws of the universe no longer apply.

- We have entered a realm where the Enlightenment presupposition of a well-behaved universe whose rules are accessible to our rational faculties can reasonably be denied. Reason implies nonsense. Reason is not ultimately justifying but ultimately self-defeating. *Wonderland* represents the death of the rationalist project.

- Abbott's *Flatland* takes place on a two-dimensional plane. It is a flat world populated by shapes, the narrator being a square.
  - The square is visited by a sphere, a three-dimensional figure, that appears to the square at first as a point, then a circle of increasing diameter, then a circle of decreasing diameter, then again a point, and finally, a disembodied voice. The sphere tries to convince the square of the existence of the third dimension without any success until he flings the square out of his planar world into space above it.

  - Upon returning to Flatland, the square tries to convince his fellow flatlanders of the existence of a third dimension. He is arrested and charged with heresy by the high priest, and at his trial, he is asked to provide evidence for the existence of the third dimension.

  - The square's argument is mathematical. If we can take a point and move it, we get a line. If we take a line and move it parallel to itself, we get a plane. If we take that plane and move it parallel to itself, we get space. The priest asks for physical, not mathematical, reasoning, but the square can provide none. The priest then argues that there is no reason to think that this mathematical talk is anything but trickery with no relation to anything real.

  - The argument is compelling, although the reader knows it is wrong. But it is reflective of the strange results coming out of mathematics at the time—results that threatened to undermine our certain basis for rationality.

Suggested Reading

Abbott, *Flatland*.

Bell, *Men of Mathematics*.

Carroll, *Alice's Adventures in Wonderland*.

Struik, *A Concise History of Mathematics*.

Questions to Consider

1. Are mathematical truths like other truths of the world? Is there a difference among 4 + 3 = 7, "Napoleon was short," and $E = mc^2$?

2. Given that so much of science uses equations, would the undermining of the certainty of mathematics also undermine science, or because science is based on observation, would its truths remain unaffected?

Special Relativity

Lecture 4

Some scientific revolutions seem to in the air: There is general dissatisfaction with the standard theory, setting the stage for something new. This was not the case when Einstein brought forward his theory of special relativity in 1905. Newton's theory seemed to be working just fine; nonetheless, Einstein proceeded to completely restructure our understanding of such basic notions as space, time, mass, and energy, turning them from absolute facts of the world into more restricted truths about how we see the universe from a particular frame of reference.

Newton's Space and Time

- For Isaac Newton, space and time are absolute and independent entities. Space, Newton thought, is fixed and immovable—absolute. If you had a God's-eye perspective on the universe, you could give every point and object a unique address, locating it in this absolute space. Space is where things are, and all things are located at a specific spot at every instant in time.

- Time, too, is absolute. It flows constantly and regularly. Time ticks off, moment after regular moment, and we can talk about what is happening at every point in space at any one moment. What happens at those points is governed by the three laws of motion and the law of universal gravitation.

- These rules give the same results for all observers moving relative to each other in a straight line at a constant speed, but this presents a problem: The laws do not allow us to find out which observer is at rest. That is, we could never find out whose space is absolute space. If absolute space is real, then our science should be able to determine its properties. But Newton's theory—because it holds equally well for everyone moving at the same speed—cannot do this.

Maxwell's Theory of Electromagnetism

- Scientists thought that the physical world was made up of two categories of forces. Motion and gravitation were covered by Newton's theory. Electricity, magnetism, and light were explained by four equations named for the Scottish physicist James Clerk Maxwell.
    - These equations discuss the relation between changing and unchanging electrical and magnetic charges. When the amount of electricity changes, it results in a magnetic field. When the amount of magnetism changes, it results in an electrical field. Put these laws together, and you get the equation that governs the behavior of light, which has the form of a wave equation. Thus, light was thought to be an electromagnetic wave.

    - Add to this the various ways that light adds, subtracts, and interferes with light from other sources, and physicists were sure that light was a wave of electromagnetic energy.

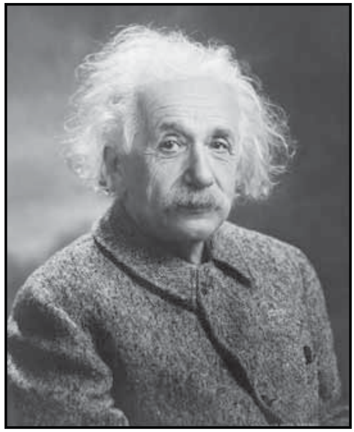
- But waves need something to do the waving. Sound, for example, is made up of waves in air. Without air, there is no sound. We get light from stars across vast regions of seemingly empty space. This must mean that space isn't actually empty but filled with something that can carry the electromagnetic waves. This something was called the light-bearing, or "luminiferous," aether. Finding evidence of it became a major task for physicists in the 19th century.

- The aether had to exist not only because waves need a medium, but because of a strange quirk in Maxwell's laws: the result that the speed of light is a constant. If this were true, physicists thought that it must be constant with respect to something, and that something was the luminiferous aether.

- If the luminiferous aether was just an aspect of Newton's absolute space, then by detecting it and finding its properties, physicists would have experimental confirmation for Newton's state of absolute rest. Without the aether, there was no reason to believe that space exists as a real thing in itself, as Newton had held.

Einstein's Theory of Special Relativity

- Einstein rejected the idea of a luminiferous aether, preferring a picture of reality that he thought was simpler.
    - Consider a magnet and a coil of wire that is connected to a circuit. If you hold the coil of wire still and move the magnet back and forth inside, you create a current in the circuit. If you hold the magnet still but move the coil around the magnet at the same rate, you get the same current. It doesn't matter which one is moving, just that they move relative to each other.



After glancing back at the clock tower as he was walking away from a train station, Einstein realized that durations could change according to the speed of the observer; time is a function of one's state of motion.

    - But Maxwell's equations give different explanations for the different cases, different explanations if we assume there is an aether. If we reject the aether, then all that matters is the relative state of motion. The different explanations of the current are not really different, just different ways of describing the same thing from different perspectives.

- To figure out what that view entailed, Einstein set out two basic postulates. The first is the constancy of the speed of light. The second is the principle of relativity, according to which the laws of physics are the same for all observers who are not accelerating relative to each other.

- From these two principles, Einstein figured out the equations that allow us to translate between physical descriptions that would be offered by different observers. As the Dutch physicist

H. A. Lorentz had found, when you are moving, the lengths you measure are squished in the direction of motion. If you walk with a pen sticking straight out in front of you, the pen would get shorter. The closer you go to the speed of light, the smaller the pen gets. In this way, length moves from a real property of the world to a property of our perspective.

- Einstein's theory of relativity transforms distance from the invariant fact Newton thought it was, that is, something true of the world itself, into a covariant fact—something just true of how one person sees the world. Time works in the same way. Durations stretch, that is, time slows down when you move, and the faster you go, the slower your watch goes when observed by someone at rest.

- Putting these two together, Einstein showed that our commonsense picture of adding velocities is wrong. According to Newton, if you're on a people mover in an airport traveling at 2 miles an hour and you want to calculate how fast a traveler passing you at 5 miles an hour is really moving, you add your speed to his: 2 + 5 = 7. But Einstein calculates that the speed will be slightly less.
    - For the speeds of daily life, this decrease isn't noticeable, but the effect makes it so that if something is moving at the speed of light, adding any other velocity to it keeps it moving at the speed of light.

    - Thus, the speed of light is not only constant but a limiting speed. There is no way to get something to move faster.

- Einstein realized that this led to a startling conclusion.
    - If we think about the interactions between particles, there are certain conservation laws that must be observed: conservation of momentum and conservation of energy. You cannot get energy or momentum from nowhere, and what goes in must come out.

    - Momentum is mass multiplied by velocity (*mv*), and the kinetic energy of a body is $\frac{1}{2}mv^2$. But because the theory of relativity makes velocity dependent on the frame of reference, these quantities must be adjusted, as well. The only way for them to remain the same going in and coming out is for the mass to change in order to compensate for the way velocity changes. As a result, the faster you go, the heavier you get. As you approach the speed of light, your mass approaches infinity as measured by someone at rest.

  - This means that there is a lowest mass (the rest mass) that is measured in the frame in which the thing is at rest. A shocking result of this is that mass becomes seen as a form of energy.

  - This is summed up in the most famous equation in all of science, $E = mc^2$: The amount of energy pent up in a massive object is equal to the mass of the object multiplied by the square of the speed of light.

  - We now see another reason that nothing can move faster than the speed of light. As something gets heavier, it needs more of a push to accelerate it. But at the speed of light, its mass becomes infinite. To accelerate an infinitely heavy object even a tiny bit, you would need a push that generates infinite force. But that would require infinite energy, which is impossible. Thus, traveling faster than the speed of light is not an engineering problem we haven't figured out how to solve. It is something that, according to Einstein's theory, cannot be done.

- In 1908, Hermann Minkowski, Einstein's professor, gave a speech entitled "Space and Time," in which he set out what we now call the geometric interpretation of the special theory of relativity. In this speech, Minkowski said, "Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality." With Minkowski's interpretation, Einstein realized that we live in a four-dimensional universe.

- Thinkers as far back as Gottfried Leibniz in the 17th century had realized that the universe encompassed three spatial dimensions and time, but they claimed that there was a fundamental difference between space and time.

- Minkowski realized that the universe that Einstein gives us weaves space and time together into a single fabric, a fabric whose pattern will appear different to different observers moving at different speeds but which is the reality underlying all of the different observations. We live not in Newton's three-dimensional absolute space flowing through one-dimensional absolute time; instead, we live in a single four-dimensional space-time.

- Each of us experiences this reality differently, but through the equations in the theory of relativity, we can calculate the underlying truth about the unobservable four-dimensional space-time manifold.

- The works of Pablo Picasso and, later, Kurt Vonnegut are attempts to make sense of what the universe looks like from the new perspective given to us by the theory of relativity. Eleven years later, Einstein would rework this theory, expanding it and extending it to challenge our picture of reality in even more radical ways.

Suggested Reading

Einstein, *Relativity*, part I.

Thorne, *Black Holes and Time Warps*, chapter 1.

Vonnegut, *Slaughterhouse-Five*.

Questions to Consider

1. Is it possible to have a God's-eye perspective on anything, or are we always trapped in our own way of seeing?

2. Are Vonnegut's aliens correct when they say that corpses are simply in a bad position at one particular moment, or would there be reason to mourn deaths if we could visit people anywhere along their lifespans at will?

General Relativity

Lecture 5

Einstein became dissatisfied with his theory of relativity on two grounds. First, the principle of relativity on which the theory is based is limited to observers who are moving at a constant speed in a straight line. Second, the theory touched on every known force in physics except for one, gravitation. Then, Einstein had what he termed his "happiest thought": He realized that gravity and acceleration were different ways of describing the same thing. With this new principle of equivalence, Einstein began work on a generalized theory of relativity. In the end, the result was a picture of a space-time that curves and warps around mass and energy, an active space-time that reacts to what's in space.

The Principle of Equivalence

- Einstein saw his original work—the theory of special relativity—as descriptive of space, time, and motion in a universe without gravitation. The problem, of course, is that as soon as we have an object with mass in the universe, we have gravity; thus, the theory would need to be reformulated.

- Einstein struggled with this reformulation until he had what he called his "happiest thought." Looking at some window washers high up on a building, he imagined one of them falling off the ladder.
    - Einstein realized that although the man is falling because of gravity, while he is falling, he would not experience any of the usual gravitational effects. Objects around him would seem to float as if there were no gravity. He would feel weightless. When accelerating in freefall, it is as if there is no gravity at all.

    - This thought simultaneously answered both of Einstein's problems with special relativity: the fact that accelerating reference frames were ruled out and the lack of gravitation. Thinking about the man falling off the ladder showed him that these were related. The way to meld gravitation into the theory was to connect it to acceleration. The two would be flip sides of the same coin. This is what Einstein called his *principle of equivalence*.

- Imagine you are in an elevator with a bathroom scale. Before the elevator starts moving, you step on the scale, and it shows your normal weight. But as the elevator starts moving up, the scale reads more than it did before. We can understand this if we think about how the scale works.
  - Normally, you stand on the scale and your weight pushes down from above. The floor holds steady below and the springs inside squish; the amount of squish is read off by the dial showing your weight. As the elevator goes up, you are still pushing down on top, but now the floor is pushing up from below. There is more squish in the springs and the weight displayed increases.

  - If the cable snaps and you fall down the elevator shaft, the scale would read 0. You are still pushing down on top of the scale, but now the floor is falling away at the same rate that you are, so there is no squish in the springs. You are effectively weightless as you fall.

- Now suppose that you are in a rocket in an empty region of space, far away from any massive object; there is effectively no gravitation. You step on a scale, and your weight reads 0. You have weight on Earth because of the Earth's gravitation pulling you down, but if there is no gravity, you have no weight.
  - Now suppose that the rocket accelerates upward. You will experience a pull downward. You are floating, but the floor is pushing up against you. If you accelerated at just the right rate, increasing your speed by 32 feet per second each second, and then stepped on the scale, it would show your weight on Earth.

- If you woke up tomorrow in a small metal room with no windows and nothing but a bathroom scale, could you tell whether you were on Earth in an elevator or in space in a rocket? If you stepped on the scale and it read your normal weight, you might be at rest in the Earth's gravitation or you might be accelerating in empty space. If it read 0, you might be accelerating in the Earth's gravitational field or you might be at rest where there is no gravity. There is no way to tell the difference.

- Here, Einstein borrows a principle from the 17th-century German thinker Gottfried Leibniz: the identity of indiscernibles. If there is no difference between two things, they are, in fact, the same thing. If there is no difference between the elevator and rocket ship cases, gravitation and acceleration are just different ways of describing the same thing. Einstein would take this as the basis of his new theory.

The General Theory of Relativity

- If we add more data, there seems to be a way to tell the difference between the elevator and the rocket. If you poke a hole in one wall of the metal room, any light from outside will come in through the hole and travel across the room, and a bright spot will appear on the opposite wall. With a ruler, you can measure the height of that light spot and the height of the hole.
  - Suppose you step on the scale and it reads your normal weight. You are trying to determine if you are at rest in a normal gravitational context or accelerating upward in a region of no gravity. You measure the height of the hole and the height of the light spot on the wall.

  - Light always takes the shortest route between two points, which is a straight line. If you are at rest, you would expect the light spot to be directly across from you. But if you are accelerating, you would expect the spot to be lower than the hole because in the time it took the light to move across the room, the room itself would have moved up. From the vantage point of someone in the room, it would look as if the light rays curved down.

- Einstein pointed out that this line of thinking made two important assumptions: that light moves along the shortest possible route and that the shortest possible route is always a straight line. Einstein saw that if we want to maintain the equivalence, we need to surrender the idea that the shortest path between any two points is always a straight line.
    - In a flat space, it's true that the shortest distance between two points is a straight line. But this is not true if you are restricted to the surface of a smooth globe.
    - The shortest path between any two points on the equator of the Earth when represented as a perfect sphere is along the equator, and that is a curve.

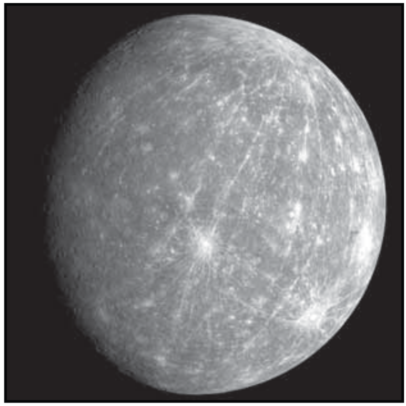
- For Einstein to make the move that solves his acceleration and gravitation problems at the same time, he had to posit that space—or space-time—is curved. With the help of his friend Marcel Grossman, Einstein then worked out the math that resulted in a theory in which gravity is thought to be the curvature of space by mass and energy.

- Newton's picture of the universe had separate space and time. Time was perfectly linear and space was perfectly flat. In space was a force, gravity, acting between all the objects but not affecting the underlying space.

- For Einstein, in contrast, gravity is not a force between objects but an interaction between space and objects. Matter and energy tell space how to curve, and the curvature of space tells objects how to move. We need to account for two basic motions that come from gravitation: straight in for objects close by strong sources of gravity and periodic orbits for those farther out.
    - To see how the curvature of space accounts for both, picture space as a trampoline. If you put a bowling ball on the trampoline, it sinks, creating a curved surface around it. If you then tried to roll a tennis ball toward the bowling ball, it would

speed up going in and slow down coming out. If it were not rolled hard enough, it would not make it out but would roll straight back to the bowling ball.

- ○ If the tennis ball were not rolled right into the curved area but close by, the path would curve, just as we see with comets. If the tennis ball were rolling at the right angle, the result would be a circular orbit, just as we see with planets and moons.



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Einstein found that his theory of general relativity explained the strange orbit of Mercury—an oval that never closes.

- If Einstein is right and space is curved by matter and energy, we could account for the gravitational phenomena we observe in a way that makes gravity a natural part of the theory of relativity and accounts for the accelerated reference frames Einstein left out in the special theory. Tests by the British astronomer Arthur Stanley Eddington confirmed that space does curve around massive objects.

Effects of Einstein's Theory

- The idea that space is curved is responsible for much of the long-distance travel in contemporary science fiction, but we don't need to resort to science fiction to find peculiar effects. Strange things can happen if we packed enough mass and energy into a small enough area. The space would warp so severely that straight lines would curve back in on themselves. Light that went into the area would never re-emerge. Emitting no light, the area would be completely black and would function as a hole in space.

- Surrounding the black hole is a border called the *event horizon*; anything that crosses it cannot reemerge.
    - An unfortunate traveler would have no sense that he or she had crossed the event horizon, but anyone watching would experience something peculiar.

    - Remember that special relativity includes an effect called *time dilation*, according to which time slows down when measured by a fast-moving observer. Because of time dilation and the curvature of space-time, a traveler would appear to move slower the closer he or she got to the black hole to an outside observer. Right around the event horizon, time would appear to stop for the observer.

- Physicists came to realize that the solutions to Einstein's equations that yielded black holes predicted that at the center there would be a *singularity*. The problem is that the curvature of the space is measured as a $1/x$ term, and if we treat objects as point masses, then the x term goes to 0. Here is a result of the equations of general relativity—1/0—that cannot be connected to reality. Einstein's theory of general relativity seems to describe a reality that cannot be real.

Suggested Reading

Einstein, *Relativity*, part II.

Gedroch, *General Relativity*.

Thorne, *Black Holes and Time Warps*, chapter 2.

Questions to Consider

1. Is it true that a difference that makes no difference is no difference? Could there be real differences underlying reality that are, in principle, not detectable at all?

2. If the universe is curved, should we keep teaching Euclidean geometry to high school students as if it is the definitive geometry?

Big Bang Cosmology

Lecture 6

Following Eddington's observation of the bending of light during an eclipse, Einstein began to consider the cosmological ramifications of his general theory of relativity. Realizing that it mandated an expanding or shrinking universe, Einstein added a term to his theory to keep space-time stable. But Edwin Hubble showed that space is indeed expanding, which means that it used to be smaller and something caused it to expand. Steady-state theorists tried to develop an account of this that kept the universe stable on a large-scale basis, but observable evidence favored a different theory, the big bang, according to which a singular event caused the expansion that we are still observing.

The Cosmological Constant

- After he published his general theory of relativity, Einstein came to the realization that the results of his theory were not stable. The pictures of the universe painted by the solutions to his equations showed space-time always expanding or contracting.

- Einstein and a colleague, the Dutch physicist Willem de Sitter, produced two possible approaches that would restore stability. De Sitter's approach to stability would work only if there were no mass in the universe. Einstein's solution showed that if there were an infinite number of stars in space, then the stars would be moving at absurdly fast speeds (something we don't see) and if there were a finite number of stars, then the universe would be expanding or contracting (which wasn't acceptable either).

- According to Einstein's theory, the presence of mass and energy causes space-time to curve.
  - The universe, Einstein argues, is like the Earth. When you look up close, there are mountains and valleys, but when you pull back, it is a smoothly rounded surface. In the same way,

Einstein thought, there would be local bumps in the curvature of space-time, but from a cosmological perspective, the universe had to have a smooth and constant curvature.

- The only way to get this smoothness and not have the universe expanding or contracting was to add a term to his equations, which came to be known as the *cosmological constant*.

- There was nothing in physics or observation that demanded this term. It was required only to ensure that the picture of reality as regular could be maintained.

- Younger physicists objected. The Russian Alexander Friedmann produced a solution to Einstein's equations that showed an expanding universe. Georges Lemaître, a Belgian physicist and Catholic priest, also found the general theory of relativity to require an expanding universe. But Einstein refused to accept their solutions. The idea that there were large-scale changes happening violated the basic idea that we live in a stable universe.

The Expanding Universe

- But in 1929, the universe told us otherwise. Edwin Hubble, working on the newly built telescope at the Mount Wilson Observatory in California, discovered other galaxies outside the Milky Way. Hubble also noted that the farther away these galaxies were, the faster they were moving and the more likely they were to be moving away from us. From these facts, Hubble concluded that the universe is expanding.

- All stars work according to the same mechanism: They turn hydrogen into helium. Each element has a set of telltale frequencies of light it emits because of the structure of the atoms. Thus, the light from all stars and all galaxies should look the same.

- But light is subject to the Doppler effect. Light waves move at the same speed, no matter the state of motion of the light source, but the number of peaks per second changes based on the relative motion of the light source. If the light source is moving toward you, you see more peaks per second, and the light shifts toward the blue end of the spectrum. If it is moving away, then you see fewer peaks per second, and the light shifts toward the red end. The amount of redshift or blueshift tells us how fast something is moving and whether it is moving toward or away from us.

- In space, Hubble noticed that the farther away something is, the more likely it is to be moving faster and moving away from us. Very few objects are blueshifted, and they tend to be objects that are among the closest. From this, he inferred that the universe is expanding.

- When we say that the universe is expanding, we mean that space-time itself is expanding, not that the things in it are moving away from each other in a fixed space. It is not that the universe is an island of mass taking up more space as time goes on. It is that the universe itself, space-time itself, is expanding.

- If the universe is expanding now, that must mean that it was more compact previously. What is causing this expansion?

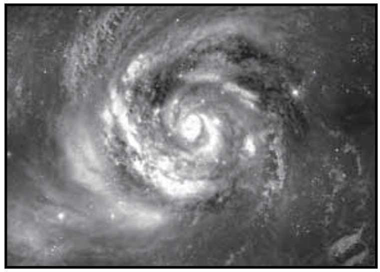
The Big Bang Theory

- Two theories arose to explain the expansion of the universe, the first of which is what we now call the *big bang theory*. The central idea here is that if the universe is expanding now, it must have been compressed before. But if it is getting larger, something must be causing the expansion.

- There seem to be two possibilities: either a constant force that is always at work repelling things or an initial event that caused the expansion. Of course, the only force that can operate over long distances is gravitation, which is an attractive force. Thus, we are left with the second possibility. There was some singular event that happened at the beginning, and we are still seeing the results of that singular event everywhere.

- Scientists largely hated this idea, in part because unique events seem utterly unscientific. To claim that we can rewind the film to a point where all mass and energy is concentrated at a single point only to explode into a universe like ours is tantamount to theology—it is positing a creation event.

- Although the big bang theory offered some scientific advantages, it also posed some problems.
    - If all mass and energy were concentrated at a point, the amount of energy would be too great to allow atoms or even subatomic particles to form.
    - If this point "exploded," then such a central force would send the energy out in a spherical wave, but we see a chunky universe, not a smooth one. The energy congealed into clumps of mass in stars and galaxies with huge amounts of dead space in between. What would account for the clumpiness of our universe? How did we get the elements we have? How could atoms have formed and collected into stars?



The finite age of the universe posited by the big bang theory provided an answer to the question: Why is the night sky dark?

The Steady-State Theory

- This last question was investigated by George Gamow. In an important paper in 1948, Gamow and his graduate student Ralph Alpher showed how the basic elements hydrogen and helium could form and how much of them we should find. But they also concluded that there should be some energy remnants of the big bang spread evenly throughout space. This energy should be everywhere, and it should be decreasing as it fills an increasingly expansive universe.

- Many scientists preferred the idea of constant expansion to Gamow and Alpher's theory. But what, then, is causing the expansion seen by Hubble, and why do we see galaxies? Where do they come from? Why don't they all die out? If the universe is getting larger, then the energy density—the amount of stuff in any region—is getting smaller; this should mean that the universe is dying. But that isn't what we see when we look at the night sky. Any theory that would preserve a static universe while allowing for expansion would have to account for the apparent continuity of energy density in the universe.

- Two astronomers, Thomas Gold and Hermann Bondi, posited that perhaps the expansion allowed the universe to create itself by allowing for the spontaneous creation of bits of mass and energy. But this seemed to contradict one of the fundamental principles underlying the paradigm of modern physics: Energy is neither created nor destroyed. Where would this energy and mass magically come from?

- Another astronomer, Fred Hoyle, argued that we should think of the Einsteinian static picture in terms of the conservation of energy density. Yes, the universe is expanding, but as it expands, there must always be the same amount of stuff per unit volume. There is a field throughout space that itself stores energy. When the universal expansion drops the average amount of stuff in a region below a threshold, this energy-storing field concentrates its energy and increases the mass and energy of the region.

- If this were true, then we would have the conservation of energy and the conservation of energy density. This view was called the *steady-state theory* because it proposed that the universe was always in a constant state with respect to how much stuff there is per unit volume.

Microwave Background Radiation

- If Gamow and Alpher's work was right, the detectable background radiation left over from the big bang would be in the microwave part of the electromagnetic spectrum. The physicist Robert Dicke believed that if he could figure out exactly what he was looking for and create a strong enough radio-telescope, he could answer the question that divided big bang and steady-state theorists.

- Dicke enlisted fellow physicist Jim Peebles to rederive Gamow and Alpher's results, only more exactly. They determined that the background radiation should be about three degrees above absolute zero.

- At the same time, at Bell Labs in New Jersey, Arno Penzias and Robert Wilson had access to a radio-telescope that NASA was no longer using. Other researchers had been analyzing the radio waves coming from the space between galaxies, but Penzias and Wilson wanted to look at the signals that came from between galaxies. These would be faint signals that required precision observation.

- First, Penzias and Wilson needed to remove all interference—radio broadcasts and radar—but there remained a low hum in the background that they could not seem to eliminate, nor could they determine where it originated. No matter where they pointed the antenna, they could not eliminate this background noise.

- Penzias and Wilson had accidentally found the signal that Dicke was working so hard to discover. Gamow's background radiation had been discovered, and it was just what Dicke had said it should be. The best explanation for it is that it is the leftover energy from the big bang.

- Cosmology now gave rise to questions about the beginning of time. Did the universe have an origin? Will gravitation cause it to recollapse on itself in a big crunch? Will it cause another big bang?

Or will the universe expand to the point where the energy density is too low to support stars and galaxies? Is the universe doomed to a slow, cold death?

Suggested Reading

Gamow, *One, Two, Three … Infinity*, part IV.

Hawking, *A Brief History of Time*, chapter 8.

Suggested Viewing

Dead of Night

Questions to Consider

1. When a question moves from theology or philosophy to science, does that mean we were wrong in the initial classification? Is the original theological or philosophical issue still valuable after the reclassification?

2. Steady-state cosmology emerged from scientists watching a horror movie. Should art be more widely considered valuable as a source of scientific discovery? Should scientific training require exposure to the arts?

The Reality of Atoms

Lecture 7

Although physicists at the end of the 19th and the beginning of the 20th centuries were comfortable with the atomic hypothesis, chemists were not. Physicists since Newton had used the concept of a point mass, and atoms seemed to be a realization of it. For chemists, in contrast, the idea that matter is composed of invisible little balls seemed to take chemistry away from its place as a proper empirical science. By the start of the 20th century, the observable evidence, however, forced chemists to agree that matter is made of atoms.

Debating the Atomic Hypothesis

- The story of the atomic hypothesis at the turn of the 20th century is interesting because it pits physics against chemistry, two scientific communities with contrasting paradigms.

- Physicists are famous for their simplifying assumptions. This is not a weakness in physics but a necessity.
  - When we think of two things bouncing off each other, say, billiard balls on a pool table, the case is complicated if the ball has shape and size, especially if the shape is not perfectly round. Thus, physicists begin by considering the object as a *point mass*, that is, a thing with no shape and all of its mass focused at a single dimensionless point. Once that case is understood, the mass is given a shape, generally, a sphere.

  - Because the point mass is a standard way of thinking in physics, physicists were naturally comfortable with the atomic hypothesis—that the world is, at its most basic level, just a collection of joined point masses.

- Chemists, in contrast, largely hated the idea of atoms, in part because of the historical link between chemistry and the practice of alchemy.

- Alchemy had originally sought to study changes that could be created from things in nature, such as metals. It later became associated with the supernatural—a door to powers beyond nature.

- Because of the association of the two fields, chemists in later generations were sensitive about their status as rigorous researchers. Science is empirical, and because chemistry is a science, it should deal only with that which could be observed and measured.

Evidence for Atoms

- For 2,000 years after the high point of classical Greece, Aristotle's chemistry ruled supreme. We had earth, water, air, and fire, which were combinations of the fundamental properties of hot/cold and dry/wet. When combinations were mixed appropriately and subjected to various conditions, we could create new combinations in well-documented, predictable ways.

- Leucippus and Democritus had advanced an atomistic picture of the world in ancient Greece, but it was rejected. The word *atom* comes from a Greek word meaning "uncuttable" because atoms were thought of as indivisible particles bouncing around in a void. This was the reality the ancient atomists put forward: that the world is filled with little bits bouncing around in nothingness.
  - No one had ever seen these little bits, nor could the atomists provide any way to isolate them. The nothingness seemed to be filled with air, which certainly did not appear to be anything but continuous.

  - Further, no matter how small a thing is, there seemed to be no reason to think that it could not be cut in half. Classical opponents threw a range of objections at the atomists, whose account seemed no more explanatory than Aristotle's.

- In the 19th century, there was the added problem that any theory that bases its view of reality on invisible particles responsible for observable particles seemed to move science back into the realm of alchemy. Atoms seemed to be a form of magic.

- The first major blow to the chemists' arguments against atoms came with the discovery of oxygen.
    - Joseph Priestly was a minister and scientist. He lived next door to a brewery in England and was fascinated with the brewing process, especially when he looked at the air around the grain that was fermenting.

    - Recall that for Aristotle, air is an element—a single thing. What Priestly did in his experiments was to isolate some air that had different properties from normal air. If you had a burning piece of paper, you could pump in some "fixed air," as Priestly called it, and the flame would extinguish. If you put a mouse in a bottle and filled the bottle with fixed air, the mouse would die.

    - Priestly also found what he called "dephlogisticated air." If you put out a flame, then pumped in dephlogisticated air, the flame would return. If you pumped dephlogisticated air into the bottle, the mouse would come back to life—but only if you did it in time.

    - Dephlogisticated air is what we now know as oxygen, and fixed air is carbon dioxide.

- All in all, Priestly was able to identify many different kinds of air, which created a serious anomaly for the Aristotelian system. It set off a rush, with scientists finding more and more substances to experiment on. It was found that some substances combined with others and could be derived from others but could never be broken down any farther. The list of elemental substances grew throughout the 19th century. This meant that a new non-Aristotelian basis would be needed to account for the observed behaviors.

- The big breakthrough came with the work of the British chemist John Dalton and the French researcher Joseph-Louis Proust, who independently discovered that whenever elemental substances are combined to create compounds, there is a fixed ratio of what goes in to get out a given amount.
  - The ratio of the amounts of stuff in to get one unit of stuff out is always a ratio of counting numbers: 2 to 1, 3 to 1, 4 to 1 to 3, and so on.
  - If nature is using counting numbers, it is probably counting something, which means that there must be something to be counted. Perhaps elemental substances are made up of countable bits. Chemists grew nervous that atoms were making their way back.
- The Italian chemist and atomist Amedeo Avogadro believed that the work of Dalton and Proust showed something important: The reason we could combine fixed ratios of elements and create an integer's weight of a new substance was that there were basic building-block things joining with other basic building-block things to create hybrid things. He called the bits of elements atoms and labeled the combinations molecules.
- Avogadro proposed that "equal volumes of all gases, at the same temperature and pressure, have the same number of molecules." Before Avogadro, we could use the idea of atoms as a heuristic, a way of thinking that gives us an easy image to hold in our minds. But chemists were careful not to mistake this mental picture for reality. It was Avogadro who took the next step and introduced the number of molecules, and you cannot have a number of things without having those things.
- When Avogadro's law was added to the other gas laws, it became possible to formulate a new combined law known as the *ideal gas law*: For any gas, the pressure multiplied by the volume is proportional to the number of molecules multiplied by the temperature.

- In 1873, James Clerk Maxwell published a paper called "Molecules," in which he derived the ideal gas law from a mechanical picture of gases—a picture in which a gas is a collection of atoms. It would have been a massive coincidence if the law accidentally fell out of the atomic picture. Everything in the results is macroscopically measurable except one thing—the number of molecules. The anti-atomistic chemists would have to say that it was a lucky but meaningless occurrence that assuming atoms generates a world that behaves exactly like this one.

- From Avogadro's work, it follows that the number of molecules in a mole of a substance is a fixed quantity, which was given the name *Avogadro's constant* or *Avogadro's number*.
    - To determine Avogadro's number would be to make a statement about the reality of atoms. Such physicists as Albert Einstein and Jean Perrin became serial derivers of Avogadro's number and found it everywhere—in the study of gases, liquids, alpha particles, cathode rays, and so on.

    - Einstein proposed a way to experimentally determine Avogadro's number but concluded that it would be difficult to do. Perrin took up the challenge and, through painstakingly delicate work, determined Avogadro's number and showed it to be a constant across many different situations. Perrin's work was so good that finally, even the most strident anti-atomistic chemists gave in, and atomism became the scientific consensus.

Discovery of the Electron and the Nucleus

- In 1897, the British physicist J. J. Thomson discovered that the cathode rays physicists had been investigating were actually negatively charged particles, what we now know as electrons. Scientists eventually realized that these were pieces of atoms that were capable of being stripped out. Atoms had parts and structure.

- Because atoms were electrically neutral and electrons were negative, there had to be a positive part of the atom to balance out the electrons. But there didn't seem to be a positive correlate to the

In the art of the 1880s, the modern concept of the atom emerged as pointillism; representations of the world were not smooth but made up of individual dots of color.

cathode rays. Thus, Thomson proposed what came to be known as the *plum pudding model* of the atom, in which the atom was a smear of positivity (the pudding) with the electrons as negatively charged nuggets inside of it (the plums).

- This model went by the boards when Ernest Rutherford and his assistants found the nucleus of the gold atom. Atoms were mostly empty space with virtually all of their mass concentrated at the middle. The empty regions were the domain of the negatively charged electrons.

- However, if the electrons are negatively charged and the protons are positively charged, they should attract, making the atom unstable.

    - The idea of a large central mass attracting a smaller external mass suggested that the atom was similar to the solar system. The planets don't collapse into the Sun because the gravitational force attracting them to the Sun is balanced by the centrifugal force of their motion, pulling away.

    - The result of this thinking was the solar system model of the atom, with the nucleus as the Sun in the middle, and the electrons orbiting outside.

- But there is a problem here, too. We had long known that when an electrically charged object moves, it causes a magnetic field. Given that the "planets" are negatively charged electrons, if they were to orbit the nucleus, they would create a magnetic field. The magnetic field requires energy, which would be drained from the electron, diminishing the centrifugal force that prevents it from moving closer to the nucleus. Ultimately, the atom would collapse. Obviously, a new theory of the atom was needed.

Suggested Reading

Pullman, *The Atom in the History of Human Thought*.

Von Baeyer, *Taming the Atom*.

Questions to Consider

1. When such artists as Georges Seurat are influenced by advances in science, does it matter if they really understand the science, or is an evocative misunderstanding equally as valid for art as long as the art is new and innovative? Should artists receive training in science?

2. Did alchemy stop being a science when it was given a mystical interpretation, or given that earlier findings could be replicated in an observable fashion, does it always remain a science?

Quantum Mechanics

Lecture 8

The solar system picture of the atom, in which electrons orbit the nucleus, is problematic because it is unstable. The electrons would crash into the nucleus after a fixed time, and matter would become impossible. Planck's solution to the problem of blackbody radiation and Einstein's solution to the problem of the photoelectric effect led Bohr to posit a quantized atom. The result would the development of a full theory that made probability a necessary component of physical law.

The Ultraviolet Catastrophe

- As mentioned in the last lecture, the solar system model of the atom would result in instability. If electrons orbited the nucleus, their motion would create a magnetic field that would sap the energy that kept them orbiting. All atoms would quickly collapse, making matter impossible.

- A clue concerning this mystery came from work of the German physicist Max Planck on the question of blackbody radiation.
    - Consider a hollow black metal sphere, heated up. We know that metal glows when it gets hot; that is, it gives off light, electromagnetic radiation. Because the sphere is hollow, some of the light would be given off inside. And because the walls are black, that light would be completely absorbed by the inside walls of the sphere, giving them more energy, which would mean the walls would give off light. That light would then be absorbed by the walls, which would then have more energy, and so on.

    - The higher the frequency of the light, the more energy the sphere would contain. The classical theory predicted that the amount of energy inside the sphere would become infinite.

    - We know, however, that for a given temperature, the energy peaks, then drops off to zero when we move toward the ultraviolet end of the spectrum—where the classical theory said it went off to infinity. This discrepancy became known as the *ultraviolet catastrophe*.

- Planck decided to approach this question in reverse: to figure out the mathematics that would result in the empirically generated curve. He then realized that the problem could be solved if the emitted and absorbed light were treated as if it came in packets, which he called *quanta*.

- Planck was committed to a picture of the world that was completely continuous; everything from energy to matter was smooth. He wanted to think of light emissions as having a dimmer switch, but his equation said that reality had a toggle switch, with only discrete settings.

The Photoelectric Effect

- Einstein, in the year he developed the special theory of relativity, also solved another problem, accounting for the *photoelectric effect*. If you shine ultraviolet light on metal, electrons are emitted. It was known that electrons in metal were only weakly bound to the atoms, and if light were thought of as waves, then the waves would cause the metal surface to vibrate.

- If we make the light brighter, then we make the wave bigger, and we should see faster-moving electrons emitted. But that isn't what happens. More electrons are emitted but not faster ones.

- Picking up on Planck's work, Einstein saw what would happen if we treat light as packets. If we turn up the light, we do not get faster-moving light but more packets of light. More electrons are emitted, but because the speed of light always remains the same, the emitted electrons come out with the same energy.

- Einstein showed that Planck's claim that light acts as if it were quantized was actually part of reality. But light behaves like a particle only when it is emitted or absorbed. When it travels, it exhibits wave behavior. Is it a particle or a wave?

Niels Bohr's Atom

- The Danish physicist Niels Bohr applied Planck's notion of quantization to the atom. He posited that the orbits of the electron were quantized and that electrons could be found only in fixed tracks. An electron could jump from track to track, but it would never exist in the area between tracks. It would instantaneously absorb exactly the right amount of energy and appear in a track farther out.

- Similarly, an electron could give up energy but only in exactly the amount that accounted for the difference between an outer and an inner track. This is what we call a *quantum leap*; the term does not refer to a big jump but to an instantaneous jump, rather than a smooth transition.

- This solved a longstanding problem: Why did each element, each type of atom, have a unique set of light frequencies it gave off when it was excited it with electrical current?
  - The classical picture of the atom could not explain this, but Bohr's quantized atom gave physicists the finger from which the fingerprint emerged; it was the orbitals, the quantized tracks of the electrons.

  - Electrons must occupy fixed tracks, and each requires a particular amount of energy to be absorbed to get an electron in that track. When an electron surrenders some of that energy, it would have to jump from a higher to a lower track and give up exactly the difference in energy between them. There would, therefore, be light energy coming out of the atoms in only the quantities defined by the difference in energy of the tracks particular to that element.

Development of the Quantum Theory

- There were two main problems with Bohr's picture. The first is whether light is a particle or a wave. The second is the quantum leap: How could something move from A to B without ever having been in the middle? Eventually, Bohr's assistant, Werner Heisenberg, discovered a way to mathematically account for the strange quantum behavior of the atom. In some cases, however, his solution required infinite-dimensional matrices.

- Heisenberg's theory also had another strange feature: *non-commuting observables*. Because of the mathematical form of the theory, there would be pairs of observable properties—for example, position and momentum—such that when you observe the value for one, the other ceases to have a value. This came to be known as the *Heisenberg uncertainty principle*: For these pairs of measurable quantities, there is a limit to how precisely we can know the values of both. The more exactly we measure one, the more uncertain we are about the other.

- In quantum mechanics, this is not a feature of our knowledge or lack of knowledge but a feature of the universe itself. When an object has a well-defined position, it no longer has a well-defined velocity. It's not just that we don't know it; it's that the object ceases to have a single value for that property.

- The Austrian physicist Erwin Schrödinger developed a way to do everything that Heisenberg's infinite-dimensional matrices did with a simple equation that resembled the equation for the conservation of energy. It was now easy to calculate the behavior of a system over time, but there was a problem.
    - Every physical theory has what are called *state variables*—important measurable quantities that the theory connects. In Newton's theory, if you're given the position, mass, velocity, and acceleration of each ball on a pool table, you can know the exact values for each at any point in the future. Those are the state variables, and the theories determine how they change over time.

- ○ With quantum mechanics, according to Schrödinger's formulation, the state variable is represented by the Greek letter *psi* (Ψ), the wave function. But what is the wave function? What does it represent?

- ○ It can be expressed in terms of any given observable, but then, according to the theory, it is a combination of every possible state the system could be in; the term used by physicists is a *superposed state*. If we express Ψ in terms of position, then according to Schrödinger's equation, the object will simultaneously be in every place it could be. Of course, things are not spread out through space; everything we see is in a place.

- ○ And here is the real strangeness in quantum mechanics: When we do not observe a system, it obeys Schrödinger's equation and is in its superposed state. The moment we observe it, it collapses into one of its states, where we can see it, but we cannot tell which value it will take.

- This superposition plays into the question of whether light is a particle or a wave. The answer depends on how you observe.
  - ○ If we turn down a light source until we have just one packet of light—a *photon*—coming out at a time, we can shoot it at a wall with two slits cut in it. If light is a wave, then it should go through both slits at the same time. As a result of the adding and subtracting behavior of waves, the light would show up on a screen behind the slits as a series of alternating light and dark bands. If light

To say that light is sometimes a wave and sometimes a particle seems to make no sense; it's the same as saying that light is sometimes a thing and sometimes not a thing.

is a particle, then the slits would act like shotguns, spewing light particles at random angles. There would be no light and dark bands but random flashes on the screen.

- If we take the first approach, we find that light is a wave. But if we then turn on the photodetectors and test the second approach, it is a particle.

- If we do not have the photodetectors on, then we are not testing for position. The result is a superposed state of both possible positions. But when we plug the detectors in, we are observing position, and the effect of the observation is to collapse the wave function into one value, to give the light a definite position. But that value is random, not predictable. Thus, the Schrödinger equation is a description of reality when we are not looking at it but fails whenever we check.

- Three main pictures of reality are suggested by this theory.
  - John von Neumann contends that the superposed state is real, that things are spread out without well-defined values until we measure. The act of measuring causes a disturbance that collapses the wave function into a single value. Measurement is a physical act that changes the system, and this is what causes the change from the results of the Schrödinger equation to the random results we see.

  - Eugene Wigner proposed that the collapse occurs when the system interacts with the human mind. It is our consciousness that affects the system.

  - According to the picture proposed by Hugh Everett, when a system is not observed, it is simultaneously in every possible state, but once it is observed, reality splits and new sub-realities—parallel universes—are created. Every time we observe a system, we do not collapse a wave function; rather, we divide reality, creating multiple worlds.

Suggested Reading

Gamow, *One, Two, Three ... Infinity*, part III.

Greene, *The Elegant Universe*, chapter 3.

Questions to Consider

1. Is reality chunky or smooth when you get smaller and smaller? Even if there are atoms, what about the underlying space? Is it just the void, as held by the ancient Greeks, or does it make sense to speak of a quantized space?

2. Waves need a medium, but do particles need anything else in order to exist? If we removed everything from the universe except a single particle, could it be said to exist as a particle, or does it need other particles with which to have relations in order to have properties?

Quantum Field Theory

Lecture 9

One of the early results of quantum mechanics was particle-wave duality, where light could be thought of either as a particle with existence as an object in itself or as a wave of some sort. That result was extended to mass, so that both light and matter could be seen either way. But waves need a medium; that is, waves must be waves in something. That something is the quantum field, and the theory was extended to what is now called the standard model, which accounts for all forces and subatomic particles as waves in the quantum field that can interact with one another.

Particle-Wave Duality

- In 1924, the air was full of talk about two major discoveries in science.
    - One was Planck's quantization of energy from blackbodies, such that for a single photon $E = h\upsilon$ (h = Planck's constant; υ = frequency). This was the basis for the wave-particle duality of light.

    - The other was Einstein's theory of relativity, according to which $E = mc^2$. Mass, Einstein said, was just another form of energy, and there should be ways to convert this energy back and forth as long as the energy in total is conserved.

- The French physicist Louis de Broglie noted that energy is something that changes form. We can turn electricity into heat, and heat into chemical reactions, such as making water into steam. Steam can be used to power an engine that does mechanical work; mechanical work can lift an object, giving rise to gravitational potential energy; and so on. If Plank says that $E = h\upsilon$ and Einstein says that $E = mc^2$, it ought to follow that $h\upsilon = mc^2$.

- But the simplicity of this equation hides deep ramifications. In the middle of $h\upsilon = mc^2$ is an equal sign, which tells us that what is on the left side is just another way of saying the same thing as what is on the right side. On the left is frequency (υ), and only waves have a frequency. On the right is mass (m), and only particles have mass.

- What de Broglie did by joining the two equations is to assert that the strange particle-wave duality attributed to light would also hold true for matter. Matter, if this were true, would have to be thought of as a wave.

- This concept gives rise to what physicists call *quantum decoherence*.
  - If we have two electrons that bounce off of each other, then classically, we think of the interaction as similar to a game of billiards. The cue ball hits the eight ball and goes off in one direction, and the eight ball falls into a pocket.

  - But in quantum mechanics, all we can know is that two electrons went into the interaction and two electrons came out. There is no sense of identity throughout the collision.

  - The problem here is that self-identity is the most basic property of "thinghood." Something is an entity—a real object—if it retains its identity over time. If we surrender identity over time, then we give up on the existence of things.

The Search for Smaller Particles

- In the years after de Broglie's work, physicists probed the structure of the atom, with surprising results. Rutherford had shown that the atom was largely open space with virtually all its mass focused in the central nucleus.
  - Because atoms were electrically neutral and electrons were negatively charged, the nucleus must not only be massive, but also positively charged. Because we knew that nuclei of light atoms could be stripped of electrons and the nuclei isolated into

beams, we also knew that there were particles called *protons*. But when we added up the masses of the protons and electrons, the atom was heavier than the result. There was something else heavy inside the atom.

  - Further, we knew that elements come in different forms, called *isotopes*, which have the same number of electrons and the same number of protons but different masses. Because the mass of the atom is in the nucleus and all isotopes are electrically neutral, there must be something else in the nucleus that contributed mass but not charge. This was the *neutron*.

- Eventually, we were able to isolate neutrons and observe their decay, which resulted in an electron and a proton.
  - If electrons and protons get too close, then their opposite charges ought to bring them together into a single electrically neutral object. The combined mass matched what the proton had to weigh given the atomic masses of the various isotopes, but there was a problem.

  - We had conservation of charge, energy, and momentum but not *angular momentum*, a measure of spin, which must remain constant overall. Thus, a third component was proposed to account for the discrepancies before and after the decay, a particle with no charge and virtually no mass, the *neutrino*.

- When there was a heavy-positive/light-negative image of the atomic world, things were simple. But the neutrino suggested that the subatomic realm was more complicated, and physicists began to try to see what the world inside of atoms looked like.

- Here, two more problems emerged.
  - If the nucleus is small and is populated by protons, which share the same positive charge, how does it remain stable? Like charges repel, and the closer they get, the stronger the

repulsion. Nuclei should blow themselves apart because of the electrostatic force between protons. The only forces we knew of were gravity and electromagnetism, and neither could explain what held nuclei together.

- Another problem concerns the neutron. Electrical charge explains how the proton and electron stick together in making a neutron, but what about the neutrino? There must be some sort of force that acts on neutrinos, and it would have to be different from electrical forces (because the neutrino is neutral) and gravity (because it is so tiny).

- The force that binds protons together would have to overcome the electrostatic force and must be the stronger of the two and active only in the nucleus because it is seen nowhere else. It was called the *strong nuclear force*. The force that exposes itself when the neutron breaks down to emit an electron and a neutrino is called the *weak nuclear force*.

- What started out as a simple picture of reality with two forces—gravity and electromagnetism—and two basic components—electrons and protons—had been exploded. Using particle accelerators, physicists began to discover a wealth of new particles; ultimately, these were categorized into what is now known as the *standard model*.

The Standard Model

- According to the standard model, there are two groups of particles, fermions and bosons. Fermions come in two classes, leptons (elementary particles) and hadrons (made up of quarks). Leptons include the electron, the muon, and the tau. Each lepton has an antiparticle that is identical except for its charge. Additionally, each lepton has an associated neutrino and antineutrino.

- The hadrons are made up of quarks, which come in three pairs, up/down, top/bottom, and strange/charm. Quarks and their associated antiquarks can join together to form mesons, but usually, they come together in triplets, creating *baryons*. There are 14 baryons, including the proton and the neutron.

- Breaking things down to their most elementary bits, from the six quarks and the three leptons, we can build up all the particles we see. Those particles interact, and theory accounts for their interactions in terms of the exchange of other particles called *bosons*.

- There are four gauge bosons, which carry the various forces between fermions. The most famous is the photon or light particle, which carries electromagnetic force between particles. Light is thought of as a particle, a quantum of electromagnetic energy that is emitted and absorbed by fermions or collections of them. This is how forces allow particles to act on one another.

- In this scheme, there was one element left out, the Higgs boson, which was required to give mass to those particles that possess it. It was proposed only as a fix for situations where the standard model gave anomalous results. But if this boson was added to the mix, things worked out smoothly. With the confirmation of the Higgs boson in 2012, the standard model has been accepted as a nearly complete account of the physical world.

The Quantum Field

- The usual way of talking about the standard model makes us think of the subatomic world as being composed of basic uncuttable particles—the classical Greek atoms. But recall that this is coming out of quantum mechanics. We can think of particles because we are talking about quantized elements, but elements of what? Here is where we return to de Broglie.

- According to de Broglie, we need to see both light and matter as wave and particle. Waves require a medium. All the elements in the standard model are understood by physicists as excited states of the requisite fields, which can overlap and exchange energy. Change is the result of fluctuations in the field.

- Quantum field theory does away with what we usually think of as the most basic aspect of metaphysics, substance. Thingness is no longer fundamental but subsumed into a more basic underlying entity, the field. The field is what is real, and all we think to be individual things are just transitive aspects of the dynamic field.

- This shift to a metaphysic based on an all-present field was not lost on many beyond the world of physics.
  - If the object is not the basic unit of being, it not only changes the basis of science, but it completely undermines the basis of the visual arts. A painting—whether it is a still life, a landscape, or a portrait—has an object, and that object is the basis for understanding and judging the work. Do away with the object as a real thing, and you seem to do away with the possibility of painting as we understand it.

In Newton's conception, time was absolute, fixed, and immutable, but after Einstein, time became softer, able to be stretched and contracted; surrealist artists attempted to capture this revision of our notion of time.

- As the meaning of the physics began to leak into the broader culture, it caught the ear of a group of artists who were interested in the question of the fundamental basis of visual art, the surrealists. Perhaps the most well-known member of the group was Salvador Dali. Some of his most famous works, such as *The Persistence of Memory*, place the artistic endeavor in direct discussion with the results of modern physics.

- Quantum field theory and the standard model forced a radical revision of our notion of reality. We move from a world of things to a world of fields, a world in which what there is sits underneath reality and undulates and condenses in ways that create what we think to be things.

Suggested Reading

Davies, *The New Physics*, chapter 14.

Greene, *The Elegant Universe*, chapter 5.

Questions to Consider

1. Particles are independent things; they exist on their own. Waves are not independent things but disturbances flowing through a medium. For example, water waves are not things in themselves but just a change in the shape of the water's surface. The water exists; the wave is not its own thing. Does it make sense to say that mass is a wave and that forces are particles? Is this just a convenient way of talking because of the math, or is it part of reality? How can this be when particles and waves are fundamentally different types of things?

2. If quantum field theory is correct and atoms are made up of smaller particles that are really just waves in an underlying quantum field and you are made up of nothing but atoms, does that make you just a complex wave? Are you really not a thing with an identity that maintains itself after you bump into something?

Chaos Theory

Lecture 10

Probability has long been a part of our descriptions of the physical world. In statistical mechanics, it is the result of having a large number of particles. In quantum mechanics, the equations tell us how likely it is that a system in a combination of possible observable states will be found in any particular state if we observe it. In chaos theory, the probabilistic element is different still. In these systems, the behavior is completely determined by the laws of physics, but the system is so sensitive to initial conditions that the tiniest change will lead to wildly different results. The equations that lead to this kind of behavior have unique properties that make them fascinating to study.

Development of Probability Theory

- In 1654, a French nobleman, the Chevalier de Méré contacted the French philosopher and mathematician Blaise Pascal about a gambling question. Pascal, in turn, contacted the great mathematician Pierre de Fermat, who answered by creating the mathematical theory of probability.

- A century and a half later, Pierre-Simon Laplace, one of the greatest geniuses of the 19th century, became interested in extending Fermat's notion of probability beyond games of chance to show how it functions in science.
    - His first book on the subject, *An Analytical Theory of Probability*, showed how to use statistical methods to solve problems in science. His second book, *A Philosophical Essay on Probabilities*, argued that the use of probabilities in science is the result of our own lack of knowledge, not the result of a world that is in any way random. In this book, Laplace posited an intellect that has since become known as *Laplace's demon*.

    - The demon is a being with a super-intelligence, capable of remembering an infinite amount of facts and making computations with infinite quickness. Given the true laws of nature and complete information about all the masses and energy in the universe at any moment, the demon could predict with absolute certainty the state of the universe at any time in the future and could deduce the exact state of the universe for any time in the past. The universe, Laplace claimed, would be completely transparent to this mega-intellect.

- Laplace's demon is the ultimate statement of the Enlightenment project embodied in science. Science's true aim, according to this line of thinking, is to develop a unified account that is capable of predicting and explaining every event, everywhere. This true aim of science makes four basic assumptions about science and the universe it is trying to describe.
    - First, the universe is deterministic. The state of the universe and every part of it, at any given time, is completely determined by the state of the universe immediately before. If a system is in state A, then it will always transition to state B.

    - The second assumption is that the rules by which we can derive state B from state A admit of *steady-state solutions*. That means that we will see recurring patterns of states. The future is not only determined by the past but determined in ways that are simple, elegant, and clean.

    - A third assumption inherent in Laplace's Enlightenment view is the stability of those steady-state solutions, the idea that a small difference in makes only a small difference out.

    - The fourth assumption is predictability. Because things develop as they have to, according to the rules in a simple, orderly way, if we have the rules and the data, we can predict what is to come.

- Quantum mechanics has thrown doubt on the deterministic and predictability aspects, but recent work on chaos theory has led us to believe that even if there are aspects that are deterministic, this does not necessarily mean that the results are steady-state solutions that are stable and predictable. Perhaps the most famous example of this is the *three-body problem*.

The Three-Body Problem

- Newton became famous when his theories of motion and gravitation were combined to explain the elliptical orbits of the planets as shown by Kepler. Kepler crunched the numbers and came up with the shape (an ellipse with the Sun at one focus), but no one knew why the planets moved elliptically. Newton gave us his three mechanical laws and his law stating that the attraction between any two masses is inversely proportional to the square of the distance between the masses.

- Applying these rules to two bodies in space, we ask the question: How does the gravitational attraction between these two bodies make them move? We can set up the equation, plug in the initial conditions, and find a simple solution: The bodies move around each other in such a way that if one were thought to be nailed down, the other would move around it in an ellipse.

- But we don't live in a universe of only two things. Suppose we enlarge our scope to look not just at the Earth and Sun but at the Earth, Sun, and Moon. As we know, the Moon orbits the Earth, and the Earth orbits the Sun. The Moon's pull on the Earth is tiny compared to the Sun's because the Sun is so much bigger. As a result, the Earth's orbit is not perfectly elliptical but perturbed in some way.

- The problem is that when we use Newton's laws the way we did for the two-body case, the equations are no longer solvable. There is not a class of steady-state solutions—repeating trajectories—that is the general solution to the equations. There is no way in our mathematical language to set out a description of the path in space.

- We do not have an exact solution, but using simplifications and ignoring certain elements, we can come up with approximations. These approximations are extremely useful, but there is much that is interesting in the gap between the approximate and the real solutions. It is in that gap where we find chaos theory.

Nonlinear Systems and the Butterfly Effect

- Such cases as three-body systems are complex, where *complexity* is a technical term denoting an important aspect of the equations taken to govern the system. Such equations stand in opposition to state equations that are *linear*; these equations can be graphed so that their solutions form a line.
    - A nice property of linear equations is that they are stable; a small change in the initial conditions leads to a correspondingly small change in the outcome.

    - Nonlinear equations, however, exhibit sensitivity to initial conditions and represent unstable systems. The commonly used phrase to describe this sensitivity to initial equations is the "butterfly effect."

- Edward Lorenz, the father of chaos theory, investigated the butterfly effect in his work creating computer models of the weather. Lorenz found that incredibly subtle changes in the values input into the model yielded massive changes in the weather as it developed.

- Such sensitivity to initial conditions is a problem because no matter how sensitive the measurements, the act of collecting data itself is accompanied by *experimental error*. This phrase refers to the fact that there is always a resolution attached to any instrument that limits how precisely something can be measured. If the system's sensitivity to initial conditions is sufficiently small, it will fall below our ability to distinguish between relevantly different states of the system. The development will appear random and unpredictable, even though it is thoroughly deterministic.

- Such systems as the weather are physical systems—they must obey the laws of physics and, in that sense, must be deterministic. But they are also sensitive to small changes in initial conditions and are unstable, that is, they do not have simple repeating behaviors.

- The job of physicists is to find ways to represent intricate systems as simply as possible with equations. Small deviations from the large-scale order are dismissed as noise; only the large-scale regularities are given attention. Chaos theory, however, demands that scientists heed the microdeviations. When they started to focus on these, scientists found that the behavior of chaotic systems is, indeed, nonrepeating, but it is not random. When scientists began charting the development of chaotic systems, large-scale regularities appeared in the results.

Strange Attractors and Fractals

- The evolution of chaotic systems over time does not return to the same state, but when the states are mapped out in a mathematical structure called *phase space*, patterns began to appear.
    - If the chaotic system were truly random, then its path through phase space would be like that of someone who is inebriated wandering down a street. There is no state that the system might not occupy, and the sequence of states in which the system would be found could lead to any other state.

    - This randomness does not appear in a plot of the development of a chaotic system. The line that is the representation of the system's time evolution is complicated in odd ways, but it takes definite forms, such as a torus or a saddle. The path of the system represented in phase space will stay on these surfaces and eventually fill them in.

- Mathematicians call these surfaces *strange attractors*, and the mathematical structures of these surfaces are the most popular element in chaos theory, *fractals*. A fractal is a shape that is self-similar at different scales.

- One of the simplest fractal patterns is the Koch curve, also called the Koch snowflake. This shape is constructed by starting with an equilateral triangle and building additional equilateral triangles off it. Because of the way it is constructed, any place we look at the Koch snowflake, no matter how close or how far we are from it, it looks the same. This self-similarity across different scales is the hallmark of fractals.

If you look at a fractal pattern and zoom in on any segment, that segment will look like the larger section with which you started.

- We find this sort of geometry in all sorts of irregular but not random places in nature: leaves on trees, cracks in the Earth, coastlines, the internal structure of crystals, and so on. Because we find fractals in nature, we also use them to model nature, not just in scientific models but in art. Since 1982, artists have been using fractals to create more realistic landscapes in computer-generated graphics used for the backgrounds of movies.

- Reality seems more real to us when it is modeled on chaos. Science seeks order in nature and finds it, but that order is so complex that it seems to give rise to disorder. In examining that disorder in a closer way, we find new order. Chaos is not randomness but a complexity within the universe that we never thought was present.

Suggested Reading

Barabasi, *Linked*.

Bradbury, “A Sound of Thunder.”

Gleick, *Chaos*.

Questions to Consider

1. Linear equations are wonderful because they are so well-behaved and allow scientists to accurately predict all sorts of things. But is life linear? Are the linear equations scientists use oversimplifications of a messy, nonlinear universe, or is the universe well-ordered for us? Do physicists and other scientists assume spherical chickens too often to be giving a real description of reality?

2. Chaotic systems are still deterministic systems. The present determines the future with absolute certainty. Nothing could be otherwise. The lack of predictability comes from our inability to measure as precisely as we need to and from the difficulty of the mathematics. Is the universe random or not random but very complex?

Dark Matter and Dark Energy

Lecture 11

Earlier, we talked about Thomas Kuhn's view of the history of science. According to Kuhn, normal scientists work within a paradigm that sets out a certain picture of reality. Occasionally, however, anomalies appear; when this happens often enough, science enters a period of crisis. In this lecture, we'll look at cosmology at the turn of the 21st century to see if it's in a state of crisis. There are interesting developments around inflationary models of the big bang and the positing of dark matter and dark energy. New elements are being added to our understanding of reality that have not yet been experimentally or observationally discovered. Is this a simple tweak or the harbinger of something more important?

Problems with the Big Bang Theory

- Although the big bang theory has become nearly universally embraced, it still has some inconsistencies. The first of these problems concerns a class of missing particles called *magnetic monopoles*.
    - Like electricity, magnetism involves two charges, referred to as north and south; further, like magnetic charges repel and opposite charges attract. There is, however, one major difference between electricity and magnetism: Particles can have a particular electrical charge in and of themselves, but we never see this with magnets.

    - For example, a bar magnet has a north end and a south end. If you break the bar in half, you end up with two dipolar magnets—each with a north and a south end. We have never seen a magnetic monopole, one that is just a north in itself or just a south in itself.

    - But if the standard model is correct, then there was a stage in the early universe when the energy density would have been just right to create many magnetic monopoles. Further, these magnetic monopoles would have been massive compared to other particles, so big that they would have hampered the process of creating the sorts of particles we have around us now that make up planets and people.

- In short, the formation of magnetic monopoles should follow from the big bang, and they should have wreaked havoc on the formation of stable matter. Magnetic monopoles should be plentiful today, but they are at best rare and, possibly, nonexistent.

- The second problem has to do with the cosmological principle, according to which the universe is homogenous and isotropic. That means that there are no privileged points in the universe, and from every vantage point, the universe looks pretty much the same in large-scale structure in every direction. Deviations occur locally in small neighborhoods, but in the large, the universe looks the same in any direction.
  - The same is true of the Earth, although it would not be true if, say, the Earth was shaped like a crescent. On a crescent, there would be certain points that were unique, and the curvature would be variable. But this is not so on a sphere from the larger perspective and not so with regard to space in the larger perspective.

  - The problem is that with space, this shape is determined by the density of mass and energy. This is what Einstein said in the general theory of relativity: that gravitation is the curvature of space-time by mass and energy. Constant curvature over all of space-time means that there is equilibrium, that some sectors are not more energetic than others. But why should this be?

  - Such equilibrium makes sense in small regions, but there are parts of the universe that are so far away from each other that there could not have been a process that brought them into equilibrium. According to the theory of relativity, the speed of light is the fastest possible speed, and the regions of space are so greatly separated that no process could cover those distances and establish the equilibrium. What, then, accounts for the uniformity? Nothing could cause it without violating the theory of relativity, and it is too eerie to be random.

- The third concern is similar. When we look at the universe, we see that geometrically, it is flat. But flat is a unique point—halfway between positive and negative curvature. If one were to pick a geometry randomly, it's next to impossible that flat would come up and hold across all of space-time. Why is the universe flat; why is the energy equally distributed; and why has it remained flat over time? If it deviated even a little from flat, that curvature would become exaggerated as the universe expanded and the energy density decreased. What accounts for the flatness we see here and everywhere else?

Inflation

- These problems were weighing down the big bang theory when Alan Guth and Andrei Linde came up with the notion of inflation. If, early in the history of the universe, 10^{-35} seconds after the big bang, for a time of only 10^{-30} seconds, the universe underwent a rapid expansion, blowing up to a size increase of 10^{50}, then we could account for all three of these problems.

- First, if the early universe created any magnetic monopoles, the expansion would remove them so far from each other that their density through the universe would be nearly zero. Further, the expansion would cause a rapid cooling of the universe that would keep the environment that was ripe for creating magnetic monopoles from being the norm across the universe. The universe would have created many fewer than first thought and scattered them so much that they might never be found.

- Second, inflation gives an easy explanation for the cosmological principle. The problem here is that we have portions of the universe that could not have caused any changes in the others all homogeneous and isotropic. If the universe had been tightly packed immediately before the inflation, then the parts would have been close enough to be causally connected; the concern about needing processes faster than light would disappear because these parts were in such close proximity. Following the rapid inflation, the parts that had brought themselves into equilibrium would be so far isolated that further influence would be impossible.

- Third, we had the flatness problem. Of all the geometries, why should the universe be universally flat? The inflation would have to be driven by an energy field. Working out the mathematical form of it, the effect of inflation would be to flatten out space because of the uniform expansion, giving a uniform energy density.

Problems with Inflationary Theory

- Most cosmologists today accept the inflationary theory, but again, questions remain. First of all, what caused the inflation? What sort of field could give rise to such a violent explosion of space and time?

- Another problem is the smaller-scale irregularities. What caused the galaxies and clusters of galaxies?
    - According to inflationary theory, the condensed, tightly packed pre-inflationary universe would be in sufficient proximity to give rise to the equilibrium necessary for the homogeneity and isotropy we see now.

    - But equilibrium is never perfect; there are always small deviations from place to place. The inflation would have distributed these irregularities throughout space in a random way. And the process would have magnified the irregular nature of them such that they would form the seeds necessary to spawn galaxies.

    - Skeptics, however, contend that the seeds planted by irregularities would have been magnified at a time when the universe was still too hot. Protons and electrons may have been able to form in that environment, but the energy density would have made them move so fast that they would not have been sufficiently gravitationally attracted to the irregularities to form galaxies.

- Inflationary advocates agree that it would have been too hot for galaxies to form because normal matter would have been overheated and not subject to the requisite gravitational force. But they posit a different sort of matter that started the process: dark matter.

Dark Matter

- Dark matter comes into play in efforts to determine the masses of galaxies and the universe.
  - To determine the mass of a galaxy, astronomers have counted the stars in the galaxy, identified the masses of the various sorts of stars, then calculated the total. They have also figured out gravitational effects that would give them the mass of the galaxy as a whole.

  - The problem is that these two methods don't lead to the same answer. The galaxy as a whole is much more massive than the sum of the masses of the stars. The gravitational effects of the galaxy mean that there must be hidden mass.

- In 1975, the astronomer Vera Rubin found the same thing by examining the way galaxies rotated. In order for them to do what we see them doing, the mass of the galaxy had to be six times more than the masses of the visible stars in it. The overwhelming amount of mass in the universe was unobservable by us. What kind of stuff is it? Physicists have posited that dark matter is made up of weakly interacting massive particles (WIMPs).

- We need such particles to make sense in terms of our best theory of matter, the standard model. Physicists have played with quarks and leptons to see if they can come up with the recipe for the sort of thing we need, but it isn't there. It was then realized that if we extend the standard model with *supersymmetry*, we can explain WIMPs.

- This tweaking of the theory worked so well that by the 1990s, it was the scientific consensus. The universe had been very densely packed; it underwent a rapid inflation; and it has been expanding ever since.

Dark Energy

- The only one of the four physical forces that works over long distances is gravitation, and gravity is an attractive force. As such, all the matter in the universe must be pulling on all the other matter in the universe, opposing the expansion. It seemed, then, that there were only two possible options for the large-scale history of the universe.
    - If there is enough matter in the universe, this gravitational pull will be strong enough to stop the expansion and cause the universe to begin contracting.

    - If there is not enough energy to fully stop the outward momentum, the expansion will slow, but it will continue until the energy density becomes so low that it extinguishes itself; the universe will become cold and dead.

- But in 1998, Saul Perlmutter, Brian Schmidt, and Adam Reiss found that the expansion of the universe is speeding up. If gravity is a drag on the universe yet the universe is expanding, there must be some kind of energy driving the expansion. If the invisible stuff increasing the mass of galaxies is dark matter, then the invisible energy driving the increasing rate of expansion would be dark energy.

Suggested Reading

Nicolson, *Dark Side of the Universe*.

Panek, *The 4 Percent Universe*.

Questions to Consider

1. Our theories of matter and of the origin of the universe are so intricate and so well confirmed that we seem to have good reason to believe them. But the universe continues to throw us curveballs, such as dark matter and dark energy. Are future advances likely to be minor corrections and additions to what we already have, or is another full-blown Copernican-style revolution in the offing? Should we think we are generally correct, or will we have to dump our current concepts at some point and completely retool?

2. Situations that bring together subspecialties, as we saw with cosmologists and particle physicists, are increasingly rare in this time of super-specialization. Does this increasing specialization of science mean that revolutions are less likely?

Grand Unified Theories

Lecture 12

One way of making progress in science is to come up with new theories or discover new phenomena, but another way is to unify the theories we have to cover new ranges of phenomena. A major goal of contemporary physics is a theory of everything, that is, a grand unified theory that brings together all four of the known forces in the universe, showing them to be different elements of a single force. The leading candidate for this unification is string theory.

Unification as a Mode of Science

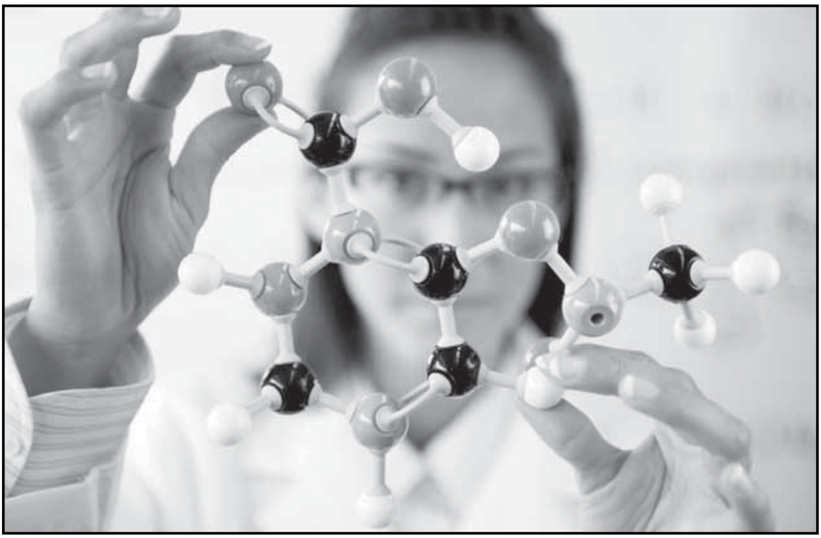
- William Whewell, a scientist and writer in the first half of the 19th century, held that the mark of a true scientific theory is "consilience," that is, the ability to bring together results and make predictions in fields of science other than that which a theory was created to explain. Good scientific theories, Whewell argued, simplify science; they bring together what seem like different fields into a single explanatory scheme.

- Earlier, René Descartes had undertaken to rebuild all of human knowledge in a clear, systematic way. Indeed, his famous dictum "I think, therefore I am" is the justification for the first absolute truth—the existence of the self as a thinking thing—that he would use in this project. He would go on to apply this unifying project outside of philosophy when he combined algebra and geometry into what we call analytic geometry.

- Newton extended Descartes's analytic geometry in the creation of his mathematical theory of fluxions, now called calculus. Using calculus, he created a scientific theory—a combination of mechanics and gravitation—that replaced Aristotle's separate theories of terrestrial physics and astronomy.

- Similarly, James Clerk Maxwell, in the middle of the 19^{th} century, changed how we saw the universe by bringing together the separate laws that were discovered to hold for electrical phenomena and for magnetic phenomena into a single account. This account showed that electricity and magnetism were just flip sides of a single coin, that what we thought were two separate aspects of reality were just different expressions of a unified picture of reality.

- As we've seen, light was then shown to be understood in this way, as well. Optics was thought to have nothing to do with either electricity or magnetism, but a coherent approach showed them all to be interrelated in a way that simplified the underlying picture of reality. It made the universe a more elegant place by creating a single theory that unified our understanding of the happenings within it.



Einstein's work spurred a reductionist movement in scientific unification; the separate realms in the study of the universe are increasingly complex instances of an underlying science, physics.

- Einstein had similar motives at the start of the 20th century, when he found himself dissatisfied with his theory of relativity because it lacked an organic place for gravitation. This lack of unity is what, in part, fueled his obsessive search for a general theory of relativity. Nature had to be unified, and if the theory did not display that, then the theory needed to be changed. This is what brought Einstein ultimately to his field equations, according to which space itself curved.

Hermann Weyl and the Unification of Field Theory

- Hermann Weyl was a student of the mathematician and philosopher Edmund Husserl and went on to become an important figure in physics. He opposed the positivists' reductionist project, but he did see unification as crucial to the advancement of science. As a result, he was the first person to attempt to develop a unified field theory.

- Recall that, with the general theory of relativity, Einstein had transformed gravitation from being a force between two bodies into the interaction of mass and energy with the underlying space. Space became malleable, curving and bending based on the distribution of stuff in it and dictating to that stuff how it would move.
    - The way to determine how much space curves is to compare the orientation of unit vectors. A *vector* is an arrow and a *unit vector* is an arrow that is one unit long.

    - Place the arrow at a spot in the space so that it is pointing straight up according to someone who is standing at that spot in space.

    - Allow the arrow to move around the space such that an observer at every new point it occupies fixes the arrow so it points straight up according to the observer. If we were on a sphere and starting at the North Pole, the arrow would be pointing straight up as we normally think of it.

- But as we move away from the pole, the arrow would turn because "straight up" changes for people at different points. We can determine the amount of curvature in a space by looking at the angle between the arrow's directions at different places.

- This was how we thought about the curvature of the space-time field for Einstein. But Weyl realized that along with this gravitational field, physicists also employed a second field, the electromagnetic field. Weyl's suggestion was to make these two fields into a single field.

- Weyl cleverly determined how to fold the electromagnetic field into the gravitational field. Vectors have two elements: a length and a direction. If we compare the angle at different points to tell us about the gravitational effects from the field, perhaps we should vary the length according to the electromagnetic contribution of the unified field. Compare the arrow at point 1 and point 2. The change in angle tells us about the gravitational effects, and the change in size tells us about the electromagnetic effects. The result is a unified field theory with a single metaphysical element underlying our observations.

Unification of the Forces

- Just like James Clerk Maxwell in the 19th century, theorists in the mid-20th century were trying to unify forces. Sheldon Glashow, Steven Weinberg, and Abdus Salam were able to do this in 1967, when they showed that the electromagnetic force and the weak nuclear force were different instances of the same thing.

- Recall that forces are transferred by the exchange of particles called bosons. The boson for the electromagnetic force is the photon. The weak force is transferred by a particle called W.

- Glashow, Weinberg, and Salam hypothesized the existence of a second boson for the weak force, that is, a second type of particle that carries the weak force, which they called Z. This hypothesized Z would be a sort of middle ground between the photon and W—more like the W in some respects and more like the photon in others.

- If this were true, then it could be shown that the electromagnetic force and the weak force could be thought of as the same thing. The new Z particle would be a bridge that, at extremely high temperatures, would cause the photon and the W to collapse together.

- If the Z boson were real, then photons and W bosons were just different flavors of the same underlying force.

- Experimental physicists at CERN were able to produce W and Z bosons in the 1980s. The missing part from the picture that Glashow, Weinberg, and Salam produced was the Higgs boson, which was discovered in 2012.

- We now have two of the four fundamental forces unified, giving us a universe in which there are three active forces. But these three are not seen as a trio, more like a pair and a third wheel. The combined electromagnetic and weak force (the *electroweak force*) and the strong force are part of the standard model and come from a quantum view of the universe. Gravitation is described by Einstein's general theory of relativity, which has a fundamentally different view of the universe than quantum theory.

- However, because there is only one universe, the hope is that we will find some way to unify the three remaining forces in a way that creates a single coherent, elegant structure to reality. Because the electromagnetic and weak forces have been unified, the next candidate would be the strong force, thereby completing a quantum world synthesis.
  - Such a combination has been called the *grand unified theory* (GUT) because it is a unification of the nonrelativistic elements. A theory that then brings together the elements of the grand unified theory with gravitation is called a *theory of everything* (TOE).

- Great press has been given to a potential TOE known as string theory. It is an attempt not only to unify the electroweak and strong forces but also to include a quantized picture of gravitation. If true, it would give us a new image of our universe.

String Theory

- Around the same time that Weyl was attempting to unify gravitation and the electromagnetic fields, the physicist Theodor Kaluza proposed a picture that was subsequently developed by the Swedish physicist Oskar Klein. According to the Kaluza-Klein model, we could bring gravitation and electromagnetism together if the field underlying reality was not four-dimensional but five-dimensional.

- Although it was later discarded, this multidimensional approach came back in the 1970s as string theory. String theorists seem to have come up with a way to account for all four forces if we think of the points of space as small loops of string. These strings can move in very different but independent ways, that is, they can vibrate or spin in ways that do not affect other sorts of movements. If we think of these independent motions of the string as dimensions, then we have a rich Kaluza-Klein type model.

- In 1995, Ed Witten showed that we can use these modes of string vibrations to account for quantum and gravitational effects if they have 11 distinct modes, that is, if we take reality to have 11 dimensions, 10 for space and 1 for time.

- Some theorists have argued that we should not think of the points of quantized space as strings but as two-dimensional surfaces, like the head of a drum. Such surfaces could vibrate in much more interesting and intricate ways. Space is, therefore, made of membranes (branes), not strings.
    - A string is a simplified membrane of degree 1, where a drumhead membrane is degree 2. Others extended the idea to take higher-degree membranes.

- Wanting to speak generally about such theories, physicists refer to arbitrary branes of degree p, or p-branes. The idea is that in the properties of these p-branes, we will find a way to unify all the forces in the universe into a single picture of reality.

Suggested Reading

Greene, *The Elegant Universe*, part III.

Questions to Consider

1. Is Occam correct that the simplest theory is usually the right one? Is this true because fewer assumptions give you fewer things to be wrong about, or is it because the universe itself is an elegant place? If the universe is messy and complex, does Occam's razor lose its edge?

2. Would a theory of everything really be a theory of everything? Would it just be a theory of all four known physical forces, or because everything is made up of atoms, would it really be a theory of everything? Could it account for chemistry, biology, psychology, and economics?

Quantum Consciousness

Lecture 13

Some people take the idea of a theory of everything to literally be a theory of absolutely everything, including the human mind. We know that the brain is made up of molecules and functions through electrochemical signals. The level of cells is small enough that quantum effects might be relevant to the mechanisms of the brain. If this is true, then the probabilistic elements of quantum mechanics might be relevant to understanding how the brain works; the uncertainty that accompanies them might, on the one hand, give us a purely physics-based understanding of consciousness, and on the other hand, provide us with a lack of determinism that would make room for human free will.

Reductionism versus Dualism

- Reductionists contend that everything in the universe is made up of atoms and energy. The longstanding resistance to this claim points to the existence of life as a metaphysically different kind of thing. We equate being a person with having something else beyond a body. Traditionally, this something else is a soul. This two-part picture of reality, with physical bodies and nonphysical souls, is what philosophers call *metaphysical dualism*.

- The great name attached to dualism is Descartes. With his "evil demon" thought experiment, he concluded that the mind exists separate from the body. Indeed, mind and body are completely different kinds of substances, and reality comprises two separate realms, the material world and the world of minds.

- The problem for Descartes is that what we want is not just mental but often physical. This means that these two separate realms must interact, and that is problematic.

- ○ We know, for example, that matter influences mind. A physical interaction, such as your foot kicking a desk, gives rise to a mental experience, pain. Further, a mental state, such as wanting to write a certain word, gives rise to the physical appearance of the word on a page.

- ○ How does this interaction between the mental and the physical take place? It is the size, shape, and mass of one object that lets it act on another. If ideas have no physical properties, how can they give rise to physical movements, such as writing? This problem of interaction seems to plague the move to include nonmaterial things in the universe.

In a dualist view, the properties of material and mental entities are completely different; a basketball is round and orange, but the *idea* of a basketball is not round and orange.

- Descartes tried to solve this problem anatomically, positing a fluid in the body called animal spirits that carried news of the physical world to the brain and sent out the brain's commands to the body. Of course, this view is incorrect, but the central metaphysical question remains: Is there a single sort of thing in reality, just material, or is there some other sort of entity? For Descartes, this "other sort of entity" was a soul and was particular to humans.

- Over time, living things were held to possess what the French philosopher Henri Bergson called an *élan vital* ("vital force" or "vital impulse") or what the German thinker Arthur Schopenhauer called the will to be. Living things have a will that nonliving things do not.

- In this view, the brain is necessary but not sufficient. We can see from CAT scans that when someone has a certain kind of thought, a certain area of the brain is active. There is, thus, a correlation between a state of the brain and a human experience, but the dualist will say that this correlation is a relation between two different things.

- The materialist, someone who contends that there is only one sort of metaphysical entity and that reality is strictly material, must hold that brain states and mind states are the same thing, that they are different descriptions of the same occurrence.

The Measurement Problem

- One physicist who made the case that consciousness is nonmaterial was Eugene Wigner. He was concerned with the measurement problem in quantum mechanics.
    - As we've said, when a quantum system is not observed, it occupies a state of superposition; it is in a combination of every possible state it could occupy. But the instant we observe the system, it collapses into one state. The Schrödinger equation gives us the odds that we will find it in each of the possibilities, but the best we get is a probability.

    - We have a physical law in the Schrödinger equation that always holds, except when we look. Wigner sought to determine what it is about us looking that causes the violation of the physical law.

- Quantum systems become entangled. If two electrons bounce off each other, we may be able to label them as A and B coming in, but we cannot say which one is A or B coming out. The two electrons cease to be independent things but, rather, are just disturbances in the underlying field. When we talk about the behavior of the field, the reality of the things themselves is lost; we can describe only the system as a whole.

- This is what makes the thought experiment called Schrödinger's cat so troubling.
  - We can create pairs of electrons such that when we do not look at them, both are in superposed states of clockwise and counterclockwise spin, but as soon as we observe one, both collapse into a single state such that one is always the opposite of the other, but we never know which will be which.

  - Imagine that we attach the apparatus that creates these pairs to a spin detector that will observe the spin of one of the particles. We then attach the detector to a circuit connected to a poison gas canister. If the detected particle is spinning clockwise, then the circuit does nothing. If it is spinning counterclockwise, the canister is opened, allowing the gas to escape. Finally, we place the canister in a closed box containing a cat.

  - We push a button, a correlated pair of electrons is emitted, and the detector determines the spin of one. If the electron collapsed from its superposed state into a clockwise spin, the cat lives. If the electron collapsed from its superposed state into a counterclockwise spin, then the gas escapes, and the cat dies.

  - But suppose we do not look in the box? The detector is a physical thing subject to the laws of quantum mechanics. If we have not observed the detector, its atoms will be in their superposed state, which is now entangled with that of the emitted electron.

  - Likewise, the circuit is just more atoms that are unobserved and, thus, are entangled with the state of the larger system. And it is the same with the canister of gas and the cat. All are just atoms, all unobserved, all in superposed states in a grand entangled system.

  - When we do not observe the system, it is in one superposed state, meaning that the cat is in the superposed state of alive and dead. But the instant we open the box to look, we see either a dead or live cat.

- ○ Because we are just atoms, we, too, should be part of the system, as should the rest of the universe. There should be no collapsing from the superposed state into a single-property state. Wigner concluded that the only place in the process that a different sort of entity could be active is in the making of the observation—the point when our consciousness becomes involved and we learn of the result. Other than our consciousness, there is nothing but atoms and nothing that should affect the system to cause the collapse.

- ○ Perhaps we need to hold that matter and mind interact but are completely different. If this were true, it would allow us to make sense of one of the most troubling aspects of quantum theory. But what sense do we then make of a nonmaterial consciousness, and how does it cause the collapse of the wave function?

Quantum Theory and Free Will

- In a materialistic view, the universe is just matter and energy, and these behave according to mathematically expressed laws of nature. Humans have no ability to do other than what we do. But materialists can try to save some sense of nondeterminism in human action based on the laws of nature. The fact that the universe is a well-behaved place does not mean that human actions are a deterministic product of history and environment. This is the view taken by the British theoretical physicist Roger Penrose.

- Penrose starts with the simple proposition that our actions are controlled by the brain, which is made up of neurons in intricate networks. Neurons work together by the release of neurotransmitters that allow for the flow of electrical charge. When one neuron releases a particular chemical into the gap between the cells, it will either facilitate or stop an exchange of electrical signals, and it is the propagation of these electrical signals through the brain that results in bodily movement.

- Aiding in the delivery of neurotransmitters are parts of the neuron called *microtubules*, small, thin tubes made of a protein called *tubulin*. Penrose has argued that the structure of the inside of the microtubules may be such that it creates an entangled quantum system within and between cells.

- Being inside of a tube, this structure may be sufficiently isolated from the effects of the environment outside the body on the brain to remain—at least for a while—in a superposed state. This superposed state eventually is acted on by the chemical environment of the brain, causing it to collapse and fire a particular constellation of neurons. Because this process occurs at the quantum level, there will be in this fully material system an element that is necessarily noncomputable.

- In other words, the brain is nothing but a physical system, working according to physical laws, but because the structure of the brain is so fine, there may be a quantum-level effect that makes our actions not determinable. We are governed by the laws of physics completely, but that does not mean that our actions or intentions are uniquely determined by the environment and the absolute laws of the universe.

- Further, the fact that the quantum states of these microtubules are entwined into a single system means that this sort of quantum consciousness involves the structure of the entire brain. Thus, our idea of free will is not that we have a rational agency that has no dependence on the physical universe, but we are not robots acting at the whim of absolute physical rules either.

Suggested Reading

Longhair, *The Large, the Small, and the Human Mind*.

Penrose, *The Emperor's New Mind*.

Questions to Consider

1. Would the randomness of quantum mechanics just save the appearance of human free will, or would it give us free will? Is it more important that our every choice is not predetermined or that it is determined by us?

2. Is there reason to think that the human mind is not material? Is there a difference between the brain and the mind?

Defining Reality in the Life Sciences

Lecture 14

To see how modern science has forced us to redefine reality in the life sciences, we need to understand the starting point. Traditionally, our picture of biology comes from Aristotle, who believed that species endow their members with the same sort of soul and, thereby, the same goal. Life is the process of each member of a species trying to actualize its innate potential. The church took over this view and ranked the species in order of their perfection in the Great Chain of Being, a fixed picture of reality since the creation. Darwin's theory of evolution upset this fixed picture and started the 20th century off with an unsettled image of life in the world.

Classical Biology

- As with the physical sciences, the biological sciences trace their roots to Aristotle. Recall that Aristotle's worldview was teleological: All change is originated within the thing changing and is geared toward a goal or aim of that thing. For earthly chemical elements, that meant seeking their natural place in the universe by moving toward it in a straight line. For living things, however, the goal is a bit more abstract.
    - Remember that Aristotle was a student of Plato, and Plato said that reality was not to be found in the material world because all material objects are imperfect. Change, for Plato is also teleological, and if something is changing, it is trying to reach its goal, which makes it imperfect. A perfect thing would have no reason to change because it had reached its goal.

    - Thus, what is real is not what we find in the material world but, rather, the perfect, idealized conception of it. Plato called these the forms, and they reside not in the world of material things that we see with our eyes but in the eternally unchanging world of forms, which we see with the eye of the mind.

- Aristotle thought that this world is the real world, but he still incorporated Plato's view into his understanding of it. The perfect, unchanging forms of which all material things are imperfect representations are taken out of the ethereal world of forms and packed into the living things themselves. All living things contain within them a potentiality, an essence, and the course of their lives is the history of them trying to actualize their potential.

- Aristotle thought that all things are made up of matter and form, substance and structure, and changes in both result from the organism trying to reach its potential, a potential that is a part of it and that remains the same for all members of the same species. In the process of reproduction, the potentiality is encoded in the organism.

- The study of biology, according to Aristotle, is the study of potentialities, the essential properties that make each species unique and the properties that some species share in common. Biology, therefore, has two steps.
    - First, the scientist must carefully document the anatomy of the organism. Then, through observation, he or she must determine the essence of the species—find out the goal of that species.

    - Second, the scientist must incorporate the species into an organized catalogue of all species. Species are grouped according to common elements of their essences.

- When the church discovered Aristotle and took over his scientific views as official doctrine, the biological elements were easily adapted for theological purposes. Plants and beasts weren't thought to have souls, but they did have plans, and these were placed inside them based on the ultimate blueprint for creation.

- In this way, we could still account for anatomical differences and categorize species, but now, the list of species could have an order of perfection imposed on it. The result was the Great Chain of Being, in which every organism was in a species, and every species had a place. The Great Chain was fixed and immutable, as perfect as the God who created it. Of course, Charles Darwin's suggestion that species developed over time challenged the church's account in radical ways.

Darwin's Revolution

- Darwin showed that the plans according to which organisms develop are not fixed. The properties of species change over time in accordance with selection procedures that determine from the outside, not the inside, which features of the species will remain. Further, these changes are not progressive; they do not proceed according to some larger plan in which things become more perfect. Species merely adapt themselves to the current circumstances, which themselves will change for no reason and in accordance with no plan.

- Darwin's theory can be set out in terms of four basic principles, each one based on experience: (1) Children look like their parents. (2) Children don't look exactly like their parents. (3) You must be alive to have children. (4) You must get a date before you have children.

- The idea behind the first principle is that certain traits are heritable. Certain family resemblances exist that are not widely shared outside the family and, thus, come from being part of the family.

- Although many traits are heritable, the second principle tells us that offspring occasionally exhibit new traits for seemingly no good reason. Random mutations occur, some of which are good and some of which aren't. Sometimes, these mutations could be passed to offspring, and sometimes they couldn't.
    - Because he raised pigeons, Darwin knew that he could breed for a certain mutation and, eventually, would have a group of pigeons who shared the mutation.

    - If you select strange enough traits, breed only those with that set of traits, and separate them from the original population, you will eventually develop a group of organisms that bear little resemblance to the others. In isolated areas, where physical and geographical boundaries prevent interbreeding, the result will be groups of organisms that are quite unlike each other. Ultimately, these differences can amount to sufficient change that a completely new species emerges.

- The third principle—you must be alive to have children—is the well-known doctrine of natural selection. It begins with the presupposition that the world is a dangerous place, in which the stuff you need to survive is limited in quantity and you are the stuff some other animals need to survive.
    - Darwin was familiar with the work of Thomas Malthus, a clergyman and social theorist who had written *An Essay on the Principle of Population*. According to Malthus, human resources are growing linearly, while population is growing exponentially. Eventually, this will result in intense competition for the limited goods needed for survival and a crash in population due to mass starvation.

    - Darwin saw in Malthus's work a reflection of the natural world. There is constant competition for scarce resources within a species and danger from others. If an organism is to be successful in passing on its traits, it needs to procreate and for this, it needs to survive.

    - The random mutations that pop up will most likely not be a help to survival; indeed, most are a detriment. As a result, the probability of an organism with the deficiency living to have children is decreased and over time, and the deficiency will disappear from the population. But in the rare case that the mutation conveys a positive trait, an aid in surviving, there is a greater likelihood that the organism will procreate and, therefore, a higher probability that the trait will not only continue but increase its appearance in the population.

The colorful plumage of male birds is the result of sexual selection; the plumage makes them more likely to be found attractive by potential mates and, thus, more likely to pass on their traits to the next generation.

- Although surviving is necessary for procreation, it is not sufficient. This fact leads to our fourth pillar of Darwinian theory: You must get a date before you can have children. Mate selection becomes important in terms of the ability to spread properties through a population over generations. The more attractive an organism is, the more likely it is to mate and, thereby, pass on its traits to the next generation.

- Combined, these four principles give us the basis of Darwin's theory, which forced a radical shift in the way we see the world. Although nature may be well-ordered, with interlocking parts, no longer is it a static system.

- Although this aspect of the theory was bothersome to our view of reality, the real shock came when Darwin applied it to the history of humanity. In the Great Chain of Being, our status as superior to the rest of creation was fixed and assured. We were created in the image of God and, therefore, not only higher but of a different category than mere animals. But with his work *The Descent of Man*, Darwin brings humans "down" into the realm of nature. We are animals, and we are not special in the ways we thought.

Darwin's Cultural Influence

- Perhaps the greatest cultural influence of Darwin's theory was the sense of pessimism it conveyed. When the universe could be seen as well-ordered, it seemed to be created for us. It was a friendly place, and we should reflect its amicability. But now, we were just another sort of animal in a world hostile to animals and hostile with animals. To be successful, we must become fierce.
  - The result was the adaptation of Darwin's thesis into the policy known as *social Darwinism*.

  - This view holds that our empathetic and sympathetic natures must be kept in check for the sake of the species. If survival pressures are necessary for development, then acting out of kindness to assuage the suffering of the needy is a detriment to all of us. Helping the less fit to survive through social programs and government aid retains those who should be winnowed out of the gene pool. If we are animals, then for our own sake, we should start acting like it.

- One of the most striking portrayals of this thinking appeared a century after Darwin with William Golding's classic novel *Lord of the Flies*. In it, we literally see the descent of man when upper-class British boys become stranded on an island.
  - At first, the boys form a version of adult society, with political and social institutions designed to serve the common good, protect equality, and support the well-being of all.

- But eventually, the wilder among the boys break off and acquire power. As the boys shed their culture, they lose their humanity, ultimately becoming murderous savages. Removed from the structure and enforcement mechanisms of human society, the boys revert to their base animal selves.

- Although Golding's book is considered one of the great works of English-language fiction in the 20th century, we also see versions of this work in today's reality television. Nowhere is this more apparent than in the program *Survivor*, which clearly sought to model Golding's plot.

Suggested Reading

Bowler, *Evolution*.

Darwin, *The Origin of Species*.

———, *The Descent of Man*.

Questions to Consider

1. There may not be a ranking first to last, but is there some way in which we can say that certain species are more perfect than others? Is this akin to Plato saying there is one definition of *good* that holds for the whole of reality, as opposed to Aristotle saying that there is only *good for*? Is a sponge less perfect than a horse or just different? Is killing a sponge the same thing as killing a horse?

2. Is the competitive nature of sports and reality television healthy for us in making us more fit for the tough world, or does it bring out an uncultured side of us that is undesirable?

Genes and Identity

Lecture 15

Darwin posited that children look like their parents but never understood the mechanism. Twentieth-century biology showed that the mechanism of inheritance is the transfer of genetic material located on chromosomes in the cell's nucleus. The genes are made up of DNA, which codes for protein production that gives rise to the observable properties. This discovery allowed us to understand how certain illnesses have their roots in a person's DNA and leads us to ask whether it would be good for individuals and the species to breed out these genetic problems, that is, whether eugenics is morally necessary or necessarily immoral.

Mendelian Genetics and Chromosome Theory

- The first great name in the study of genetics was Gregor Mendel, the Czech monk whose work with pea plants first disclosed the regularities in inheritance. Mendel showed that some traits are dominant, others are recessive, and the passing on of traits can be modeled mathematically. But he was unable to discover the operative mechanism—the genetic coins that are being flipped in the reproductive process.

- Around the same time that Darwin and Mendel were doing their work, the focus of biology turned to the role of the nucleus in cell division, especially in fertilized eggs. One structure in the nucleus, the chromosomes, seemed a good candidate for the cellular "coins" biologists sought for three reasons:
    - First, the number of chromosomes in a cell nucleus was the same in all the cells of every organism of a given species but different for different species.

    - Second, the chromosomes were two seemingly identical strands that were tangled together; during cell division in most cells, they untangled themselves, with each new nucleus getting one of them.

- Third, for sperm and egg cells, the cells contained only one strand, so that when they combined to form a zygote, the new potential offspring received one from each of the parents. Thus, it seemed reasonable to hypothesize that the chromosomes carried the units of Mendelian inheritance.

- Not everyone accepted this chromosomal theory of inheritance. One of the most vocal and stubborn critics was the American biologist Thomas Hunt Morgan. If the chromosome theory was correct, Morgan argued, then the environment had little to do with the determination of traits. But there seemed to be cases in which the environment had effects on the properties of the organisms conceived.
  - Morgan set out to disprove the chromosome theory using fruit flies. In this research, he changed environmental factors and kept track of all the traits of the parents and offspring.

  - After years of work, however, Morgan realized that no matter what environmental factors he toyed with, the only thing that seemed statistically relevant were the properties of the parents, and that seemed to point to chromosomes.

- Morgan and his students examined chromosomes more closely and found that they had a structure—parts that were termed *genes*. A later researcher incorporated that term into two new coinages: *genotype*, which refers to the difference in chromosomal makeup, and *phenotype*, which refers to the difference in observable properties of an organism. The question now was: How does a difference in genotype create a difference in phenotype? In other words, how does a difference in your chromosomes make a difference in your body?

- Morgan studied this question and found that genes that were close together on a chromosome often were passed along together; this reflected the passing of traits from one generation to the next. One of Morgan's students, Alfred Sturtevant, created the first map of a chromosome, showing that the distance between genes was important in understanding heritability and birth defects.

- The key to understanding how we pass down our traits from one generation to the next was to be found in the genes. But how do genes work? Because the community was focused on mapping, it made the physical architecture of the genes the primary factor. It was a mechanistic picture. There must be something in the structure of the genes that is the determining factor.

The Discovery of DNA

- Max Delbrück and Linus Pauling were two scientists who held the reductionist view that biology is just a complex application of physics. Thus, they began the search for the molecular processes that were responsible for the differences in genes. The scientific world was split between those who thought that proteins were the responsible agents and those who thought that deoxyribonucleic acid (DNA) was the active molecule.

- Pauling and Delbrück were convinced that it was DNA and set out to describe its structure, certain that once they had figured out how it was built, the processes of heredity would reveal themselves. If only we knew the architecture of DNA, we would be able to reduce the most important property of life to a purely physical basis.

In turning his attention to the DNA molecule, Max Delbrück sought to translate biology-speak into its true physics-based nature.

- In competition with Pauling were two researchers in England, Francis Crick and James Watson. Ultimately, they were able to show that DNA is a double helix, with two strands of biopolymers on the outside and pairs of nucleotides on the inside.
  - The four nucleotides form base pairs such that each step on the twisted ladder is made up of either adenine and thymine or guanine and cytosine. Because they bond in only those pairs, you can split the ladder and peel the biopolymer chains apart such that one member of the base pair stays bonded to the chain, and the other side of the chain can be re-created in a completely unique way, thereby restoring the complete information held by the molecule.

  - The information is the template for protein creation. The encoded sequence directs the creation of proteins that perform the needed functions in the body that give rise to phenotypic properties, the observable traits. In this way, the instructions are replicated into every cell, and that is the basis of heredity.

Eugenics

- Although the standard picture of reality has humans imbedded in it as free beings, there has always been a degree of determinism allowed. There are some properties that are not purely a matter of will. We may want to be taller, but wanting will not effect change. We may want a different singing voice or a different level of mathematical ability, but that will not happen. It is later in life when we discover these lacks and talents. What accounts for them?

- Traditionally, the answer is seen to be one of two mutually exclusive possibilities: nature or nurture. The genetic revolution gave significant ammunition to the nature side of the debate. Sickle-cell anemia is a molecular disease. Those who have it are biologically determined to have it. There is no choice and no escape. What makes you who you are is your unique genetic code. Your uniqueness as an individual is not your biography, your decisions, or your memories; it is your sequence of genes.

- This picture of illness is quite different from the one we had for centuries. Many health problems are the result of interactions with the environment, and in these cases, you cure the illness by repelling the invader. But with genetic ailments, the problem isn't that the person is being made sick by something; it is the person who is, in essence, the problem.

- Illnesses are necessarily bad, and if the illness is the result of the genetic code, then the code is bad. But the code is the person; thus, the person is bad. If our job is to alleviate sickness of every sort, then we will need to eliminate genetic-based diseases by eliminating the genetic flaws that cause them. This can only be done by preventing those who have that code from becoming a part of the gene pool.

- This was the central doctrine of the movement called *eugenics*. The term today has a deeply negative connotation because of events in the middle of the 20^{th} century, but the idea of social engineering was one that came from a desire to eliminate human pain. People with genetic diseases suffer. If we could act to minimize human suffering, we seemed morally required to do so.

- In this case, we cannot do anything once the person is born; thus, our ethical obligation begins before birth. Everyone who is born with a genetic ailment or deformity will be limited in the ability to flourish as a human, and that detriment is not their fault; it is ours. It is our moral failing that we allowed that unsuccessful life to come into being. Eugenics was not a dastardly plan to create perfect people but, rather, a movement to minimize human suffering. Eugenics sought to eliminate genetic diseases from the human population by making sure there were no more carriers in the population.

- But what exactly do we mean by the term *disease*? Is a disease a condition that shortens lifespan? What about debilitating conditions that cause pain or deformity but do not kill the person before the natural lifespan concludes? Should we think of disease as any condition that keeps one from being maximally successful as a member of the human species? But now we have an even trickier question: How do we determine what constitutes human success, and who makes that determination?

- It is, in the end, a political question, and political questions are sometimes resolved by rational means, but they are always a function of power. Natural selection develops in accordance with changing environmental stresses, while artificial selection, such as animal husbandry, proceeds according to the whims of those in power. Eugenics (animal husbandry applied to people) will inevitably give those with power the ability to define what counts as human flourishing, and this will always resemble those who already have the power.

- Although differences are exaggerated into genetically determined inferiority, our art shows that actual genetic diseases do not eliminate the possibility of authentic human existence. For example, the film *My Left Foot* shows episodes in the life of the Irish poet and painter Christy Brown, who was born with cerebral palsy. Instead of eliciting pity for the character with this severely life-affecting condition, we are shown the humanity that lies beneath it. Brown is both charming and obnoxious, alternatingly arrogant and insecure, both strong and weak. In a word, he is human.

- The eugenicists, in trying to remove the suffering that comes from genetic defects, failed to see that people with genetic diseases are people; they are defined by their humanity, not by their disease.

Suggested Reading

Mason, *A History of the Sciences*, chapter 42.

Sturtevant, *A History of Genetics*.

Questions to Consider

1. How much of who we are is determined by our genes? If genetic differences cause bodily differences, even brain differences, how much of who we are, how we are, and who we become is up to us?

2. Curing diseases is a good act because it allows for the avoidance of human suffering. If someone found a cure for cancer, we should consider that person a hero for all the lives he or she will have saved and all the suffering he or she will have stopped. If some diseases are genetic, their only cure is to stop people from acquiring them in the first place. Why, then, should we not keep certain pairs of people from having children, given that it would create less human suffering?

The Birth of Psychology

Lecture 16

Philosophy had long wrestled with the idea of mind, but in the 20th century, it became a concern of science. The difficulty, of course, is that one cannot directly observe the mind, but researchers began to derive tests that showed how the mind made sense of the world. The next move was to connect the mind with the brain, showing which parts of the brain controlled which functions. Freud began his career in this mode, believing that mental phenomena were brain based and that surgical fixes were necessary for mental illness. But he soon developed a different image of mind, one that was experience based and gave rise to a nonmedical talk therapy, psychoanalysis, as a cure for mental problems.

Psychology as a Science

- Scientific investigation of the mind began at the end of the 19th century, when Wilhelm Wundt and Gustav Fechner began to investigate the ways in which our internal experiences relate to the world around us.
    - Fechner, for example, studied just noticeable differences. If two stimuli are slightly different, our anatomically based sensory detectors are not sensitive enough to detect the difference. Fechner wanted to know how different two things must be for us to notice the difference. He found a mathematical relationship that seemed to hold true for touch, sight, and hearing.
    - That there was a way of expressing such relationships involving the human brain according to the strict standards found in physics sparked intense interest in a science of the mind.
- The science developed further from the medical project of curing illness. For example, the physiologist Paul Broca was able to determine that damage to a portion of the frontal lobe of the brain, now called Broca's area, led to speech problems. From this, he

inferred that the function of that region is speech. The picture grew much more complicated as it became evident that interconnected areas of the brain were responsible for complex human actions.

Talk Therapy

- Sigmund Freud was a physician in Vienna who was very much in the mainstream of the brain-based medical research paradigm. After his marriage, however, Freud moved to clinical work in private practice. He was consulted by a colleague, Josef Breuer, about a patient called Anna O. who suffered from a range of symptoms, including blackouts, periods when she couldn't speak or move her limbs, and loss of vision. Breuer found that when Anna talked to him about her symptoms, they would vanish. Breuer believed that the relief of symptoms was an effect of catharsis.

- The idea that simply talking could have a curative effect on a patient suffering real symptoms ran completely counter to the paradigm in which Freud had been working.
  - He had been accustomed to looking at the structure of the brain to explain psychological problems. If the mind is not working properly, there must be a part of the brain machine that is malfunctioning. But here was a real patient whose psychological symptoms were made better by addressing the mind, without mechanical changes.

  - The possibility of effective talk therapy was revolutionary. It led Freud to look beyond the acceptable topics defined by the paradigm.

Hypnosis

- In the late 18th century, the German physician Franz Mesmer had discovered hypnosis in his investigations of the effects of magnets on humans. In the late 19th century, Jean-Martin Charcot, a giant in French medical circles, became interested in hypnosis. He began to investigate it both as a psychological occurrence and as a possible treatment for mental issues.

- Charcot found that there were women suffering from hysteria, often with accompanying paralysis, who were not insane but experienced episodes that were disruptive and troubling. He posited that this sort of hysteria was the result of a traumatic event.

- This was a radical proposition. Instead of seeing brain injury as the cause of mental illness, Charcot suggested that mind injury—a lived experience of a certain sort—caused mental problems.

- He also contended that there was an anatomical aspect, that certain women had brain-based issues that made them susceptible to hysteria, but the problem was in part experiential. Once suffering, these women were capable of being hypnotized, and the result of the hypnosis could be helpful.

- Hypnosis was not, according to Charcot, something that could happen to anyone, but rather, susceptibility to hypnosis was itself a symptom of hysteria, albeit one that could have curative powers. In this way, it was much like Breuer's talk-induced catharsis.

- Freud went to Paris to learn from Charcot. He returned to Vienna and found that hypnosis yielded mixed results. He became disillusioned with hypnosis as the basis for therapy, but it was highly suggestive in terms of a picture of the human mind.

- Freud was fascinated with the fact that hypnotized subjects sometimes recalled events they did not remember when awake and fully conscious. This meant that there is a repository of memories in the mind to which we do not usually have access, and hypnotism was one route to tapping into them. Other methods, such as free association or dream analysis, might be more reliable than hypnotism but do essentially the same thing. Hypnosis is not a byproduct of mental illness, Freud conjectured, but one path to a part of the human mind that everyone possesses, although it remains out of sight when the mind works as expected.

- Charcot's hypothesis that trauma could lead to mental illness and Breuer's observations that talking could make a patient better implied that there was more going on in the mind than we normally see. Perhaps some mental illnesses are the result of traumatic events stored in this inaccessible part of the mind, the subconscious. These events remain hidden from our minds because they are too painful to confront, but we must work hard to repress them. The struggle for repression remains below the threshold of consciousness, but the mental strain takes its toll and instantiates itself in sometimes bizarre and seemingly unexplainable ways.

Freud's Theory of Mind

- The result of Freud's study over several years was a tripartite theory of mind, encompassing the ego, the id, and the superego.
    - The ego is the conscious mind. Traditionally, it had been thought of as the complete self. Reasoning, arguing, deliberating, organizing, planning, and making sense of sense experiences are all the work of the ego.

    - The id is the repository of our urges and desires. It is where instinct and primal needs are located. Freud contended that the child's mind is pure id, something we learn to mitigate later in life, when we become proper and cultured.

    - The superego is the conscience. In Freud's thinking, this is the internalized father, the parent who teaches us how to behave and punishes us if we do not follow the rules.

- According to the Freudian model of the mind, we think we are free to decide what to do, but there is always conflict beneath the surface during the time of deliberation. The id and the superego are fighting, and the result is wrongly perceived by us to be a matter of free choice.

- This is always the case, even with a healthy mind. But in some cases, traumatic events seat themselves firmly in the subconscious. These, according to Freud, sap the person's mental resources by having to be constantly repressed. They lead the id to urge certain actions that the superego will not even allow us to consciously consider.

- To cure those who suffer from hysteria as a result of traumatic experiences, the experiences must be exposed through psychoanalysis. The analyst has tools to plumb the depths of the subconscious to bring the repressed to light in hopes that exposure will allow catharsis. Failure to do so keeps the psychological injuries buried within the psyche, constantly wreaking havoc on the person and those around him or her.

- Freud's view was not completely novel. The idea that there is a repressed part of the human mind whose lack of expression gives rise to mental illness is present in the 19th-century German philosopher Friedrich Nietzsche.
    - Nietzsche picked up on an idea from Arthur Schopenhauer that inherent in all beings is a will, a spirit. For Nietzsche, this is the will to power. We all have a primal instinct to exert ourselves on the universe. But this urge is foiled by acculturation. Social mores train us to ignore our instinctive animal selves. Ethical codes thought up by the weak to contain the strong are enforced by threat of law and eternal damnation.

    - But these false idols cause an illness of the soul for all humanity: They breed *ressentiment*, a sense of self-hatred that becomes transformed into hatred of the other. This hatred is poisonous and creates an unhealthy culture in which people fail to be fulfilled, denying their will.

Freud's Redefinition of Reality

- Freud's redefinition of reality is similar in influence to Newton's theory of gravitation. Where Aristotle had the falling of objects originate in an internal drive, for Newton, it is the result of gravity, which requires a relation between objects.

- With the genetic approach, we are who we are based on our genetic code. Our identity is derived from something purely internal to ourselves. But with Freud, we are more than the people we think we are, more than just our ego.

- The id stores the memories we cannot bear to remember. It is a store of our relationships with others that are deeply painful. The superego is the result of our parenting. The goals we aspire toward and the values we internalize are not of our own creation; they are the result of a parent/child relationship that in one form or another is a part of every human being.

Freud's picture of the human brain and mental illness has permeated our culture as a staple of Hollywood horror films.

- If we want to understand the reality of a human life, we cannot look at the person atomistically, according to Freud. People are not individuals but internalized relations: relations between the people in our lives, between the parts of the mind, and with events in the past. Like Newtonian masses acting on each other through the invisible force of gravitation, human beings have an invisible connection between them. Those relations, Freud argues, are a part of reality.

Suggested Reading

Freud, *Three Case Histories*.

Phillips, *Becoming Freud*.

Wertheimer, *A Brief History of Psychology*, part II.

Suggested Viewing

Nightmare on Elm Street.

Psycho.

Silence of the Lambs.

Questions to Consider

1. Are the mind and the brain the same thing or different things? When we have an idea, is it just a brain state, or does that brain state give rise to a mind state that is related to, but different from, the brain state?

2. Do we have a subconscious? Do we know what we are thinking, or is our brain just making us think we want things we think we want? Are we in control of our minds, are our minds in control of us, or are we our minds?

Jung and the Behaviorists

Lecture 17

After Freud, psychology developed in two different directions. On the one hand, Carl Jung took Freud's picture of mind and spread it out across all of humanity. All people share a collective subconscious, which can be glimpsed in the fact that completely isolated cultures share similar characters and themes in their mythologies and cultural foundations. On the other hand, some psychologists thought of these concepts as too strange to be included in a real science; psychology needed to purge itself of everything not capable of being observed or measured in a laboratory setting. Behaviorism did away with everything in psychology that is not strictly scientific, including the idea of a human mind and free will.

The Freudian Model Applied to Culture

- In one of his great works, *Civilization and Its Discontents*, Freud moves the discussion about the nature of a human from a purely individualistic position to one in which the larger culture plays a role.
  - In his original formulation, the individual strives to emancipate himself or herself from the rules of the father. The contents of the subconscious are purely a matter of experiences between the self and particular individuals in the person's life.

  - But in *Civilization and Its Discontents*, Freud places the state or culture in the role of the father. There is in the human a struggle between the urge to be a self—an individual free from constraint—and the urge to be a good citizen of a culture that demands conformity, uniformity, and control.

  - This control leads to laws and rules of etiquette, which are enforced from outside and become internalized, thereby becoming a source of repression of basic urges.

- We find ourselves once again with an unhappy subconscious, but now, instead of being Oedipus, who wants to kill his father and marry his mother, we become closeted anarchic revolutionaries.

- The state is not the only cultural institution that becomes a collective superego by playing the role of the father. Organized religion does so, as well.
    - In observing those who were deeply connected to organized religion, Freud saw the same types of behaviors that he observed in his patients who suffered from obsessive compulsive disorder, including the need to repeat certain rituals and a sense of guilt as a motivator for the rituals.

    - The major difference between obsessive compulsive individuals and those involved in organized religion is that the former are indeed individuals. They do not have a community who share their neurotic behaviors or enforce and reinforce the need to perform them. As such, Freud labeled organized religion a collective neurosis.

- This view of a collective superego and collective neuroses opens up the possibility that other parts of the Freudian scheme could be collective, as well. This was the line taken by Freud's star student, Carl Jung.

Jung's Collective Unconscious

- Jung was a Swiss psychiatrist who became Freud's closest disciple, although a rift later developed between the two. Jung accepted Freud's notion of the subconscious as a well for primal urges and desires and agreed that inner conflicts between the conscious and unconscious mind and the resulting repression were the cause of many neuroses.

- But Jung expanded the id to include what he thought was a crucial element Freud had missed, the collective unconscious. There is, Jung contends, a part of the mind that contains memories and experiences that are not our own, that come from our ancestors. This collective unconscious is part of the structure we use to make sense of, and give meaning to, the world.

  - Jung pointed out that the same sort of images, characters, and events appear in myths, religions, and beliefs in contemporary and ancient cultures around the globe. We see the wise old man, the trickster, a great flood, and other similarities in the central stories of cultures that could not have been in contact.

  - Jung called these basic ideas *archetypes*, and *synchronicities* was the term he used for the repeated appearances of archetypes in isolated cultural systems that could not have influenced each other.

- The collective unconscious does not provide us with specific details of human history but, rather, archetypes that we use as the building blocks of meaning. Meaningfulness comes from interpretation by the mind, but the human mind does not start from scratch; it begins with these basic archetypal patterns, using them as the basis for a sense of significance that becomes attached to events, objects, and people.

- Each culture applies the shared archetypes to its own geographical and historical context, thereby creating the differences we see in central mythologies. But when we look at what is valued, we see a peculiar amount of commonality, more than we would expect if the cultures developed purely autonomously.

Cultural Influences of Jung

- Notice that Jung's extension of Freud's work follows the larger pattern we have discussed elsewhere in this course. We start with the human mind as a thing, an object unto itself to be studied alone. With Freud, the move is then made to considering humans in terms of relations. With Jung's collective unconscious, we take the final step of eliminating the individual objects and positing a sort of unified field. What is real is not the object but the whole; the object is just a mode of the larger collective reality.

The use of drugs by some in the counterculture of the 1960s was based on the idea that these substances cleared away the ego, leaving one in a position to connect directly to the collective unconscious.

- This aspect made Jung's views deeply influential in the middle of the 20th century with the growth of the 1960s counterculture in America.
  - The hippie movement combined a back-to-the-land sentiment with a deep commitment to equality that grew out of the political liberation movements that were prominent at the time.

  - The cultural revolution was set out in terms of "expanding one's consciousness," which referred not only to being more open-minded about violating longstanding social mores but also to affecting one's psychology through meditation or drug use.

The Rise of Behaviorism

- The popularization of unobservable elements of Freudian and post-Freudian psychology concerned mainstream psychologists, who wanted to inoculate psychology from the seemingly nonscientific direction it was taking. A new approach was sought, the result of which was behaviorism.

- Behaviorism was an attempt to make psychology a completely rigorous science, and to do that, unobservable entities would need to be purged—first and foremost, the mind. According to the behaviorists, we cannot speak of the mind at all, much less unconscious, empirically unavailable regions within it. We can talk about only what we can see and measure: stimulus and response.

- This movement grew out of a philosophical school of the time known as *logical positivism*.
    - The logical positivists tried to formulate what they called a *criterion of cognitive significance*: Only entities for which we have evidence would be allowed to be considered meaningful. What is evidence? It is a sense perception that gives you good reason to believe it exists. Seeing is not only believing, but it is essential for having any meaningful beliefs whatsoever.

    - If physicists had to give up absolute space and the luminiferous aether, then psychology would have to give up the mind, the id, the collective unconscious, and other such fluffy concepts.

- The Russian physiologist Ivan Pavlov had won the Nobel Prize for his work showing that he could teach dogs to salivate at the sound of a bell. Such operant conditioning opened the door for this new psychology, in which the rigorous connections of stimulus and response could be measured and associated.

- The American psychologist John Watson first clearly enunciated the criterion of cognitive significance as an explicit affront to the expanding view that psychology was the study of consciousness. Consciousness is inaccessible, if it even exists at all. Therefore, the study of psychology should be merely the study of human behavior.

- Watson's work was picked up by B. F. Skinner, who was heavily influenced by the ideas of the logical positivists. Skinner limited psychology to the study of how people behave when confronted with particular stimuli. He closely studied how various environmental factors affected subjects and how positive and negative reinforcement could predictably change the mathematical relationship between the stimulus and response.

Cultural Influences of Behaviorism

- The ability to use psychological research not only for pure purposes of gaining knowledge about the structure of reality but also to manipulate people had deep ramifications. In his book *Beyond Freedom and Dignity*, Skinner argues that people are not autonomous agents, rationally deliberating on hard questions and coming up with creative answers. Instead, we are creatures of habit, and these habits can be shaped to limit human growth or to further human advancement.
    - Like Pavlov's dogs, we are malleable, and the best course of action is to design the culture we find to be most suited to human development and set up the conditions—the positive and negative consequences—that will shape people into the form we want. The myth of free will is a barrier to human advancement and satisfaction.

    - This is exactly the notion behind the plotline of the Anthony Burgess novel and Stanley Kubrick film *A Clockwork Orange*.

- When the founder of behaviorism, John Watson, was fired from his academic post at Johns Hopkins University, he took a position at the J. Walter Thompson advertising agency. The expertise he developed could be used not only for human flourishing but also for the enrichment of business owners by manipulating the masses. Edward Bernays, the nephew of Sigmund Freud, also came to realize the power that could be attached to psychological research. After a stint with the government, he opened an advertising firm himself.

- Psychology, which had begun as a search for the nature of the reality of the human mind, had become a field that was used to create false realities within the mind for the sole purpose of enriching business owners and electing public officials. This notion was not lost on the artistic community, which responded by shining a light on the practice.
    - In the 1910s, Marcel Duchamp began a series of works he termed Readymades. These works involved placing a mass-manufactured good, such as a urinal or a snow shovel, in a gallery as a piece of art.

    - We had been conditioned to see these objects in certain ways by their marketers. Now, they were being placed in an incongruous context, forcing us to see them anew and to question why we see them as we normally do.

    - Duchamp and other artists were pointing out that we had become the white mouse in the psychologists' maze. We had been conditioned, manipulated. The hope was that we could at least be reconditioned, given, as Skinner argued, that it is not possible for us to regain our freedom and dignity as autonomous individuals.

Suggested Reading

Bernays, *Propaganda*.

Huxley, *The Doors of Perception*.

Lawson, *Carl Jung*.

Skinner, *Beyond Freedom and Dignity*.

Watson, *Behaviorism*.

Wolfe, *The Electric Kool-Aid Acid Test*.

Suggested Viewing

Century of the Self.

A Clockwork Orange.

Questions to Consider

1. Jung was fascinated by synchronicities, that is, coincidences that seem too coincidental to be accidental, coincidences that seem to be giving us a message. Have you ever experienced such a coincidence, and is the message something that you get from the coincidence or something you project onto it?

2. The behaviorists wanted to do away with talk of the mind because they thought it unscientific, given that we can never observe someone else's mind; even if we can observe their brains, we cannot see what is in their minds. Yet with people we know well, we often make such remarks as "I know what you're thinking." Can we meaningfully talk about what is in someone else's mind?

The Rediscovery of the Mind

Lecture 18

In the first half of the 20th century, psychology had the luxury of debating whether a subconscious mind existed and whether scientific methodology required limiting the field to the study of stimulus and response. But after the horrors of World War II, psychology changed. The specter of the Holocaust raised troubling questions about the human mind and its relation to authority. The reaction to Nazi atrocities in the scientific world was shaped by what are perhaps the three most famous psychological experiments: Stanley Milgram's obedience study, Solomon Asch's groupthink study, and Philip Zimbardo's Stanford prison study. Taken together, they stand as a challenge to the Enlightenment picture of humans as rational beings, leaving us with serious concerns about ourselves.

Solomon Asch's Groupthink Study

- In 1951, the Polish psychologist Solomon Asch tested the ability of people to act independently. In his experiment, test subjects were seated at a table with seven other supposed subjects—confederates of the experimenters. A researcher then informed the group that the purpose of the study was to examine perception and asked participants to look at two charts placed in the front of the room.
    - One of the charts had a single line on it, while the second had three lines. One of the lines on the second chart was the same height as the line on the first chart, and the test subjects were asked to identify this line. In all cases, the correct answer was plainly obvious.

    - The researcher asked each of the subjects to identify the correct line, always asking the real subject last. For the first three rounds, the confederates gave the correct answer, and the test subject followed. But on the fourth round, the confederates all gave the same wrong answer. Of the 18 sets of lines, the confederates intentionally got 6 correct and 12 wrong.

- Interestingly, three out of four test subjects answered with the faulty majority at least some of the time. And once people started conforming, they were much more likely to continue.

- The test subjects were interviewed after the experiment and reported some interesting reactions.
    - Of those who answered with the majority, some became convinced that they were wrong and the majority was right; they believed that it was important for them to be right because they did not want to spoil the data for the researcher or because they did not want to stick out.

    - But as Asch wrote, “More disquieting were the reactions of subjects who construed their differences from the majority as a sign of some general deficiency in themselves, which at all costs they must hide. On this basis they desperately tried to merge with the majority, not realizing the longer-range consequences to themselves.”

    - Universally, everyone who participated in the test said that independence was preferable to conformity. Yet most conformed; that is, they acted counter to what they knew to be false and counter to their own values.

- When Asch expanded the study, he found that the larger the majority, the stronger the pull to conform, but that if even one person dissented before the test subject, the subject was much more likely to also voice his or her view. Asch showed empirically that having someone else agree with you is a powerful tool in making people willing to take a contrary position. But if that person were deserted by the fellow dissenter, conformity followed rapidly and continued even after the deserter left the group.

- Notice again the move from studying individual elements, to relationships, to larger, unified systems. Psychology began as an investigation of the mind of the individual. Freud moved the study to relationships. Social psychology began to locate the mind, in part, in the group. To understand the reality of the human mind, we must see it as part of a larger social consciousness that affects decisions, beliefs, and actions.

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Adolf Eichmann had been responsible for transporting millions of people to concentration camps, yet he didn't appear to be a monster; he was, in one observer's words, a "desk murderer."

Adolf Eichmann and Stanley Milgram

- The trial of Adolf Eichmann, a lieutenant-colonel in the SS, took place in 1963. During World War II, Eichmann had been in charge of transporting millions of people from their places of arrest to concentration camps and death camps.
    - Eichmann's arrest and trial led many people to ask how someone could have done what he did. The easy answer was that he was a monster, but the trial disabused us of this notion. Multiple psychiatrists assessed Eichmann and testified that he was not only sane but a normal, pleasant fellow.

    - Observing the trial was the German-Jewish philosopher Hannah Arendt. She realized that the greatest evil can be carried out by people who see themselves as simply following orders without assuming any responsibility for their actions. Arendt famously coined the phrase "the banality of evil" to describe situations in which we create structures that shield people from the real effects of their actions.

- American psychologist Stanley Milgram conducted his famous obedience studies in the shadow of the Eichmann trial. In these experiments, a test subject (the teacher) administered what he or she believed were real electric shocks to a confederate (the learner) if the learner was unable to provide correct answers to a learning task.

- At first, the learner gave mild responses to the shocks, but as the shocks increased in intensity, he or she began to cry out in pain. Eventually, the learner fell silent, leading the teacher to believe that the experiment might have resulted in death.

- Each time the learner gave an incorrect answer, the authority told the teacher to apply the shock and verbally accepted all responsibility for the outcome. The point of the experiment was to place obedience to authority and an obviously immoral act in conflict.

- In the first round of the experiment, using Yale undergrads as test subjects, 25 of 40 administered what they believed to be the most dangerous shocks. In other words, more than 62% of the subjects were willing to act in a way they thought might kill another person, just because someone in authority demanded that they do it. In experiments conducted with other populations of test subjects, even more subjects were willing to follow orders from the authority.

- Milgram summed up his study as follows:

> This is, perhaps, the most fundamental lesson of our study: ordinary people, simply doing their jobs, and without any particular hostility on their part, can become agents in a terrible destructive process. Moreover … relatively few people have the resources needed to resist authority.

Philip Zimbardo's Stanford Prison Study

- In 1973, Stanford psychologist Philip Zimbardo demonstrated that authority does not even have to be real to be effective. In his experiment, Zimbardo randomly assigned Stanford University graduate students to take on the roles of prisoners or guards in a fake prison.

    - At first, the prisoners did not take the experiment seriously, acting in ways that showed a lack of respect for the guards' authority. The guards soon decided that they needed to constantly reinforce their authority with demeaning and dehumanizing activities designed to ensure that the prisoners remained subservient. Their treatment of the prisoners became increasingly brutal.

    - The experiment was originally supposed to take two weeks, but it was cut short, ending after six days because the effects were so shocking and potentially harmful.

- In the wake of Zimbardo's study, the usual claims that prison mistreatment was a function of a few sadistic guards seemed false. It was not that bad things happened when a few sadists ended up in positions of authority. Rather, it seemed to be the structure itself—the establishment of a system where some had authority over others—that created the conditions for inhumane treatment.

The Nature of Humanity

- Taken together, these three experiments formed an empirical approach to a question that had been around since at least the 17th century: Are human beings inherently good or inherently evil?

- Thomas Hobbes, an English philosopher, had argued that we need a strong central government to keep us in check from our naturally dark selves.
    - Before there was any social structure, Hobbes asserted that humans lived in a "state of nature." Here, there were no rules and the aim was simply to survive. In these conditions, we would seek that which would help us survive and try to eliminate that which threatened survival.

- Because everything could be useful in some way, we were in constant conflict with everyone else over literally everything. Similarly, because everyone else was a potential mortal threat, the state of nature was a constant war. Life in this state, Hobbes famously said, was "solitary, nasty, brutish, and short."

- Realizing that we would be more likely to survive if we ended the state of nature, humans entered a social contract that gave our natural rights to a central government that we expected would keep order. Any oppression we experienced from the government would be preferable to the state of nature. We are, at heart, brutal animals, and the glory of human culture needs a strong authority to keep us in check.

- The 18th-century French thinker Jean-Jacques Rousseau disagreed. To him, the state of nature was idyllic. Without a political structure restricting our natural freedom, we would blossom into creative beings. If we are nasty and brutal, it is in reaction to the authority of the state and to the existence of private property. For Rousseau, we did not cease to be savages when we became civilized; civilization turned us into savages.

- What these psychology experiments contend is that it is not the structure of civilization itself that made us or corrupted us, but rather, it is the distribution of power and authority that corrupts.
    - Artistically, we find this represented at the beginning of the 20th century in Joseph Conrad's *Heart of Darkness* and even more so in its film adaptation by Francis Ford Coppola, *Apocalypse Now.*

    - In both the book and the film, the character Kurtz is sent into a region that Westerners consider to be controlled by savages in order to secure something of value to those with power in the civilized world. But instead of subduing the savages, Kurtz lives among them, establishing himself as a deity to them. Through sheer brutality, he becomes the ultimate authority over them.

- To the narrator of the book and film, Kurtz explains how he has learned from the so-called barbarians; how the façade of civilization has weakened us; and how, in his position of authority, he has achieved a sense of wisdom he could never have learned otherwise. But that insight into human nature discloses the savage truth lying beneath the mask of civilization, and as Kurtz dies, his last words echo the sentiments we too may glean from the findings of post-Holocaust social psychology: "the horror, the horror."

Suggested Reading

Arendt, *Eichmann in Jerusalem*.

Asch, *Opinions and Social Pressure*.

Conrad, *Heart of Darkness*.

Milgram, "The Perils of Obedience."

Suggested Viewing

Apocalypse Now.

Questions to Consider

1. The Asch and Milgram experiments seem to show that humans are not purely rational but can have their actions altered by external authority and groupthink. In light of these findings, are there safeguards that would need to be put into place to defend a democratic system from these sorts of effects?

2. Given the results of the Zimbardo Stanford prison experiment, could we ever really think of prisons as institutions dedicated at least in part to the rehabilitation of inmates, or because of the necessary power imbalance, are prisons destined to be only institutions of isolation and retribution?

The Caring Brain

Lecture 19

The role of the mother was long denigrated in psychology, but two figures forced us to reconsider the place of caring in human development and well-being. Harry Harlow's famous studies with baby monkeys demonstrated that from a young age, caring was deeply influential on an individual's ability to become a functional social being. Carol Gilligan worked under Lawrence Kohlberg, whose work on moral development led to the result that men were more likely to reach the peak of ethical reasoning. Gilligan proposed a picture of two different approaches to morality, one based on contracts and another based on care. These advances led to a reconceptualization of the role of women and the meaning of interpersonal relationships.

Harlow's Monkeys

- The fact that mothers seem to play a crucial role in child development might lead us to believe that psychology would focus on the effects of mothering. But up until the 1950s, that wasn't the case. Freudian psychology saw the mother, at most, as a source of mental illness, and for behaviorists, mothers were primarily a food source—suppliers of positive reinforcement.

- In the 1950s, Harry Harlow began his work with rhesus monkeys. Harlow was studying learning and, therefore, needed to isolate young monkeys in an environment where he could determine which stimuli were the most effective and expeditious in skill acquisition. But Harlow found that the monkeys' mothers were teaching them, too, a fact that contaminated his experiments.

- When Harlow separated newborn monkeys from their mothers, he noticed that the nursery-raised monkeys were more emotionally fragile than other monkeys. They would cower or quickly become aggressive, and they were not properly social. This observation led him to begin one of the most famous research programs in the history of psychology: raising baby monkeys with wire or cloth surrogate mothers.

- Harlow found that monkeys raised with wire surrogates exhibited a greater degree of psychological distress and abnormal development, which led to them becoming maladjusted adults. He also found that baby monkeys preferred the cloth surrogates, even if they weren't the source of food. Mothers, it seemed, fulfilled more than merely biological needs; they were necessary for emotional development.

- Harlow's work meant that the mind, the internal world of personal experience, had to be reinserted into psychology. The behaviorists' attempt to limit the world and vocabulary of psychology to only observable stimuli and responses created a universe that was too limited in concepts. Reality, after Harlow, had to be redefined to once again include the mind and mental states, not only as existing but as central elements in who we are as human beings.

Kohlberg's Theory of Moral Development

- At the University of Chicago, Lawrence Kohlberg became interested in the ways we develop our internal means of moral deliberation. He identified six stages of moral development, divided into three groups of two (shown below). He found that some people use each stage to propel themselves to the next—to a more mature approach to ethical dilemmas—and others progress up to a point, then become stuck at one level.

Post-Conventional	• Universal principles • Social contract
Conventional	• Abstract commitment to rules • Rules as socially enforced norms
Pre-Conventional	• Maximizing self-interest • Obedience to avoid external punishment

- The first two stages are what Kohlberg called pre-conventional, that is, they see ethical situations as isolated, not part of a larger rule or convention.
    - In the first stage, decisions about what to do in situations concerning other people are completely a matter of obedience to authority to avoid external punishment.

    - From there, we grow into an internalized version of pre-conventional thought. We become egoistic; all that matters is figuring out what is best for the self as an individual.

    - The pre-conventional level of moral development, then, focuses only on the here and now, at first gaining pleasure and avoiding pain from external authorities, then gaining pleasure and avoiding pain from personal wants.

- The second level, an adolescent approach to morality, is what Kohlberg termed conventional; that is, there are conventions or rules that guide us in our ethical deliberations.
    - In the first level, we see rules as a form of etiquette, as socially enforced norms. If we act in the right way, others give us approval, and that is what we seek at this level. If we act wrongly, others express their disapproval, and we never want others to think ill of us.

    - The second conventional level moves from getting the approval of others to serving an abstract duty. We do the right thing because we are law-abiding citizens. The rules at this level are abstract, not dictated by a concrete social context, but there is no philosophical deliberation about them. They simply are the law, and the law is to be followed.

- In the highest level, the post-conventional stage, we seek justification for the rules. Here, we are engaged in what philosophers call *meta-ethics*, that is, setting out the means by which we generate ethical rules. We are now adult in our ethical deliberations because we seek a more general understanding of the nature of morality itself, not individual commands.

   - At the fifth level, we consider ethical prescriptions in terms of the social structure in which they are embedded. Rules serve a larger function of helping us create a society that is well ordered, safe, and conducive to human flourishing. When we think about ethics at this level, we are thinking about how to set up an entire system of rules in comparison to other systems. The systemic viewpoint is more abstract, and this is the mark of a more mature mind.

   - The final step is to take the meta-ethical thought beyond its cultural context and assume a universal standpoint. True human wisdom is achieved when we engage in completely abstract reasoning about universal principles that generate the action-level rules. The pinnacle of human moral thought is the most theoretical.

- Kohlberg contended that women tended to remain stuck at the conventional level, not making the move to the conceptual way of thinking, primarily because they tend to worry about nurturing those around them.

Carol Gilligan's Model

- This claim did not sit well with Kohlberg's research assistant, the psychologist Carol Gilligan, who had noticed a blind spot concerning gender throughout all of psychology. In trying to discover truths about the human mind, psychologists studied only men and boys. Gilligan, however, argued that there might be two quite different ways of being in the world, one that stresses the experiences of traditionally male gender roles in Western society and one that focuses on the experiences of traditionally female gender roles in Western society. Both focus on a central virtue, but these virtues are quite different.

- Men tended to take jobs that focused on the marketplace, the courtroom, or the legislature, where the ruling principle is justice. In these contexts, rules are put in place to guarantee that exchanges can be counted on. The standard relationship between people in this masculine picture of human reality is based on the idea of a contract.
    - A contract must be undertaken willingly by both parties. When a contract is made, the result is that each party must do something for the other, and this exchange is agreed upon as fair. When the parties execute their agreed-upon duties, they are freed from the contract. If one party fails to carry out his or her end of the bargain, the other can bring in the authorities.

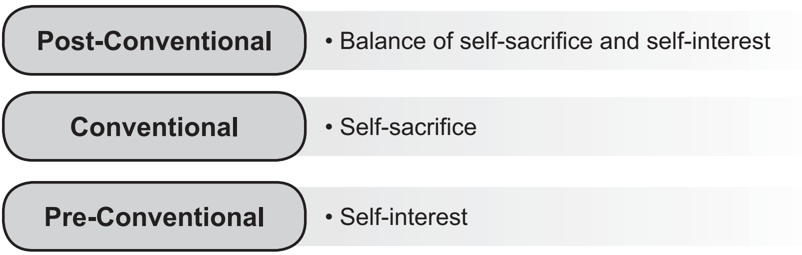
    - Aside from these expectations, there is nothing else binding the two parties. Once both parties have done what they said they would, the contract has been fulfilled, and there is no longer a relationship between them. Acting frees you from a contractual relationship.

- But, Gilligan argued, women tend to have different relationships based on the expectations shaped by traditional gender roles. Women tended to be secretaries, nurses, teachers, and mothers and wives. The relationships in these roles are not based on contracts but on caring.
    - Entering a care-based relationship is quite different from entering a contractual relationship. In a contract, there is an explicit period of negotiation to make clear what is expected from each party, and if either is not satisfied, then the contract is not agreed to; the relationship is not brought into existence.

    - In a care-based relationship, however, there are no explicit terms. The point is not to do one specific thing for the other party but to get to know that person's needs and to foster his or her fulfillment as a human being. You do things for the other person, not because you have promised to, but because you are legitimately concerned about the other's well-being.

- ○ In a contract-based relationship, you act because you think it will lead to the best outcome for you; in a care-based relationship, you act because you think it will lead to the best outcome for the other person. Further, in a contract, acting frees you from the relationship, but in a care-based relation, acting further embeds you in the relationship.

- Kohlberg was right, Gilligan contends, that women approach ethical issues differently from men. But this is not because they are morally retarded; it is because there is a different virtue, a different model, guiding their development. In this way, Gilligan constructed a Kohlberg-like series of steps for moral development in a care-based fashion (shown below).



- ○ The pre-conventional stage is again self-centered. In this stage, there is no sense of the self as a part of a larger whole. There is a sense of abandonment and alienation from others. In this stage, it is natural to act out of pure self-interest.

- ○ Unlike Kohlberg's conventional stage, which is rule-bound, for Gilligan, the second stage is one in which the self is no longer the focus; indeed, self-sacrifice takes center stage. The approach here is purely altruistic and other-oriented. The energy is always focused on the other person, not the well-being of the person acting. It is playing the martyr.

- The final stage is where we come to see ourselves as part of the larger world, where we take our relationship with ourselves as central, alongside the relationships with those whom we care about. This is not the selfishness of the first stage but, rather, a stage in which we see ourselves and others as projects, as walking along a developmental path, and we act in such a way that we advance everyone along that journey as much as possible. This is wisdom for those with a care-based perspective.

Suggested Reading

Blum, *Love at Goon Park*.

Gilligan, *In a Different Voice*.

Kohlberg, *The Philosophy of Moral Development*.

Shelley, *Frankenstein*.

Suggested Viewing

Thelma and Louise

Questions to Consider

1. Are the differences between men and women the result of biology or the result of socially enforced gender roles? How much of who we are is determined by our sex, and is it open to being changed if we so desire?

2. *Frankenstein* the book was written by a woman. *Frankenstein* the movie was written and directed by men. Is that why the two are so different, or is it a function of other factors, such as audience or historical context?

Brain and Self

Lecture 20

The study of psychology changed forever with the development of such imaging techniques as the CAT scan, MRI, and PET scan, which allowed us to see inside the brains of living, acting, and reacting beings for the first time. By seeing how the brain works, we could recast our questions in terms of brain structures and relational activities among brain centers. At first, we thought that this would reduce psychology to brain talk, but what actually emerged was the intricate study of the ways in which the brain is a part of the larger environmental system. Human consciousness is more deeply entwined with our relationships with other people and the world around us than we might have thought.

Neural Imaging Techniques

- Among the first modern neural imaging techniques was the computerized axial tomography (CAT) scan, which is a computer-aided x-ray process. CAT scans give us a three-dimensional perspective and enable us to see the structures of working brains. However, CAT scans present two problems. First, x-rays are dangerous to patients, and second, CAT scans provide only snapshots of structure. We don't see action, changes inside the brain, or the actual working of the parts.

- These concerns were answered by two new technologies, one of which was magnetic resonance imaging (MRI).
    - Recall that moving electrical charges generate a magnetic field and that atoms have a central nucleus with negatively charged electrons outside. As such, atoms, and the molecules into which they combine, all generate magnetic fields.

    - Exposing those molecules to a strong magnetic field causes them to line up in the direction of the field. If we then cut the external field, the internal magnetic fields fall out of alignment, but the time it takes them to do so varies based on the composition of the molecules. By measuring this relaxation of the magnetic fields once we cut the external field, we can determine what kinds of substances are inside.

  ○ This technique allows us to do what CAT scans do—look inside the brain without having to physically go into it—but at a higher resolution and with no cancer-causing radiation.

- MRIs, however, still provide only snapshots; they allow us to see tumors and structural abnormalities but not the brain at work. For this, we need positron emission tomography (PET) scans.
  ○ In a PET scan, a radioactive form of oxygen attached to a sugar molecule is injected into the patient and is taken into the blood and used by cells in the same way as normal sugars.

  ○ When a part of the brain is active, blood flow to it increases. The radioactive molecule in the blood allows us to detect, at any given moment, which part of the brain is active because it results in a spike in the emitted radioactivity from the sugar in that part of the brain.

  ○ The advantage of the PET scan is that instead of looking at architecture, we are now looking at process. We can literally see parts of the brain light up in various sequences when the person engages in different sorts of activities.

- With these new tools, psychologists believed that they could decode which parts of the brain were responsible for what. This research included not only behaviors, such as speech and movement, but elements of internal consciousness, such as falling in love or thinking someone untrustworthy. This project continues to provide us with unexpected insights into human behavior.
  ○ It has also shown us that we are not, as we had thought, autonomous individuals acting on the world through the force of our will.

    - Instead, we are a part of the world. We are shaped by the world and react to it in ways that show us to be connected to each other and to externalities in a deeper fashion than we are accustomed to considering.

The Developing Brain

- The development of the brain in the human fetus is, in part, guided by genetics: 25,000 of our genes are active in the creation of our central nervous system. Cells divide from the fertilized egg and differentiate themselves to take on specific roles, giving rise to daughter cells that form the various organs of the body. To form the brain, hundreds of types of cells must develop.
    - Some of these cells are neurons, which emit and absorb electrical impulses to give rise to neurological functions. Neuronal cells form complex webs to send particular signals.

    - There are also glial cells. If neurons are the bricks of the brain, glial cells are the mortar, holding the neuronal structure together and sustaining the necessary gaps, called *synapses*, between the neurons.

- Although this process is guided by our genetic make-up, the environment plays a crucial function, as well. The effect of the chemical environment of the mother's body greatly affects how the brain develops. The reason for this is that the brain has an inflationary phase, much like the universe in big bang theory.
    - Around the second month, the embryo develops a thin tube of fluid that becomes the brain. It is lined with progenitor cells that will ultimately give rise to all the brain cells.

    - Around the fourth month, these progenitor cells divide unbelievably rapidly, creating the cells that become the brain. Ultimately, there will be about 100 billion neurons and at least 1 trillion glial cells.

- Once they are created, these cells lose the ability to divide further. The brain cells that are made are the only ones the person will have for the rest of his or her life. Unlike other organs, the brain cannot rejuvenate or fix itself by cell division.

- Because so many cells are made so quickly and because they are the cells that will be present throughout the lifespan of the individual, how they are created makes a difference in the functioning of the brain throughout the lifespan of the individual. We know that certain environmental factors, such as exposure to radiation or the presence of alcohol in the mother's blood, will cause serious problems.

- We are often tempted to conflate biologically determined aspects of humans with genetically determined aspects. We think that our genes determine everything about us. But as we see in the explosion of neural activity during fetal development, who we become is a function of how our brain develops. Although genetic factors are certainly at play, important environmental factors also help determine who we will be. This is even more evident once the brain has developed and after birth, when we begin to interact with the environment.

Our voices radically change pitch from low to high when we talk to babies; a lack of this vocal change can affect the growing brain and give rise to cognitive problems later in life.

  - Genetically, we are predetermined to have certain connections made at certain times. Almost all children begin to make sounds, form words, crawl, and so on at roughly the same times. Because these changes are predictable, we might think that development is purely a genetic matter.

    - But it turns out that exposure to certain sorts of stimulation is also important. For example, if a child is brought up in the dark, the part of the brain responsible for sight will not be stimulated and, therefore, will never develop. There is a genetically determined period of growth, and that growth requires a certain sort of interaction with the child's surroundings.

Cognitive, Automatic, and Precognitive Processes

- Parallel processes take place in the brain. We have both cognitive processes, such as those that that involve contemplating, making meaning, and connecting events, and automatic processes, such as hearing our names spoken in a crowded room or finding faces in inanimate objects.

- We also have precognitive processes. Like the automatic ones, these occur independently of cognition, but they are more complex and more interesting to analyze.
    - For example, if you look at a group of people chatting, more often than not, they will all have the same stance. This is called the *chameleon effect* and is the result of our neurological structure.

    - We have what are termed *mirror neurons* in our brains. These cause us to internalize the behavior of the people we observe and with whom we interact. The brain actually stores the actions we observe as if we had acted in the same way.

- We can see from PET scans how the brain reacts to different sorts of observations. For example, seeing a person and a robot execute similar actions affects the brain in quite different ways. The brain recognizes the other humans as human and creates a special connection with their actions. This is what gives us the ability to empathize and is the foundation of morality.
    - This is not to say that ethics are programmed into us. Ethical deliberation is an intricate process with deep cognitive, conceptual, and philosophical aspects.

- That such deliberation is even possible, however, is the result of neurological processes that are not cognitive but fully reactive to the environment.

- We may think that we determine how we feel and behave, and to some degree, we do, but much of this is precognitive. In the 1980s, the American psychologist Benjamin Libet demonstrated that the firing of the necessary neurons in the brain to execute actions we believe to be freely and consciously determined actually occurs before the parts of the brain associated with cognition are invoked.
    - The brain has separate elements that work at the same time. The amygdala deals with many of the automatic and precognitive aspects, but the thoughtful, cognitive functions occur in the frontal cortex. Often, an action is begun or a reaction to a situation is formed in the amygdala on a purely reflexive basis, only to have the frontal lobe immediately spring into action to create a coherent narrative. This narrative is formed to provide a rationale for our response.

    - The result is that we think our action is the result of free will, and we think the gut reaction we have is not a reflex but justified by some principle. In reality, the action and reaction are independent of the higher cognitive functions.

    - According to some studies, only 5% of our decisions are caused by conscious attention to situations. The overwhelming majority of our decisions are made by the noncognitive parts of our brains. Our brains decide for us, then we interpret that decision to make it seem to ourselves that we meant it all along.

- In distinguishing between the purely material parts of the brain that deal with cognitive functions and the parts of the brain that deal with precognitive functions, we must reevaluate our place in the world. If our actions largely result from activity in the precognitive aspects, then we must see ourselves as much more deeply connected to our surroundings than we previously thought.

Suggested Reading

Glickstein, *Neuroscience*.

Lynch, *The Neuro Revolution*.

Questions to Consider

1. If we locate the parts of the brain that fire when we are in love and figure out how to re-create that pattern of brain activity artificially, would that mean we could make people fall in love at will? Would the induced brain activity be real love in the same way that a nonintentionally initiated instance would be?

2. If our hand reaches for a cookie before we form the intention to have a cookie, as Libet showed, are we morally responsible for our acts?

Evolutionary Psychology

Lecture 21

Humans are the result of an evolutionary process. If evolution favored our big brains, is natural selection also responsible for aspects of its functioning? As a species, we trace back to a band of individuals who came out of Africa about 250,000 years ago, and we now see common behaviors and desires across the globe. Because some of these would have been advantageous to our ancestors, we might surmise that they are the result of evolution working on our brains. But what, then, accounts for altruism? How could being kind be advantageous to survival in a dangerous world? Could it be that we evolved as a part of the world and, thus, are programmed to care for it?

The Basis of Evolutionary Psychology

- Evolutionary psychologists begin by noting three facts. The first is that there are certain human behaviors, desires, and reactions that are universal around the globe, regardless of culture. These recurring regularities would be extremely unexpected if we thought they developed accidentally from completely social contexts.

- The second fact is that there are dedicated elements in the brain that are context specific, that is, they are designed to do very particular things; although these elements of the brain perform their tasks quite well in specific contexts, they do not do similar things well at all. The standard example here involves what psychologists call *Wason cards*.
    - In the late 1960s, the British psychologist Peter Cathcart Wason developed a straightforward logic problem using cards and found that less than one-quarter of his subjects were able to solve it. It seems that we are not wired to be logical.

- But evolutionary psychologists Leda Cosmides and John Tooby noted that when one small change is made to the test, embedding it in a larger context of finding a cheater, the same test has different results. About 65% to 80% of test subjects can solve the problem. Supplying a context for the problem seems to make all the difference.

- The important point for evolutionary psychologists is that the programs stored in the computers of our brains are not universal schemas but, rather, are specifically designed to accomplish particular tasks. We can detect what kinds of tasks they are by seeing where they work well; then, we can start to think about why we would have such programs embedded in our brains.

- The third fact is that all humans come from a single, small group of ancestors whose brains rapidly increased in size. We all get the genetic basis for our neural development from the same source.
    - About 4 million years ago, *Australopithecus afarensis*, our earliest ancestor to have split off from the evolutionary lines of other great apes, appeared in Africa. They had brains about the same size as the ancestors of chimps and gorillas. They are not classified in the genus *Homo* because they do not share the standard traits we use to differentiate our later relatives.

    - About 2.5 million years ago, we find *Homo habilis*; we see some tool use and a somewhat larger brain—about half the size of that in modern humans.

    - About 1.8 million years ago, *Homo erectus* appeared, with a much more recognizably human body shape and a significantly larger brain. *Homo erectus* spread out across Africa and Asia but was eventually overrun by *Homo sapiens*, who evolved out of a small group in east Africa about 250,000 years ago. Indeed, the biochemist Allan Wilson was able to trace the roots of humanity back to a single ancestor, Mitochondrial Eve.

- For 238,000 of the last 250,000 years, we all had ancestors who lived the same sort of Stone Age life, hunting and foraging in small groups. Only the last 12,000 years have been different and have seen the development of agriculture, metallurgy, antibiotics, and so on.

- In evolutionary terms, 12,000 years is the blink of an eye. If we figure a human generation is 15 to 20 years, then 12,000 years is only 600 to 800 generations—not nearly enough time to result in substantial changes. But the preceding 238,000 years encompassed 12,000 to 18,000 generations, all experiencing the same way of life and the same selection pressures. That could be enough time to develop neurological features that would then be shared by all their progeny—us.

- For these reasons, the advocates of evolutionary psychology contend that we have inherited parts of our mind shaped by the evolutionary pressures felt by our Stone Age ancestors.

Our Inheritance from the Stone Age

- Many of us associate the terms *Stone Age* and *caveman* with being primitive and lacking intelligence, but our ancestors were actually quite like us. They were as clever and resourceful as we are, but they lived in an environment and historical context that forced them to start from a rougher place.

- Evolutionary psychologists argue that the sustained, consistent environmental stresses on our ancestors would have led to adaptations. Some of those would be advantageous and, over the 238,000-year period, would have made their way into the population. Some foundational aspects of our psychology are the remnants of what they went through.

- Our Stone Age ancestors adapted quite well to numerous challenges, such as giving birth, winning social support from band members, hitting game animals with projectiles, and many more. Evolutionary psychologists contend that any behaviors that are uniquely well suited to solving these problems and that are unlikely to arise accidentally are the remnants of the human brain's evolution, the leftover fingerprints of our historical development.

- As an example, evolutionary psychologists point to our ability to read emotions from other people's faces, even when they are trying to hide them from us. We sense when something is wrong with someone or when someone is harboring ill intentions toward us. This is a skill that is innately part of the human mind, but it seems unlikely to have arisen accidentally, and there don't seem to have been any inborn features that would have permitted us knowledge of one another's intentions from looking at faces. Thus, we tend to think of this ability as inherited from our evolutionary past.

- One of the questions for evolutionary psychology relates to altruism in humans. Why are we as a species so sociable, thoughtful, and empathetic? We have cultures everywhere, and these could not occur if there was not a presumption of cooperation. If we are so influenced by our evolutionary past, why is selfishness not the norm?
    - Some offer the explanation that we are primarily altruistic toward those who are like us. Our ancestors did not live in societies but in small bands of relatives. If they did not care for one another, then the group as a whole would fail. Because the Stone Age clan was a small group who shared genes, mutual survival was as important as individual survival; indeed, group survival aided individual survival.

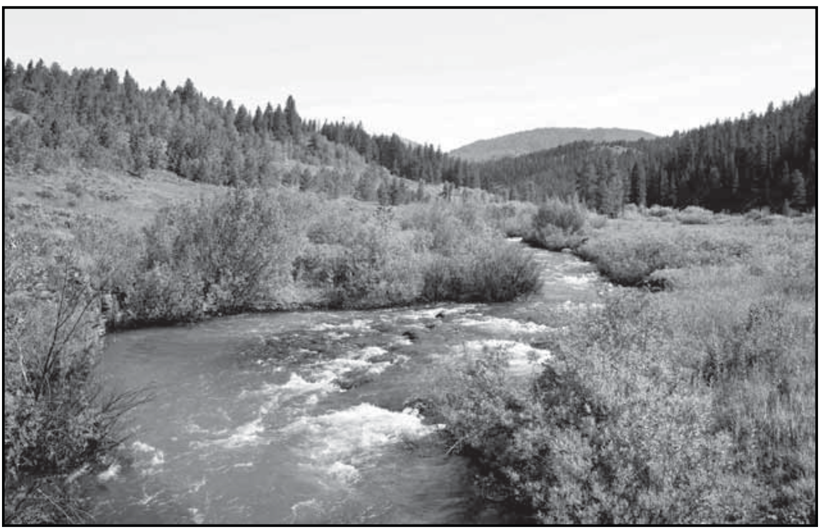
    - We developed the predilection to be nice to people who seem like us because doing so made it more likely that we and our offspring would survive to procreate. When the context changed and we started living in more diverse communities, this got tweaked to a general altruism.

Ecopsychology

- A different account came out in 1962 from the Scottish ecologist Vero Copner Wynne-Edwards. He contends that because animals depend on their surroundings for survival, they have a deep connection to those surroundings. They see the surroundings as a part of themselves and, thereby, have a natural predisposition to take care of them.

- This sense that evolution is not simply a matter of individuals looking out for themselves but of seeing all of nature as an interconnected web is a holistic perspective not uncommon among some ecologists. Where ecologists see evolution as a foundational principle, they see it in a systemic sense: The group, as well as the individual organism, evolved and adapted.

- The extension of this approach to evolutionary psychology has become known as *ecopsychology*. The idea is that the human brain is indeed a product of an evolutionary process, but it is not one guided only by selfishness and the desire to perpetuate one's own genetic code. Rather, the human brain evolved as part of an ecosystem—a complex web of interconnected species at home on the Earth.



Ecopsychologists claims that we feel restored and rejuvenated when we return to nature because our brains evolved as part of an ecosystem.

- As such, when we look at the innate aspects of the human mind that have come down to us from our ancestors, what we see is a connectedness to the Earth and to all of the plants and animals we share it with. This is reflected in the fact that we generally relax when we return to nature.

- A hypothesis of ecopsychology is that our neurological wiring is such that we are a connected part of the natural world, and threats to the health of the environment are reflected in our own mental states.
    - The ecological damage we see around us should affect us on a cognitive level. We should understand that resources are finite and that sustainability is crucial on a planet with an increasing human presence.

    - Although this cognitive level is important, ecopsychologists also argue that damaging the environment has a deeper, precognitive effect on. We harm ourselves when we harm the Earth, and this harm is manifested both physically and psychologically. We become mentally less stable; we suffer from a malaise that suffocates the spirit when we allow our belief in human and technological progress to overshadow our connection to the Earth.

- Ecopsychology is to evolutionary psychology as Jung was to Freud. Freud and evolutionary psychology both rely on a subconscious, but where Freud creates the id and locates it in a nonobservable place below consciousness, the evolutionary psychologist makes use only of the brain science coming out of neurological research. Where Jung takes Freud's notion and expands it in a holistic sense, creating a collective consciousness and endowing it with a spiritual element, so, too, we observe ecopsychology expanding the line of argument from evolutionary psychology and applying it in a holistic way that also has a spiritual element.
    - We can see the distinction between these two views by comparing two similar science fiction films: the 1968 classic *Planet of the Apes* and James Cameron's 2009 epic, *Avatar*.

- *Planet of the Apes*, which is based on evolutionary psychology, wrestles with questions of determinism in psychology, especially with the question of inherent violence and the lack of altruism. Can we develop intelligence from a brain that is the result of an evolutionary process that is inherently competitive and come out caring?

- In contrast, *Avatar*, an ecopsychological film, asks whether this difference in viewpoint is a choice or whether it is instilled within us and is just masked by our competing baser desires.

Suggested Reading

Cosmides and Tooby, "Evolutionary Psychology: A Primer."

Workman and Reader, *Evolutionary Psychology: An Introduction*.

Suggested Viewing

Avatar.

Koyaanisqatsi: Life Out of Balance.

Planet of the Apes.

Questions to Consider

1. Are there aspects of human behavior that are leftovers from our prehistoric ancestors? If so and if we find some of these behaviors and desires no longer advantageous, can we change them or are we stuck with them?

2. Do we have a special emotional bond to nature? We use such phrases as *mother earth*, but do we really feel an emotional attachment to the planet in the same way as toward a parent? Are we programmed to be uncomfortable with ecological destruction?

The Birth of Sociology

Lecture 22

In looking at reality, we can examine individual elements or larger structures, relations, and institutions. At this advanced level, we can find truths about the structure that do not reduce to truths about the members; such features are called *emergent*. The study of emergent properties in human groups is sociology. When we take a sociological viewpoint on reality, we see correlations and influences on human life and action that would otherwise remain invisible. Culture is real in that it has a direct influence on what we think, what we do, and what we want. Although it can be affected by our decisions—we can change the culture if we so chose—the influence also works in the other direction.

The Concept of Emergence

- The term *emergence* refers to a nonreducible entity that has parts that do not share the properties of the whole.
    - Earlier, we looked at thinkers who held a view about the unity of science: that psychology reduced to biology, biology reduced to chemistry, and chemistry reduced to physics; thus, all science is just complicated physics of some level or another. When we eventually reach a sophisticated enough level in our physical understanding, these placeholder scientific disciplines will disappear; we will arrive at a theory of everything that is a complete description of nature.

    - But those who contend that there are emergent elements to reality hold that we can know all about how the parts work and never gain a sense of the full nature of reality.

- The emergentist view is that reality has levels. In the case of biology, we cannot understand the organism without knowing genetics, but genetics, although necessary, is not sufficient. We also need ecology. The grand-scale questions may have genetic- or molecular-level aspects, but they must be seen in the interaction on this larger level—the ecological level—to be understood. The fact that there is a mountain range separating two groups of organisms that share a common ancestor is important when we try to explain how the two became different species. Looking at the molecular level would never give us the relevant insight.

- This emergentist point of view not only surfaces in work on biological species, but it also comes into play when we start thinking about humans. Are there human groups that have a reality independent of the individuals within them? Intuitively, the answer is yes. Think about professional sports teams or corporations. Even though the people in such organizations change, the organizations remain. Further, we can say things about the organization that are not true of any single member yet are true of the whole. The group is a thing with a reality distinct from those who belong to it.

- The place where emergence makes its most important debut in science is in the birth of the youngest of the scientific disciplines, sociology.

Early Sociology

- Auguste Comte coined the term *sociology* in 1838 and discussed a general science of culture. He held that society progressed through three phases. Cultures begin in the religious phase, where all change is the result of the will of God. Then, society moves to the metaphysical phase, where a divine consciousness is replaced with unseen forces. Finally, we emerge into the scientific phase, in which we no longer seek to answer "why?" but only "how?" In the final phase, we accept that there are regularities to the way the world works and that these are not the result of some supernatural desire or unseen forces.

- Comte's particular theory is not as important to us as the fact that the subject of his study is the emergent whole of society. He argued that his phases can be applied to societies of all sorts, from professional groups to nation-states. His science does not look to explain social phenomena by appealing to individuals but to the emergent group, the societal level itself.

- We see this also in the writings of Herbert Spencer, one of the early social Darwinists, and Karl Marx. Spencer viewed society as an organism that adapts to environmental changes. Marx put forth a theory of cultural development that focused on class as an operative factor driving large-scale social change. Again, our concern is not whether these theorists were right or wrong but that they viewed society as an emergent entity unto itself.

- From Comte, Spencer, and Marx, we get the precondition of sociology, namely, that society is a thing itself, not just a collection of individuals.

Durkheim's Statistical Sociology

- The book recognized as the beginning of sociology as a science is Émile Durkheim's masterpiece, *Suicide*. The motivation for the study was a sudden dramatic uptick in suicides across Europe in the late 1880s. Why were people killing themselves at an unprecedented rate?

- On the one hand, the decision to end one's life is incredibly personal. If one were to ask the victims beforehand why they were thinking of taking their lives, each would appeal to his or her own circumstances. Perhaps there would be similarities in the stories, such as financial difficulties or medical problems, but every story would be based on idiosyncratic aspects of the person's individual life.

- Despite the fact that each decision was made individually, people were making the same decision at a rate much higher than previously. Was there a factor at work at the sociological level that could not be reduced to individual deliberation?

- Durkheim believed that the answer could be found at the sociological level, especially once he started collecting and evaluating data. Immediately, one pattern jumped out. The suicide rate was correlated with religion. The greatest number of suicides per capita occurred in the primarily Protestant nations, while the lowest rates were in the predominantly Catholic countries.

- At the turn of the 20th century, the Protestant/Catholic divide was mapped onto other socially relevant differences. Protestants tended to have more wealth, to be better educated, and to hold positions of power, while Catholics tended to be poorer and less educated and held menial jobs. Protestants and Catholics occupied very different social niches. Durkheim wondered if these differences could be a result of social structure, and if so, what were the relevant features?

- Durkheim emphasized the importance of working from data, which give us access to what Durkheim called *social facts*.
    - A social fact has two elements to it. First, "it consists of a way of acting, thinking, and feeling external to the individual." We grow up in a culture, and as a result, we are acculturated into it. We develop habits by virtue of being part of a society, habits that are standard within the group. We internalize these habits so that they seem natural, but they are not the result of our own decisions. Instead, they come from the social context in which we found ourselves as children. We were taught these social facts, and they became part of who we are.

    - The second element of social facts is that there are consequences for ignoring them. In other words, social facts are norms that are enforced. They are, in Durkheim's words, "endowed with coercive power." Follow the social fact and you are normal, for which you receive perks. Disobey the fact and you are pathological, for which you receive penalties. Note that the enforcement comes from a social structure.

    - Social facts are sociological facts. They are the basic building blocks of a science that looks at the emergent entity society. It is the sociologists' job to find these social facts, classify them, and explain them.

- Sociologists look to see what is universal. The fact that something is normal everywhere means that it serves some function in the social structure. When you look at every society, Durkheim argues, one universal is crime. Crime is normal, and a complete lack of crime would be pathological. From this, Durkheim contends that crime plays a crucial function in society.

- ○ Crime is an activity that is determined by the society to be unacceptable behavior. The rules by which we determine acceptable and unacceptable behavior—the social facts—are internalized; we never think about them. But when we face a criminal or hear news about criminal activity, then and only then do we think about the social facts. In this way, criminals push the social boundaries.

- ○ Sometimes, those boundaries exist for good reasons, but sometimes they do not. Some social facts undermine our ability to live completely fulfilling lives, and these social facts must be challenged. But such challenges are criminal acts.

- ○ If there was no crime, that would mean that there is an incredible degree of conformity in the culture. Given that social facts are enforced, a society with no crime is breeding a coerced uniformity in acting, thinking, and feeling. If a society has succeeded in achieving a given amount of conformity, it will not stop there but tighten its grip, insisting on ever greater conformity. Smaller and smaller differences will become criminalized. There is no natural boundary between crime and acceptable difference. Social structures will always push for greater uniformity.

- The problem with this push for uniformity is that it creates what Durkheim called *anomie*. If we internalize an overabundance of highly restrictive social facts, the result will be an internal struggle with ourselves. We will feel pressured from inside and outside to live up to standards that we have both made a part of ourselves and that we resent. We become torn. The usual mileposts that help guide our behavior are lost, and we feel conflicted with ourselves.

- In such a case, the irrational seems rational. We know how we are supposed to live, but we also know that we cannot live that way. Perhaps the only answer is suicide. Suddenly, the inscrutable becomes understandable.
    - The reason we see the stark difference in the suicide rates between Catholics and Protestants is not a theological difference but a function of the greater integration of Catholics into their familial and institutional structures than was found among Protestants.
    - There was a sense of comfort from being within the group that Catholics were more likely to have and, thus, more alienation among members of the Protestant community—more anomie and more suicides.

In such films as *Easy Rider*, we celebrate characters who are willing to ignore the social facts that we may find overly restrictive, despite the fact that they are criminals.

- To avoid such situations of anomie from forced conformity, societies need those who push against the boundaries. We need those who demand that we constantly check the boundaries and compel us to make changes to the social facts under which we operate when necessary. We need criminals; it is only criminals who can bring about positive social change.

Suggested Reading

Coser, *Masters of Sociological Thought*.

Durkheim, *Suicide*.

———, *The Rules of Sociological Method*.

Suggested Viewing

Easy Rider.

The Stepford Wives.

Questions to Consider

1. A significant point of contemporary controversy is whether or not to treat corporations as individuals, granting them rights and privileges under the law in addition to those granted to the members of the corporation. Are there grounds for this? Can we hold corporations responsible for financial malfeasance or ecological damage if we do not also grant them a distinct existence as things in themselves?

2. Should we glorify those who break the rules? Is it important to elevate the status of the rebel, or does this sow the seeds of chaos? Should we celebrate only those who work within the rules to make improvements, or do those who seek to undermine the structure when the structure is flawed also deserve our praise?

Competition and Cooperation

Lecture 23

When we look at something as complex as human cultures, is it possible to find the sort of straightforward data that Durkheim wants? Max Weber argues that it is not and that to understand society we need a new set of tools, *ideal types*, which are simplifications that we use as lenses to view the world in a way that creates coherent narratives about it. In this way, we could see the driving force for social change as either competition or cooperation. Are humans inherently cooperative or competitive? Or is Ferdinand Tönnies correct that we are both—that we will break any unified group into factions, but we will also unite any diverse group against outsiders?

Max Weber's Ideal Types

- Before the end of the 19th century, human experience across the centuries differed little. There was some social change and technological advancement, but the day-to-day lives of people were not terribly different from those of their great-great-grandparents. But in the middle of the 19th century, technology spurred the Industrial Revolution and brought profound change to society.

- Durkheim had showed that to make sense of this new social reality, we needed to look at society as an entity to be studied unto itself. Following Durkheim was the great German thinker Max Weber, who disagreed with Durkheim when it came to the sociological method.
  - For Durkheim, sociology should be driven by data; mathematical regularities would be the foundation of the study, and theories would be posited to account for those regularities and make predictions.

  - Weber, in contrast, thought that although data are necessary, interpretation should be the hallmark of sociology. Sociology should work less like physics and more like history, using data not just to catalogue truths but to make sense of them.

- Historians create narratives that explain why events occurred as they did. Of course, there are better and worse historical accounts, but there is no single account that completely explains reality. Reality is multifaceted; thus, we need to look at its complex happenings using a number of ideological tools—different lenses—to gain insight into its range of interrelated elements.

- These tools are what Weber called *ideal types*.
    - In his allegory of the cave in *The Republic*, Plato asserted that because they can be changed, material objects are not real. What is real are the forms, idealized essences of things that we see not with our eyes but with the eye of the mind. We reach truth through philosophical contemplation, not observation. What is real is what is perfect; we can use the imperfect to start thinking about what is real, but the observable is not really it. We need to transcend the material to get truth.

    - For Weber, the material world is the real world. Where Plato argues that we use our acquaintance with the material to get to the real truth in the ideal or perfect realm, Weber argues that the perfect is never real, but we need to use it to get to what is real: our messy, complicated material world.

    - According to Weber, the world is so complex that the only way to make sense of it is to oversimplify, to cut out real elements and focus on some finite subset of what is left. We do this through the use of ideal types, which are uncluttered and neat concepts that we look for in the workings of society.

    - One example of an ideal type is the notion of economic man used in classical economics. Human beings are, for the sake of the theory, considered to be perfectly rational and perfectly self-interested. Of course, no one believes this is true, but by making this oversimplification, we can create an idealized version of transactions, where the observed effects are approximated by the idealized ones.

- Ideal types let us give explanations, and we can judge how good the explanation is based on how well the ideal type matches up with the messy reality. It will never mesh perfectly, but the tighter the fit, the better the ideal type is as an explanatory tool.

Competition versus Cooperation

- When we look at society, what is the ideal type we should use to explain its most basic dynamics? What is the single most important motivating element? Everyone believed that culture is a good thing, that a stable and functional society is necessary to create the preconditions for human flourishing. But what is the internal principle by which this stability is achieved? The answers proposed at the end of the 19^{th} and in the first half of the 20^{th} centuries were strongly tied to preexisting economic and political beliefs.

- On one side were those who thought society was designed to create harmony but required competition.
    - Society must pit interests against interests. Everyone wants everything, but only some can have it, and some will always have more than others. Society comprises inherently unequal elements: People are not just different; some are superior. Society ought to create a stage where those who are superior can lead and those who are inferior can follow.

    - A stable society is not a static society. Society can improve itself, can adapt and grow, but in order for this to happen, the internal arrangements must foster fair and ongoing competition.

- In his essay "The Gospel of Wealth," American industrialist Andrew Carnegie explicitly claims that as culture advances, "human society loses homogeneity." The ideal type that Carnegie makes use of is the law of competition.
    - People are pitted against people, and there are winners and losers. That is how things are and must be, and to try to change this situation will be to undermine the workings and the successes of society.

    - Society is composed of individuals with unequal abilities and ambition. Create a fair playing field and let the winners emerge because the winners are the ones who will drive the culture to a better future.

- This view of human groups derived much of its support through an analogy with evolution. Adaptation is the result of competition for scarce means of survival in ecosystems, and in human society, there are scarce resources, as well. If adaptation is healthy for biological species, the same should hold true for cultures.

- Although some saw competition as the basis of human social structures, others believed that humans are fundamentally cooperative. Human society brings people together, and the whole becomes greater than the sum of its parts because those parts support and build on one another.

- Those who held the view that human reality was primarily competitive took great pains to explain how their rather dark view of humanity would ultimately create better conditions for all. The contrary view, that we are primarily cooperative beings, was much more optimistic. Modernity may have created low-wage jobs and pollution, but underneath, the human heart connects us all and will ultimately lead us to a good place.
    - The name most strongly linked to this view is the Russian Pyotr Kropotkin, whose book *Mutual Aid* shows that we are not only social beings, but even more, we lean on each other, holding each other up and helping all to advance.

    - Those who favored humanity motivated by competition claimed that it aligned with Darwin's theories, giving their view a patina of scientific support. According to those in this camp, life in an ecosystem is forever competitive; survival of the fittest is a good thing because it sparks adaptation, which in the human context, inspires ingenuity.

- Favoring cooperation as the motivating force of humanity, Kropotkin felt compelled to play the game on this "scientific" turf. It may be true that resources are scarce and survival is difficult, but this challenge is not faced by individual organisms on their own. Animals largely survive the dangers of nature by working together, relying on each other, and creating cooperative situations. The same is true, Kropotkin argues, of people.

- Interestingly, this dichotomy between competition and cooperation is still with us in popular literature and film. On the one hand, we have stories in which the hero rises up against incredible odds to achieve unexpected greatness; competition brings out the best in the individual. On the other hand, we have the "it takes a village" theme, in which obstacles befall someone and the combined effort of the community overcomes them.

Ferdinand Tönnies

- In addition to competition or cooperation, a third option was put forward by the German sociologist Ferdinand Tönnies. In his most famous work, *Community and Society*, he distinguishes between two ways of being for a group.
    - Communities are collections of people who are bound together by commonalities. They exist because of a defining homogeneity.
    - Societies, in contrast, are defined by their heterogeneous nature. In a society, there are formal rules and roles. Structures are artificially created for a goal, and the members share a goal but only by virtue of belonging to the society. There is a sense of individuality among the members that comes before identity as a part of the society.

- Tönnies points out that the industrialized world has moved from a social structure that was primarily organized in rural communities to one that is becoming largely urban societies. He further argues that there is a reciprocal relation between these two structures. He contends that human groups will always and inevitably oscillate between society and community.

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A community, such as a religious congregation, has shared values, beliefs, and history, but in a society, such as a corporation, the sense of individuality among the members takes precedence over their group identity.

- When we have a community bound together by commonality, we will always find some dividing line, some difference between us, no matter how small, to separate ourselves into factions. We look for ways to recognize or create diversity and segregate ourselves as a result.

- At the same time, no matter how different we are, we will always find some external threat—real or perceived—to unify us against it. The city may have rich and poor, black and white, educated and uneducated, but when your team is going to the playoffs, everyone comes together as fans and supporters. The rallying effect of war is often used in this way to create enforced uniformity at a time of crisis.

- In Tönnies's view, the debate between those who think that culture is based on competition and those who think it is based on cooperation is a non-debate. Both are present all the time; indeed, they are flip sides of the same social coin. One always gives rise to the other.

- Although the cultural optimists and pessimists disagreed on the underlying motor of social change, they agreed that society was advancing. But Tönnies's view merely has us moving back and forth between community and society, with no engine driving forward. The question then arises: Does society advance?

Suggested Reading

Carnegie, "The Gospel of Wealth."

Kropotkin, *Mutual Aid*.

Tönnies, *Community and Society*.

Weber, *Methodology of Social Sciences*.

Questions to Consider

1. Is the desire to get ahead a virtue or a vice? If we are raising children in a society with a capitalist economy in which looking out for number one is advantageous, should we instill an ethos of self-promotion and self-interest in them?

2. Is Tönnies correct that we will always find a way to divide ourselves? Is Abraham Lincoln also correct that a house divided against itself cannot stand? If both are correct, are we doomed? Are any thoughts of the world coming together for the good of all humankind illusory?

Race and Reality

Lecture 24

The concept of race has long been a part of human culture. We have used it to justify war, to deny people rights, and as a source of pride. But biological attempts to specify it have failed. It is certainly true that there are observable differences among people from different regions, but none of the attempts to categorize people using these and their genetic sources has worked. Genetic diversity within racial groups turns out to be greater than it is across racial divides. Attempts to locate race in psychological features have not been successful either. Is race real even if it is not biological?

The Nature of Race

- Some of the dividing lines we create between communities are real, representing actual differences between people, and some of them are arbitrary, not something that is actually a part of the real world but a fiction we create. Among the most contentious boundaries, of course, are racial lines. But is race a part of reality or simply a social construct?

- For thinkers before the 20th century, there was no doubt that race was real. Immanuel Kant, in his 1775 essay "Of the Different Human Races," divided us into four categories based on skin color: "the noble blonde" of northern Europe, "the copper red" of the Americas and south Asia, "the black" of Africa, and "the yellow-olive" of East Asia and the Middle East. According to Kant, aspects of mind and moral character could be ranked in this division.

- In the two centuries following Kant, we see this notion of geography tied to visible biological features, invisible biological features, and elements of character all bound up together in one package called race that was used to justify beliefs about human worth.

- Note that there are three arguments here: (1) Geography determines visible biological markers. (2) The visible biological markers are flags for a collection of more subtle biological differences. (3) The subtle biological differences have effects that influence character, behavior, intellectual ability, and human worth. Science in the 20^{th} century tried to document and cement all three of these steps.

- The first step is a generalization from observation. Skin color; hair color and texture; eye color; eye, lip, and nose shape—all seem to vary across the globe in ways that lead to grouping. Darwin's theory of evolution led to an interest in such variations, and it was found that the observable differences among populations can fit a Darwinian explanation. For example, differences in skin color are tied to the body's needs for vitamin D and folate, or vitamin B_9, both of which are affected by the Sun and required for successful reproduction.

- Using this difference in skin color and other observable traits, anthropologists divided the human race into four races based on geographical regions similar to those of Kant: Causasoids (white Europeans), Mongoloids (Asians), Negroids (Africans), and Australoids (Australian aboriginals). Much work was done trying to track the distribution of various physical traits, called *clines*, in human populations.

- The subfield of anthropometry tried to quantify and correlate clinal variations. Two main results arose from this clinal mapping.
    - First, when we look at any given characteristic, we never see sharp cutoffs but, rather, smooth transitions in populations living between two distinct areas. If we are trying to form sharply categorized races, then the idea that the defining properties are a matter of degree undermines that effort.

    - Second, the clinal maps for different properties are all different. If we map the change in skin color, we get different maps for differences in hair texture, eye shape, and so on. It's true that there are different combinations among different populations, but if we are trying to draw sharp boundaries between races that have real significance, we need to assign more reality to one of these seemingly arbitrary properties than the others. Which one and why?

- There seem to be no good candidates for the one and only important factor, unless we find that one trait is linked to some other, deeper characteristic. That is the second part of the argument that race is a legitimate scientific concept: that visible biological differences are markers for deeper, more subtle, and more important differences between the races. This assertion, however, is just as problematic as the first, if not more so.
    - In 1972, American geneticist Richard Lewontin published a paper entitled "The Apportionment of Human Diversity." Lewontin argues that it is undeniable that there are differences in physical appearance and other properties in different groups, but he worries that "sociopolitical biases derived from human social experience [are being] carried over into 'scientific' realms."

    - If we want to have facts and not biases determine our belief in whether the observable differences in appearance have deeper ramifications, we need to see if the variation on the microlevel is in any way correlated with the standard division of race. We need to look closely at human variability within and across different groups to see if there are patterns.

    - In his research, Lewontin divided the human race into subgroups. He then examined blood samples for evidence of genetic variability. What he found was shocking to those who held the accepted belief in the biological basis of racial division. There is significant genetic variability among people, but the greatest degree of difference occurred within groups, not across them.

- When we look at the differences between races, we can account for only about 6.3% of the differences between individuals. Almost all of the variability we see in the entire human race—93.7%—occurs within races.

Race and IQ

- The failure to find race in biology suggested that perhaps racial realities are psychological. Perhaps the difference isn't in the genes but in the functioning of the brain. At the turn of the 20th century, craniologists and phrenologists sought to determine intelligence from the size of the skull and its characteristic bumps and to generalize their findings to races. Of course, the racial differences that were supposed to be found in this study weren't.

- After Alfred Binet developed the IQ test, H. H. Goddard brought it to America, altering its original purpose—an instrument to determine what resources would be needed to educate individuals with lower IQs—to use it as a judgment of innate intelligence. Goddard developed tests to show that immigrant groups contained significantly higher rates of "feeble-minded" individuals. These inferior people would require greater cultural resources and give back much less to society. Immigration, Goddard argued, must be stopped for the good of the country.

- This sort of argument—that there are inherent differences in intelligence in different races and that this difference ought to have ramifications for politics and societal resources—isn't restricted to the early part of the 20th century. In 1994, the psychologist Richard Herrnstein and the political scientist Charles Murray published the book *The Bell Curve*, in which they argue that intelligence tests strongly suggest that there are genetic differences in intelligence between races.

- This view hinges on the meaningfulness of race as a scientific concept, but at every one of the three steps in the argument, the concept of race failed to hold up as legitimately scientific.

Racial Programming

- Perhaps race is what Durkheim called a social fact, which you recall, has two elements. First, a social fact is a way of acting, thinking, or feeling that doesn't originate within the individual. Second, a social fact has coercive power attached to it. Perhaps race has its reality as a social fact, not a biological or psychological one.

- Western culture comprises societies of the sort that Tönnies describes. Our cities, towns, and states are heterogeneous mixtures of different socioeconomic classes and communities of different skin colors and ancestral origins. This isn't accidental; homogenous groups largely live clustered together. There may be both informal and formal means of enforcing the boundaries.

- This segregation has two important effects. First, it means that social customs and expectations develop in different social contexts. Second, psychological effects make the lines between us darker and deeper.

- The division that splits society into separate communities is fortified by two phenomena observed by social psychologists: in-group chauvinism and the fundamental attribution error.

- In-group chauvinism arises from the fact that humans are programmed to be irrationally optimistic. We have the strange ability to imagine a positive future for ourselves and to believe that this imagined future will materialize with a high probability.
    - We then transfer this happy projection to those whom we think are like us. We recognize aspects of ourselves in others, and the more like us we think they are, the more our brains react to them. The mirror neurons fire more for those people with whom we identify.

    - This process of identification has a sociological element; we are taught to recognize certain people as being more like us than others, and once we internalize that, there are neurological results. We are wired to prefer people whom we are taught to think of as “like us.” This generates *in-group chauvinism*, the greater likelihood that we will hire people like us, be friendlier to them and form relationships with them, and so on.

  - We have a bias toward people like us, and the social divisions that result from this in-group chauvinism only reinforce these divisions by keeping us around those like us more than we are around those unlike us. The individual bias leads to cultural barriers that further insulate us from each other.

- In the other direction is the *fundamental attribution error*. When someone who is like us acts in a fashion we deem unacceptable, we place the blame for the action on the personality of the individual. But when the person is unlike us and we see the same misbehavior, we tend to attribute it to members of the community as a whole. Our minds look for generalizations, and when we see the actions of a person we have been taught is unlike us, we generalize, filling fill in a stereotype we spend our lives building.

- If in-group chauvinism leads us to have a rosier-than-rational view of ourselves and those like us and the fundamental attribution error leads us to have a darker-than-rational view of those we have been taught are unlike us, then it seems rational to build higher walls between us.

- But society isn’t static. In the 1960s and 1970s, the walls that divided society into separate communities were beginning to be taken down. In the civil rights struggle, Dr. Martin Luther King, Jr., famously said, “The moral arc of the universe bends towards justice.” He saw the changes in the culture as an inevitable result of a fixed social trajectory. He believed that human progress is real, an undeniable aspect of social reality. But are we really growing and improving?

Suggested Reading

Gould, *The Mismeasure of Man*.

Hernnstein and Murray, *The Bell Curve*.

Kant, "Of the Different Human Races."

Lewontin, "The Apportionment of Human Diversity."

Yudell, *Race Unmasked*.

Questions to Consider

1. Would it be possible to have a notion of race that would not lead to racism? Could we divide ourselves in a way that would not lead us to think that some groups are inherently better than others? Would all divisions lead to ranking and, therefore, the belief that some groups are superior?

2. Given our ability to move freely around the globe and the inevitable intermarriage that results and given the way that modern communication technology facilitates global cultural exchange, is the notion of race on the verge of disappearing? Is it a concept that will cease to make sense in the globalized future?

Social Progress

Lecture 25

Most people believe that we are progressing as a society and that we are more likely to flourish with each new generation. Even those who disagree about whether we are inherently cooperative or competitive agree that society is on the right track. But anthropologist Joseph Tainter argues the other view. Great civilizations have always fallen, and ours most likely will, too. Societies are good at solving problems, primarily by creating institutions. These institutions improve life but use resources in doing so. Given that there are always more problems, there are always more institutions, and eventually, society becomes unable to support them all.

Marx and the Dialectic

- During the first half of the 20th century, social scientists bought into the view that positive human development and social advancement are necessary features of reality. Industrialization had transformed the world into a radically different place, giving us an abundance of food and factory-made goods, increasing the human lifespan through medical advances, and making the world smaller through transportation. There seemed to be little doubt that the history of humanity was one of triumphant growth and development.

- This view was shared by optimists and pessimists alike. Perhaps one of the most influential cultural optimists was Karl Marx, who believed in a dialectical process of cultural and economic development resulting from class-on-class struggles. In the course of history, each new socioeconomic stage provided both advancements in human life and the seeds of its own destruction. The revolution that would destroy one state of socioeconomic being was necessary to allow humanity to advance to the next stage.

  - Slavery, for example, was a necessary evil, allowing people to create the physical infrastructure of true culture. But the tension between masters and slaves would eventually lead to a revolution that would destroy the social system and leave a new one in its place: feudalism. In turn, the peasants who worked the land in the feudal system would ultimately revolt, leading to a capitalist society.

  - For Marx, capitalism was not inherently evil; it served an important role in human development. Capitalism is driven by the desire to maximize profit, which leads to minimizing labor and resources in production. Capitalists figure out how to make much more stuff than we need and how to make it quickly, easily, and cheaply. The result is the elimination of scarcity, giving humans everything they need.

  - But in making this happen, laborers become alienated, dehumanized, and removed from the meaningful relations they have with each other, themselves, and the things they create. Eventually, this will result in a revolution of the workers.

  - Moving through a time of collective ownership, we will ultimately arrive at the communistic utopia. In the utopia, because the capitalists have learned how to satisfy our needs using a minimum of resources and effort, we can spend relatively little time tending to them. Instead, we can spend the bulk of our time pursuing activities that will allow us to be truest to ourselves and to flourish.

- The fundamental picture here is that human beings are essentially social animals. We live in community, and we use that community to figure out how to solve our problems. But the structures needed to solve one set of problems ultimately cause another set of problems, until we finally figure out how to live together problem-free. Packed within this view is a presumption that history is following a path whose endpoint is a social structure guaranteeing universal human happiness and fulfillment.

Talcott Parsons and Social Evolutionary Universals

- Thinkers throughout the 20th century have followed this line. The American sociologist Talcott Parsons, for example, argued for the existence of sociological evolutionary universals, that is, social structures, beliefs, and institutions that are so advantageous that every culture everywhere eventually develops them. These universals may change over time, but they are a step in the cultural history of every society.

- According to Parsons, these social evolutionary universals include bureaucracies, money, taxes, police, and markets.
    - Power is distributed in all cultures, and as a result, some have it and some do not. When power rests with a particular individual, such as a king or dictator, and is not invested in the office apart from the office holder, civil instability occurs. If you become king by killing the current king, the result is constant changes in power, universal suspicion, and the inability to create the sort of cultural institutions that lead to higher cooperative tasks and the division of labor.

    - But once we invest power in an office rather than a person, we can establish rules by which a peaceful transfer of power occurs. Power can be distributed so that society can acquire specialists who focus on solving problems for everyone. Bureaucracy creates levels of authority that insulate the culture from special interests at the top and allow jobs to be done by those with specific competencies.

According to Talcott Parsons, as much as we complain about its red tape, inefficiency, and pointless rules, bureaucracy is an essential element of human progress.

- Parsons's picture is not the Marxist one, but it is similar in that it starts with an optimistic view of human nature and posits a set of steps that all lead in the direction of progress.

The Competitive View of Progress

- As mentioned earlier, social pessimists also see culture as progressing. According to Ayn Rand and other thinkers of the middle of the 20th century, the marketplace is as brutal to ideas as nature is to organisms. As a result, the free market and democratically elected government always produce the best results.

- Humans are rational and self-interested and will always look for an advantage. This competition causes adaptation and new developments. The innovations that work radically transform the landscape, and society moves forward.

- The key, the pessimists argue, is for people—especially the government—to stay out of the way of the progress and avoid the urge to level the playing field. It is the unevenness of the field that provides the incentive to innovate and make life better for everyone.

- There will always be inequity and suffering, but when we take the long view, the suffering will be much less as a result of letting the process run its course.

Progress in the Cold War

- In the first part of the 20th century, the modernist mind—whether it was optimistic or pessimistic—bought into the proposition that social reality is progressive. The structures under which we live are responsible for laying the groundwork for individual human flourishing. Those structures are becoming more complex and better adapted to solving the problems that plague us.

- But then, those problems changed. The 1930s saw a worldwide economic collapse. In its wake came the Second World War, in which we saw human beings at their genocidal worst. Further, we learned that those very same humans were capable of developing weapons of mass destruction. The result was the Cold War, in which every corner of the world was a pawn in a global chess match and every neighbor and friend a possible spy for the enemy. The thought of human progress seemed to become a naïve fairytale.

- Some thinkers tried to argue that the Cold War was just a detour in the long-term progress of humanity or, perhaps, even a time that showed us what we needed to do in order to safeguard human progress. The American political scientist Jeane Kirkpatrick, for example, argued that the Cold War provided a roadmap for cultures that were ready to advance.
    - It was true that much of the world was run by violent dictators who cared little for the well-being of their people and acted viciously to protect their own wealth and power. It was also true that these rulers were supported by the Americans and the Soviets. As unseemly as it might appear to aid those rulers, it was the best approach in the long run, according to Kirkpatrick, as long as we select the correct brutal dictators.
    - If we help keep brutal right-wing regimes in power, we are setting the stage for the eventual development of democratic society. If, however, we support brutal left-wing regimes, we will doom the country to wallow in terror and instability. In the dark fog of the Cold War, there still could be human progress; we just had to make sure to plant the seeds in the proper form of evil.
- In the following generation, the American political scientist Francis Fukuyama continued along Kirkpatrick's line in *The End of History and the Last Man*. He argued that history was following a necessary dialectical path, but not the one Marx would have predicted. Liberal democracy, he contended, was the end of history. All other alternatives had proved themselves to be inferior.
    - Once a country achieved liberal democracy, there would be no further development of the culture. There might be wars with nations that had not yet reached the end of history, but ultimately, those smaller nations would be defeated by the more powerful nation-states that had completed their journeys.

    - In defeat, the smaller neighbors would continue their path until the whole world was a happy collection of liberal democracies.

- Of course, not everyone was so optimistic. History is filled with great civilizations that have collapsed; perhaps all of them do so eventually. The American anthropologist Joseph Tainter concluded that the Roman Empire, the Egyptian Old Kingdom, the Mayan civilization, and others all sputtered and died from a lack of energy.
    - Tainter begins with the presumption that the job of human society is simply to solve human problems. When we join together, we can avert dangers and meet basic needs in a way that we might not have been able to do individually.

    - We create social structures—institutions—whose job it is to take care of needs and threats. But the institutions we use to solve problems generate a need for resources, and that need increases the load on all of us.

    - No matter the time or place, new problems always arise. When these challenges emerge, we create new organizations to deal with them. The new bureaucracy takes care of the problem, but the added complexity comes at a cost for everyone in the culture.

    - Eventually, Tainter argues, we reach a point of diminishing returns. The additional resources we put in are larger than the problem-solving power we get out. At this point, society has multiple layers of intertwined institutions, all of which consume energy. But the amount of energy is finite; it is limited by the available resources. It is here that we reach our cultural tipping point.

    - The beast we have created becomes too expensive to feed. When we create too much complexity, we can no longer afford it. For Tainter, this is the reason behind the collapse of every previous major civilization in history.

Suggested Reading

Eagleton, *Why Marx Was Right*.

Fukyama, *The End of History and the Last Man*.

Parsons, *Societies*.

Rand, *The Fountainhead*.

Tainter, *The Collapse of Complex Societies*.

Suggested Viewing

The Gods Must Be Crazy.

Questions to Consider

1. Is social progress progress toward something? Is there an ultimate goal, an ultimate social good or state we are working toward, or is it an endless process?

2. Is Tainter correct that cultures eventually create the conditions for their destruction? If Tainter is correct, is it inevitable? If we know what is coming, could we act to prevent it?

The Reality of Money

Lecture 26

Economics became a science with the formulation of the ideal type of *homo economicus*, the financial being who is perfectly rational and completely self-interested. The behavior of such a being in the marketplace would be predictable, and the large-scale movements of the economy would be determinable from the properties of the individual. But in the 20th century, the classical picture was undermined, both in terms of the macro picture deriving from small-scale interactions and because humans are indeed neither perfectly rational nor completely self-interested.

The Birth of Economics

- Economics as a science began in the 18th century when relations among production, consumption, scarcity, and price began to be formulated. In the shadow of Newton's work on mechanics and gravitation, the idea was that we ought to be able to model the flow of money in the marketplace on our vision of energy flowing in a physical system.
    - The problem, of course, is that physics deals with objects that have no will. People, in contrast, are seemingly not bound by deterministic rules.
    - Hence, a science of economics seemed to some to be impossible. Economics could only be scientific—could only produce universal, quantifiable regularities—if people behaved in well-regulated, predictable ways.
- Early economists objected that this romanticized image of the capricious human who acts however he or she wants at all times is an empirical matter. If we look at the functioning of the marketplace, we actually observe a well-regulated system that acts and reacts in predictable ways. Human choices are not random; to the contrary, we can fully understand why humans do what they do in the marketplace in a quite straightforward way.

- This was the birth of *homo economicus* ("economic man"). According to this view, when people interact in the marketplace, their intentions are transparent. They want always and only what is in their own best self-interest. If they are buying something, they want the most of it they can get for the smallest price. If they are selling, they want to get the highest price possible.

- This desire to maximize self-interest would be pointless if people were unable to figure out what is in their best self-interest and how to get it. Fortunately, in this view, people are rational and are able to weigh possibilities. When two vendors make offers, we can figure out which is the most advantageous to us, and we choose that one. We know what we want, we know when one option is better for us than another, and we always choose the most favorable one.

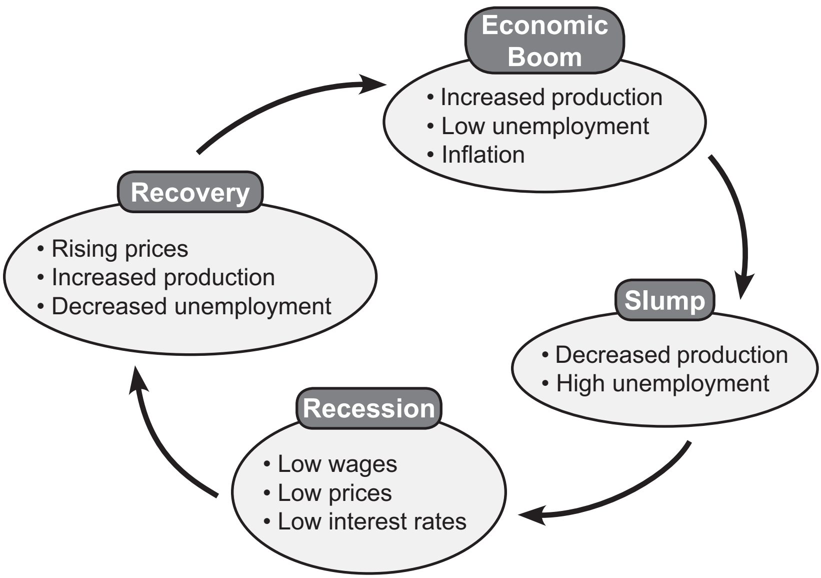
- If humans act according to this model of perfect rational self-interest, then economic interactions become mathematically representable. We can draw supply curves and demand curves. We can find the place where they meet and designate it as equilibrium. When we see prices set below this equilibrium, economic forces move prices up. When we see alternative products in the market that are cheaper, we see the equilibrium point move down and prices change.

- Note that the classical picture of economics has the macro-level fiscal phenomena derive directly from one-on-one interactions of buyers and sellers in the marketplace. What happens in the small—among individual producers, laborers, and consumers—is predictable because they are all seeking only to maximize their own self-interest. When we look at a great number of these interactions together, the behavior of the economy in the large is also directly determinable.

- Thus, the classical view of economics is based on two primary assumptions. First, at the micro level, all financial interactions are between people who always act rationally and in their own best self-interest. Second, the large-scale behavior of the economy is the result of well-behaved small-scale interactions. The 20th century would see advances that undermined both of these assumptions.

The Business Cycle

- The first of these intellectual pillars to be challenged was the second—that small-scale interactions give rise to predictable large-scale behavior. This predictable behavior is what is known as the *business cycle* (see below). According to this idea, the economy has an equilibrium point, but that does not mean that it is static. Instead, the large-scale economy alternately grows and contracts around a fixed point.



- Because people are rational and self-interested and because their decisions take time to implement—the actions of those in the market lag behind the timeframe of the actual changes in the market itself—there is never a fixed arrival at the equilibrium.

- Economists say that wages and prices are “sticky.” Workers are given contracts over a period of time and even if the going market wage is lower, bosses are locked into that wage.

- Similarly, prices tend to adjust slowly. When the market price goes down, owners may be locked in through a contract to provide products for a fixed time at a fixed price. Or they may be hopeful that they can sell at the old higher price and are slow to reduce prices.

- The result of this stickiness of labor costs and prices is that there is a lag between what is happening on the ground and the reaction by rational agents in the market. As a result, a boom-bust cycle occurs around the equilibrium point. When the economy is hot, the increase in prices and wages will keep it from overheating and cause a correction that cools it off. But when it is cold, low wages and costs will spur it back to life. Because there is a never-ending supply of human greed and ingenuity, the cycle will continue forever, always moving around a stable equilibrium point.

The Great Depression

- This theory was contradicted by the stock market crash of October 29, 1929. A bubble in the stock market from the 1920s caused an overvaluation of stock prices. Traders were buying on credit—borrowing to buy stocks and using as collateral the money they would make when they sold the stock. Once stocks stopped rising, the borrowers did not have the cash to repay their loans. They not only lost their money but also decreased the demand for stocks, which was the reason the prices had been pumped so high. Without this support, prices tumbled. Those who had their money in the market were wiped out.

- The result was the Great Depression, a period of very high unemployment and very low interest rates. The classical model held that this ought to spur a period of growth, but it didn’t. In Germany, between the world wars, the result of reparations brought on a period of high unemployment, high inflation, and slow growth.

- Under the classical model, this should not be possible. High unemployment ought to lead to low inflation, which would allow the economy to stabilize. But in the 1930s, nothing seemed economically stable anywhere.

- The old approach in which the rational self-interest of individuals would create a system that was stable in the large became untenable.

- The British economist John Maynard Keynes argued that contrary to the classical picture of a single equilibrium point, there are multiple possible equilibrium points, and it is possible for the economy to become stuck at an undesirable point.
    - Aggregate demand, the amount of goods and services required by the economy, is such that it cannot accelerate the economy when it is stuck on an undesirable equilibrium point. Because people are unemployed, they don't have money to make purchases, and because people aren't buying, businesses don't have money to invest. A deflationary cycle keeps prices pinned down, preventing growth.

    - The defenders of the classical view argued that things would straighten themselves out if given enough time. But Keynes contended that aggregate demand needed a boost, and if the business community could not supply it, the government should. If the government increased spending, even if it meant running a temporary deficit, that extra demand could pump enough life into the economy to restore it to its former healthy state.

    - Between the New Deal programs and the spending for World War II, the stimulation generated by governmental spending created enough new demand in the economy to nudge it away from its depressed equilibrium and back to its normal place.

- Keynes changed our understanding of the nature of reality when it came to fiscal matters. The classical view presupposed that the large-scale picture of the economy was determined by small-scale relations, which were based on the picture of the rational, self-interested agent. Keynes showed that the macro-level picture has emergent properties. He suggested that we need to talk about macroeconomic phenomena in a macroeconomic language, which cannot be reduced to microeconomic occurrences.

Challenges in the 21st Century

- The middle of the 20th century forced us to reevaluate the second of the two presuppositions of economics: that the workings of the small could account for the workings of the large in the economy. Then, the end of the 20th and the beginning of the 21st centuries saw the challenging of the first presumption: that we are rational, self-interested beings in the marketplace.

- There is little doubt that we are neither fully rational in all elements of our lives nor entirely self-interested. But the notion of *homo economicus* functioned in microeconomics as one of Max Weber's ideal forms. It was an idealization that was close enough to reality that it could be used as a meaningful lens through which to make sense of what we see in the marketplace.

- But modern psychology has shown that we often make decisions on completely nonrational bases. The amygdala leads us to act instinctively, and the rational brain catches up later, filling in the blanks with a story about how we reached a decision to act through thoughtful deliberation.

- Economists have shifted gears in order to catch up with psychological research, giving rise to *behavioral economics*. Humans do not make rational decisions when it comes to financial matters; indeed, we are programmed not to. The effects of social psychology—groupthink, cognitive biases, and comparative optimism—are all in play when we look at financial activities. Sociological aspects, such as the status quo bias and availability bias, are involved, as well.

- How do we account for these effects in our understanding of markets? The ideal form of *homo economicus* was useful in that it allowed us to set up a situation that was easily modeled and from which we could generate equations to govern economic phenomena. But as science has progressed, we realize that the world described in this view of economics is not our world. Instead, humans are much more complex creatures. This new picture may be less flattering, but it also gives us a more accurate sense of the reality of markets.

Suggested Reading

Ariely, *Predictably Irrational*.

Sheehan, *Understanding Keynes' General Theory*.

Questions to Consider

1. Is money real? Is money a necessary part of human culture? If we chose to eliminate all currency, would a new form of exchange, that is, a new type of money, soon appear?

2. Is economics like physics? We cannot choose the speed of light or the form of the laws that govern electricity, but can we choose the form of our economy and how it operates?

The Origin of Life

Lecture 27

The universe does not seem like the sort of place where life would be likely. Stars turn hydrogen into helium in relative isolation. But in their centers, they also create heavier elements that become dispersed when they implode, forming planets like Earth. The young Earth was hot and unstable, but from the ocean emerged the first life forms. Because life requires a consistent source of energy, particularly the light of the Sun for photosynthesis, the presumption has been that life arose from the shallow waters near landmasses. But recent discoveries of thriving ecosystems at the bottom of the ocean have led some to speculate that life began in the deep.

The Formation of Elements in Stars

- Hydrogen is simple enough that once the universe cooled down sufficiently from the big bang, simple atoms could form. Stars convert hydrogen into helium through nuclear fusion.
    - The idea here is that energy is the currency of the physical world, and it takes less energy to maintain a helium atom than it does to maintain two hydrogen atoms.
    - The energy the hydrogen atoms save by becoming helium is given off in the forms of light and heat; this is why stars shine.
- In the bellies of stars, helium nuclei find it energy-advantageous to join together, fusing into larger atoms, with more and more protons saving energy by sharing a single nucleus. But eventually, the nuclei get so large that adding more protons costs energy. The elemental point of diminishing returns is iron. Atoms larger than iron are more expensive to maintain in terms of energy than the combination of smaller atoms.

- If the star is large enough, when it runs out of hydrogen to convert into helium, it collapses on itself, imploding. This can cause a supernova, in which the heavier elements made inside the star are ejected into space. Those elements become the basis for the formation of planets, when large clouds of cosmic debris experience sufficient gravitational attraction to form into single mass. This process gives us planets, including the Earth, but where does life come from?

Conditions for Life

- Virtually all life is found on landmasses and in the relatively shallow waters around landmasses. We know from the fossil record that life existed in the sea before it appeared on land. Simple one-celled animals eventually gave rise to multicellular life, which eventually developed into everything we see now. But how did those simple one-celled organisms come to be?

- Life seems to require a very specific set of conditions. If the environment is too cold, too hot, or too dry, there will be no life. Early on, it seemed that conditions in the arctic ice and at the bottom of the ocean could not sustain life. Thus, it was only in sunlit regions that we looked for the source of life.

- Sunlight is a source of energy, and energy is essential for life. Life, as we find it, is composed of intricate collections of amino acids formed into proteins, which are then able to self-regulate and reproduce. But these functions require energy. If the life form is not fed, it cannot live. Life is organization, and organization requires energy.
    - The second law of thermodynamics holds that entropy increases. Entropy is a measure of disorder, and life is perhaps the most order-bound phenomena in the universe. If the second law of thermodynamics holds true, how do we have life at all?

    - When we formulate the second law more carefully, it says that in a closed system—one into which no energy is added—entropy tends to increase.

- If we want to decrease the entropy of a thermodynamic system—that is, if we want to add order to the system—we have to add energy in the right way. This is why the second law of thermodynamics holds only for closed systems. Open systems—systems where energy is being pumped in—could be set up to use that new energy to make the system work, to keep order and accomplish tasks.

- This is exactly what life does. When we first looked to see where the life on Earth is located, we found it on land and in shallow waters close to land. These locations have one element in common: access to sunlight. The Sun is always adding energy. Ecosystems are based on this fact. Plants have the ability to take this energy and store it for use in creating and maintaining order.
  - Plants take in water (H_2O) and carbon dioxide (CO_2). They collect sunlight and use the extra energy to break up the molecules of these chemical compounds into hydrogen, carbon, and oxygen atoms in such a way that they then form a new molecule, glucose, which uses all the hydrogen and all the carbon but not all the oxygen. The plant gives off the extra oxygen and stores the glucose.

  - The glucose stores some of the energy that was used to create it, and when broken down, it can release the energy for use in the cell to overcome the effects of the second law of thermodynamics. This is photosynthesis.

  - The plant uses the energy to fuel its internal processes, or if the plant is eaten, then the herbivore uses it for its internal processes, or it is used by the carnivore that eats the herbivore. Thus, the fixing of the Sun's energy by photosynthesis is the process that allows the ecosystems we observe on Earth to function.

- Without an energy source, life is impossible. The Sun is an energy source and is needed for life. Thus, we thought that life is only possible in a very small number of environments—on a planet the right distance from its sun, with the right carbon and water availability.

In photosynthesis, the sunlight taken in by plants triggers a chemical reaction that creates glucose, which is used to store energy; it's possible that this process developed from chemosynthesis.

Discovery of Life in the Deep

- In 1977, researchers from the Woods Hole Oceanographic Institution sent Alvin, a human-operated deep submergence vehicle, to the bottom of the Galapagos rift. The Galapagos rift is interesting for two reasons. First, it is about a mile and a half deep, and second, it lies at the intersection of three tectonic plates, which means that it's geologically very active.

- The researchers from Woods Hole discovered some interesting volcanic vents—*black smokers* that spew mineral-rich hot fluids into the ocean. Like geysers, these hydrothermal vents were shafts to a deeper layer of the Earth's core. Because the plates meet at a joint, the magma underneath can pool closer to the surface. This causes heat and metals from deeper in the Earth to come closer to the bottom of the ocean, and these can move upward through a weak spot or a hole. The water coming out of these vents can reach 750° F.

- Around these vents, the researchers discovered what they called the Garden of Eden. It was a lush, thriving ecosystem with thousands of eyeless shrimp, mussels, sea life of an amazing variety—all living where we previously thought life could not exist. Instead of photosynthesis, this life depended on chemosynthesis, a similar process that used the heat and chemical energy coming out of the thermal vents on the ocean floor.

- This was a discovery of life that functioned on a completely different basis, forcing us to redefine reality. We thought life needed the Sun; how did it arise where the Sun didn't shine? Did it arise spontaneously in different places, both in the deep and in the shallows?

An Alternative Origin Theory

- In *The Deep Hot Biosphere*, British astronomer Thomas Gold contends that this deep undersea life shows us where all life on Earth began.

- Shallow-water and land-based ecosystems depend on photosynthesis. This is an incredibly intricate process that relies on a string of chemical reactions, some powered by energy from the Sun and others that must follow in order in an appropriate environment within the cell. It is not something we would expect to develop spontaneously on its own, especially where sunlight is not incredibly strong. It is something, however, that we could easily see as adapted from organisms that already had the ability to use hydrocarbons as fuel.

- What if cells did not need to generate their own hydrocarbon? What if they existed in a world in which hydrocarbons were already floating around, ready to be taken in and used? These cells would develop one part of the process, that is, the burning of hydrocarbons for energy and the cellular elements that make use of it. Having half of the structure, some of these one-celled beings could then adapt to a different environment, one where the hydrocarbons were not readily available but energy was present to synthesize those hydrocarbons for themselves.

- What environment on Earth could produce temperatures in the range needed for life and free hydrocarbons that could be used to develop simple pre-photosynthetic life forms? The answer, of course, is the deep ocean system of geothermal vents. Given the genetic similarities of the deep, shallow, and land-based life forms, we know they are of a single origin. Because photosynthesis is more complex than chemosynthesis, there is some reason to think it developed later as an adaptation.

- Further, the Sun's energy can be stored by living things, but it is ionizing energy and can damage life, as well. As we saw in an earlier lecture, the Sun's rays are used by our skin to produce vitamin D, but these same rays also destroy vitamin B_9, folate. Life forms would have to develop a defense against the Sun. It would be easier for life to start elsewhere, away from the Sun.

- The deep oceans would also provide a more stable environment. The young Earth was hot, and it took a while before its properties would be suitable to sustain life, much less give rise to it. The oceans with the thermal vents provided a stable and constant flow of energy. This stability would make the deep ocean a more likely spot for simpler life forms to begin. For all of these reasons, Gold argues that there is good reason to believe that life on Earth began in the deep, hot biosphere.

- Gold's hot, deep biosphere theory allows for the possibility of life forming in places we had thought were inhospitable to life. Life could begin without a surface temperature like that of Earth, which means that life similar to what we see on Earth could exist in places other than Earth. A competing hypothesis, called *panspermia*, is that basic life is spread throughout the universe and arrived here from cosmic dust carried by comets or asteroids, leading us to ask: Is life purely an earthly phenomenon?

Suggested Reading

Gold, *The Hot Deep Biosphere*.

Questions to Consider

1. The second law of thermodynamics does not make life impossible but does make it more difficult. There are other aspects of the universe that if they were slightly different would make life impossible, but they happen to be in the small range that makes the universe hospitable to the formation of living beings. Is this evidence that the universe was created for life? Even if there is no God, in a universe like this, would life have necessarily come into being anyway?

2. We have seen a pattern of scientists assuming that such systems as space or the surface of the Earth must be stable, only to have to reject this view later for a picture in which the system is dynamic. Is stability a necessary starting point for scientific inquiry, or should we start off instead with the position that everything changes?

Exoplanets and Extraterrestrial Life

Lecture 28

The possibility of life on other planets has been a constant fascination of ours for quite a while, but we have not yet confirmed it. We have sent messages into space on our Voyager crafts, and we are using radio telescopes to listen for messages that may have been sent to us. In our solar system, Mars is the only other planet that has the likelihood of being home to life, now or in the past. But the search for planets around neighboring stars is perhaps our best hope; in this search, we have found at least 21 possible candidates.

Artistic Conceptions of Extraterrestrial Life

- Perhaps the scientific discovery that would most radically force us to redefine reality is one that may not have happened yet: the discovery of life on another planet. Scientists are dedicating resources to this search and have had some promising leads, but artists have been on the case even longer. Artistic portrayals of the subject tend to come in four varieties: aggressive, exploratory, cooperative, and transcendental.

- The aggressive version is the central plot device of H. G. Wells's *War of the Worlds*, in which Martians invade Earth with the intent of seizing control. Wells's story was famously revived on the radio in 1938. At the time, World War II was looming, and thoughts of mass killings and the possibility of invasion by those considered "other" were not far from the cultural mind.

- Director Steven Spielberg gave us representations of extraterrestrials as exploratory and benign in two films, *Close Encounters of the Third Kind* and *E.T. the Extra-Terrestrial*. In both films, aliens come to Earth to study humans, not to conquer us. Produced in the waning years of the Cold War, these films embody an implicit hopefulness that those who seem different can come to understand each other and coexist.

- This theme is also the central concept behind the television series and movies of the *Star Trek* franchise: "to explore strange new worlds, to seek out new life and new civilizations, to boldly go where no man has gone before."
    - In the feature film *Star Trek: First Contact*, the discovery of life beyond our own world creates peace on Earth.

Some modern science fiction has a more hopeful theme than earlier works; the discovery of life beyond our own world creates peace and harmony on Earth.

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    - In a move right out of Ferdinand Tönnies, the instant we conceive of ourselves as part of a larger collective of life forms throughout the universe, the differences between people on Earth shrink away, and we see the human race as being homogeneous.

- We see the same sort of narrative in Arthur C. Clarke's *2001* stories, where the aliens become an essential part of human history. The first visitation of the aliens helps spark human evolution, leading to the development of consciousness. Once the human species becomes self-aware and able to use tools, it is on its way to developing the ability to travel in space.

- If *Star Trek* and *2001* fold us into the plans of the rest of the universe, Carl Sagan's *Contact* takes us a step further.
    - In this book, when humans make contact with beings from another planet, we are given plans for a machine whose function we do not know. When the machine is activated, it takes its passengers through wormholes to meet these more intelligent beings.

- Our newfound alien interlocutors tell us that they have found evidence of these advanced beings in the irrational number pi. After returning to Earth, the protagonist sets a powerful computer to examine pi from multiple expressions. The computer finds a pattern like a fractal that is symbolic of a universal intelligence.

- Note that Sagan artistically makes the move that we have seen implicit in the development of science. We start with reality as a set of individuals, thinking that humans are the only life. We then move to relations, seeing ourselves as just one life form in a universe with others. Finally, we take the holistic turn: It is the entirety that is real, and individuals are modes of the entirety. In *Contact*, it is not that intelligent life is at some place in the universe but that the universe is an intelligence, and we are an aspect of it.

Finding Extraterrestrial Life

- The first approach to making contact with extraterrestrial intelligence was to send messages into space. In 1977, the United States launched Voyager 1 and Voyager 2, each bearing a "note" from Earth. But there are several concerns about this approach. First, if there is other life in the universe, the odds of finding it with these tiny craft are next to nothing. Second, extracting and making sense of our message would require intelligence.

- Another approach to discovering extraterrestrial life is to listen for any possible contact it has tried to make with us. The lead in this project has been taken by the Search for Extraterrestrial Intelligence (SETI) Institute.

- SETI's most notable effort involves the Allen Telescope Array, a collection of hundreds of radio telescopes arranged over more than two acres of land in California. In particular, the array focuses on signals coming from the so-called water hole.

- Recall that every element has a fingerprint, that is, a set of telltale frequencies of light it emits when excited. The strongest light hydrogen emits is at 1420 MHz. The strongest light radiated by the combination of a hydrogen and an oxygen atom, a hydroxyl radical, is at 1666 MHz. The combination of a hydroxyl radical and a hydrogen atom is water. Thus, the gap between 1420 and 1666 MHz was dubbed the water hole.

- All life that we know depends on water, and the idea here is that perhaps all life does. Hence, this range of frequencies could be considered universal; it could be the sort of thing another intelligent race would see as more than idiosyncratic and, perhaps, a place they would send a message if they wanted other intelligent life forms to find it. It might work like a watering hole, a gathering place for animals.

Life on Mars?

- Mars has virtually no atmosphere, only a thin layer of mostly carbon dioxide with traces of nitrogen. On the one hand, this means that virtually no heat is trapped by the atmosphere of Mars. On the other hand, the existence of carbon dioxide gives us some hope that there may have been water at some point in the past on Mars, and water might point to the conditions for life having been there, as well.

- The presence of nitrogen on Mars generates even more excitement. Nitrogen is the result of certain cellular processes, and it may be a direct sign of life. It might also signal volcanic activity, which could indicate the presence of subterranean life forms similar to those Thomas Gold describes in his deep, hot biosphere conjecture.

- There are ice caps at the poles of Mars; thus, we know there is some water present. Observations of the surface of Mars also show marks that are consistent with flowing water. In addition, spectral analysis of a sample of Martian soil showed that it contained about 2% water, which means that there is still some water left on the surface. This introduces the possibility that water might be present below the surface, creating the conditions for microbial life.

Exoplanets

- Perhaps the best evidence for extraterrestrial life is to be found on other planets around other suns. The problem is that for a long time, we had never seen such planets. Planets are small in astronomical terms and give off no light.

- One approach to detecting other planets is gravitational.
    - Strictly speaking, the Earth does not revolve around the Sun. Instead, the Sun and the Earth both revolve around a common point, the center of mass of the two-bodied system. The Sun is so much heavier than the Earth that the center of mass of the two is actually located within the Sun itself.

    - As a result, when the Earth moves around this point, it moves around the Sun. But when the Sun moves around it, it is revolving around a point inside of itself, not at its center. The result is a wobble, much like someone keeping a hula hoop going around his or her waist. The heavier the planet, the larger the wobble in the Sun.

    - We can look for these solar wobbles optically; that is, if the planet is large enough and the star close enough, we might be able to see the movement over time. But a better way to spot the movement is by observing Doppler shifts. We can check for changes in the light emitted by the star. This is how the first exoplanet was discovered.

    - Pulsars are stars that emit a strong beam of light. As the star rotates, this light flashes on and off, like the light on top of a police car. The astronomers Aleksander Wolszczan and Dale Frail noticed that the behavior of a pulsar star they were observing was a bit askew. Their calculations showed that this had to be the result of two planets orbiting the pulsar; thus, the age of exoplanets was launched.

- The exoplanet discovered by Wolszczan and Frail would not be hospitable to life, but the search for Earth-like exoplanets began in earnest. Larger planets called *gas giants* were found, but again, these planets would not accommodate life as we know it.

- An approach for detecting smaller exoplanets is to see them in transit, that is, during the phase of the planet's motion in front of the star it orbits.
    - For example, there are times when we can observe the transit of Venus across the perceived disk of our Sun. If viewed at the right time in the right way, a black spot seems to move across the surface of the Sun. That spot is Venus moving between Earth and the Sun, thereby blocking the light.

    - With an exoplanet, the amount of light blocked would be small, and the dark spot would be too small to see. But if we had a sensitive enough meter to detect a decrease in the brightness of the star, we could infer the transit of the planet.

- Between the wobble and the transit methods, astronomers have identified about 1,800 exoplanets. We had feared at one time that planets were rare, but the most recent estimate is that our own Milky Way contains about 400 billion planets.

- We need to find planets that are Earth-like and that orbit their stars at just the right radius, what scientists call the *habitable zone*. Right now, we have found 21 confirmed exoplanets that are of the right sort and in the right range of orbit. Scientists will continue this search in hopes of finding extraterrestrial life, forcing us to redefine reality once more.

Suggested Reading

Mayor and Frei, *New Worlds in the Cosmos*.

Morrison, Billingham, and Wolfe, *The Search for Extraterrestrial Intelligence*.

Suggested Viewing

2001: A Space Odyssey.

Close Encounters of the Third Kind.

Contact.

E.T. the Extra-Terrestrial.

Star Trek: First Contact.

Questions to Consider

1. How likely is it that we are alone in the universe? Given the size of space, does it have to be true that there is life elsewhere?

2. If there is life elsewhere in the universe, given how large it is, is there any real chance of us finding it or of other beings finding us?

Technology and Death

Lecture 29

We usually think of technology as tools that humans create to serve us in our quest to solve problems, but it turns out that technology, in determining the limits of what we can do, actually determines how we see the world and what we select as goals. There is a fear that this elevation of technology is undermining the basis of what makes us human. Nowhere is this more apparent than in our use of medical technology to pursue immortality. Is an acceptance of our limited time on Earth a necessary part of making life meaningful, and if so, does this technological pursuit rob life of its value?

The Nature of Technology

- The standard understanding of technology holds that technology is a set of tools we create to help us reach preexisting goals. Technology is a part of human progress because it allows us the time and space to be more human. It frees us from the tedious necessities of life, granting us the ability to pursue our real interests.

At its best, a technology such as the alphabet has the power to reveal ourselves and the world to us, but it also has the power to trap us and limit our view of the world.

- It has long been argued, however, that this progressive picture of technology is flawed. Technology does not free us from anything; in fact, the reverse is true: We have become slaves to technology. Technology governs our activities, thoughts, and goals.

- Technology's ability to alter human life seems worrisome, but the German philosopher Martin Heidegger, in his essay "The Question Concerning Technology," argues that technologies create worlds and reveal truths. Technology is a creative re-visioning of how the world could be that then changes the world. Elements that were hidden become accentuated; aspects we thought were necessary are seen as arbitrary; and choices we never realized we had become possibilities.

- Heidegger argues, however, that the wrong approach to technology not only will fail to create worlds but will endanger them. Becoming captured by technology dictates our goals and frames our view of the world, preventing truth from being revealed by shielding our eyes from the rest of the world.

- Heidegger was writing in 1949, in the wake of the two world wars, in which technology had caused horrible, painful deaths and brought about the possibility of global annihilation. Humanity had reached that point, Heidegger argued, because we had allowed our technology to redefine the very notion of humanity in accordance with its own limitations.

Defining *Death*

- In another work, *Being and Time*, Heidegger contends that the starting point for technology's disclosure of truth is the glimpsing of death. Every one of us, he contends, has the shocking realization that we will die. And it is only by seeing that our lifetimes will have an endpoint that we can project ourselves into that bounded future.

- The moments of our lives are made meaningful by the fact that they will end. As humans, we plan; we envision ourselves as being more than we are, then we make it so. Who we are, Heidegger thinks, is determined by who we want to be. But because we have only a limited amount of time, we must make choices. We must design ourselves as a project in the time we have. Because we are mortal, the life we have acquires meaning.

- At the same time, it seems as if some of our most prized technologies are created with the goal of immortality; through them, we are trying to destroy every path where we could meet our mortal end. Medical science invents drugs and procedures to cure diseases; we pasteurize food to kill microbes; we put airbags in cars; and so on. Because we think that death is bad, we spend large sums of money to try to make ourselves immortal.

- Whether or not our death-defying technologies help us to become more or less human depends on what we mean by the word *human*.
    - We use death to distinguish human from nonhuman. We use the words *body* and *corpse* to indicate that someone who has died is no longer considered a person. But what property of the body do we use to determine dead from alive?

    - Traditionally, this property is minimal functioning of bodily systems. Blood must flow through the body to deliver oxygen to the cells, and blood flows only if the heart is beating. Thus, a person is alive if he or she has a heartbeat.

    - However, technology has made this definition problematic. We now have defibrillators that are capable of shocking a non-beating heart back into service, and we say of someone who has received this treatment that he or she was dead but was brought back to life. Although we think of the person as having been dead, we usually do not think that he or she stopped being a person.

    - Death as a removal of personhood seems to require permanent death, not merely temporary death. Intervention that allows the body to regain its ability to maintain itself implies that continuing life was possible, and it seems that where there is this possibility, personhood is maintained.

- But the idea of using the body's potential to maintain or regain its functionality as a condition of personhood becomes even more complicated when we consider life-support technology. Are those who are on life-support machines still human in the full sense of the word?

- For many people, death is not bodily death, which can be forestalled by the use of life-support mechanisms, but brain death.
  - This view is clearly related to the classical metaphysical picture of dualism, in which people are made up of two different things: material bodies and immaterial souls.

  - In the dualistic view, when someone is brain dead, the body is still present, but the spirit or mind is gone. The idea that brain death is human death is tied to this dualistic view of the body, which has largely been abandoned in science.

  - Even if we think of the mind as emerging from the brain, the mind plays a crucial role in being human. The mind is what lets us plan and what gives us autonomy. When someone is brain dead, there is not a self to project itself into the future.

- Of course, the brain science we have looked at makes this problematic, too, because, as we have seen, the brain often acts on its own, with the conscious parts then backfilling a desire to match the action. If the brain is not the seat of autonomy, why should we believe that brain death removes personhood? Perhaps in the future, we will be able to resuscitate the brain in the same way that we can resuscitate the heart. This is the thinking behind cryonics, the preservation of one's body or head after death by freezing.

A Path to Immortality?

- Humans are made up of cells, and we have a natural life cycle of birth, growth, aging, and death. This happens for the body as a whole because it also happens for cells individually. With few exceptions, our cells replenish themselves in the body by dividing, but this process does not create two exact copies of the parent cell.

- Recall that cells have nuclei, and inside the nuclei are chromosomes that contain the DNA, the instruction manual for the entire enterprise. The DNA is in the form of a double helix that unravels itself; in cell division, the two halves split off, and each re-creates the other side.

- As a result, we have two copies of the DNA molecules, each of which can form the genetic material needed in the two cells that split out of the progenitor.

- At the ends of chromosomes are *telomeres*, which are the genetic equivalent of hems on a pair of pants.
    - Every time a cell divides, the end of the chromosome gets ripped off, leaving a series of meaningless repetitions of the base pairs in the DNA. This is genetic code that carries no information, making it disposable. Indeed, that is exactly its purpose. But with each passing generation, a little bit more of the telomere is shaved off, making it shorter.

    - When the telomere is gone, the meaningful genetic information gets ripped off, making it impossible for the cell to do its job because it no longer has the full manual. With the end of the telomere, the cell dies, unable to replace itself through replication. The effects of cell death in the body are the signs we all recognize as aging.

- Telomere length is affected by environment and lifestyle choices. Smoking, emotional stress, and lack of exercise are all associated with shortened telomeres, while regular exercise, a plant-based diet, and stress management are associated with longer telomeres. But even those with longer telomeres still have them shortened over time. Aging and death work at a slower pace, but the process still leads to an inevitable end.

- Although that seems worrisome, it is actually helpful in a sense. Every time a cell divides, there is a chance that the ripping apart of the strands of the DNA will accidentally knock out a rung in the ladder. It gets replaced but not always by the same base. This changes the genetic code.
    - Sometimes, this is not a problem, but sometimes, it means that the newly created DNA gives the wrong instructions to the cell. It turns the cell from a helpful part of the system to a wrench in the system. And as that non-helping cell divides, it creates more copies of itself, crowding out the cells that are supposed to be present. This is cancer.

    - By making sure that the cells divide only a certain number of times, we have an internal means of trying to minimize cancer risk.

- It seems that cancer cells would die when their telomeres run out, but some cancer cells produce their own telomerase, an enzyme that rebuilds the telomeres in cells. The cancer cells replenish themselves, which means that they continue to divide while the healthy cells die out. The result is a tumor that grows until it interferes with the body's functioning.

- Could we beat cancer at its own game? Could we cure cancer by finding a way to make telomerase ineffective, thus making the cancer cells burn themselves out? And in the other direction, could we use telomerase inducers to reverse aging and make our cells—and possibly ourselves—immortal? Research has shown that this seems to be possible in mice.

- We fear death, and as a result, our technology has raised the possibility of avoiding it. But we must ask: Does this possibility rob us of our humanity? Would immortality rob life of meaning or allow us the time to do all we want and, thereby, fully realize the complete potential of our lives?

Suggested Reading

Gervais, *Redefining Death*.

Wisnewski, *Heidegger*.

Questions to Consider

1. Would immortality be desirable if it were possible? Would infinite life lead to infinite human potential, or would it undermine human life?

2. Is a person on life support really still alive, or is he or she more like the cryogenically preserved person who has died but for whom the potential to be brought back to life remains?

Cloning and Identity

Lecture 30

If technology has influenced how we think of death, it has done equally much for how we think of birth. Earliest life has been subject to technology since the use of wet nurses, but it has become so open to manipulation that it is now possible for seven distinct individuals to significantly affect a child's biology and be considered parents. The most radical technology in this field is cloning. Offering us the opportunity of genetic immortality and to bring back extinct species, cloning also seems to have inherent technical problems, producing major genetic flaws and diseases. Is cloning a step too far ethically and technologically, or is it just the next phase in our ability to control life?

Earliest Life Technology

- Contemporary research has shown some interesting effects of breastfeeding. The most notable of these is the jumpstart that the baby's immune system receives from breast milk.
    - The colostrum, the thicker, creamier milk that is produced by mothers in the first days after birth, is high in immunoglobulin A, which is an antibody produced by the blood. Immunoglobulin A is found in the mouth, nose, ears, and any other places where the inside of the body is exposed to the outside environment.

    - Immunoglobulin A is a protein with a y shape; it works by creating a layer of mucus that traps harmful bacteria, and it then uses the ends of the y to bond to the harmful invader. It works as a red flag, identifying the threat and working as a marker for the proper immune cells to come and destroy it.

    - Immunoglobulin A molecules are programmed to recognize specific types of harmful bacteria to which we have been exposed. In transferring immunoglobulin A to a baby through nursing, the mother's biological history is being programmed into the newborn's body.

- As a result of breastfeeding, the newborn can spot, mark, and destroy infectious agents on its own, even though the baby may never have been exposed to the threat. Breastfeeding literally creates a differently functioning body for the baby.

- This leads us to our first question about birth, reality, and technology. Possibly the oldest technology we have used with our youngest children is the wet nurse. New mothers would use the breast milk of other women to feed their own children.
  - We now know that breast milk actually plays a role in how the body functions. Thus, the wet nurse shaped the way a baby's body works, creating an aspect of the newborn's immune system.

  - Given our contemporary understanding of what it means to be a parent, doesn't the wet nurse now count in some small way as one of the parents of the child because the child's body will function and develop in part as a result of the nurse's biological contribution?

In Vitro Fertilization

- With in vitro fertilization (IVF), the sperm of the father and the egg of the mother are combined in a petri dish, then re-implanted in the mother. This process has been a miracle for infertile couples and has given rise to other technological advances. Once it's conceivable to have fertilization outside the body, controls and other possibilities are introduced that were not options before. The most obvious is that the implanted zygote may not include the sperm or egg of the parent or parents who intend to raise the child.

- Sperm donation gives rise to a number of interesting issues. Often, sperm donors are unaware of when, where, or with whom their contribution will be used to create life. This is frequently intentional. The donors can donate without any concern for the ultimate results of their donation. From a purely Darwinian standpoint, this practice is both advantageous and disadvantageous.

- The use of one's DNA in creating multiple offspring with multiple partners without the energy investment of courtship and parenting is a winner from an evolutionary perspective.

- At the same time, however, sperm donation is the ultimate blind date. The donor has no idea about the fitness of the person who will make use of his genetic information. Because survival of the fittest requires not just the most to survive but the most likely to survive, sperm donation ought to seem a bit problematic.

- Further, because the infantile stage in human children is incredibly long, parenting is crucial to our species. But the very notion of sperm donation makes the genetic father absent from the process and leaves him with no confidence that his offspring will successfully reach procreative age in a functional way. The drive is to create not only offspring but offspring who will themselves have offspring. The fact that the donor has no control over this second step is a concern from an evolutionary standpoint.

- We can build on this idea to identify cultural, nonbiological concerns. If a man impregnates a woman in the normal way, there are legal means by which he will be held responsible for the well-being of the child. With sperm donation, however, the genetic father is contractually removed from such obligations. If this removal meets with society's approval, then fathers' obligations to their offspring become contractual rather than care-based.

- This contractual nature also appears in the selection process. At the sperm bank, mothers can browse through lists of possible donors to find ones they deem most genetically desirable. This is simply sexual selection made one step more abstract. But it also makes a commodity out of genetic material and takes a step toward the concern of creating designer babies.

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What the mother eats, how much exercise she gets, even how frequently she laughs—all have subtle effects on the development of the fetus in utero; thus, a surrogate becomes an integral and significant part of the child's bodily functioning.

- Just as the sperm may be donated, so may be the egg. Once the egg is fertilized, it can be implanted. The egg may be from a donor and implanted into the body of the woman seeking to raise the child, or it may be implanted in a surrogate who will then carry the fetus to term and give birth. Although the surrogate may have no genetic influence on the development of the child, she will have considerable effect on its health and well-being long after the birth.

- *Cytoplasmic transfer* is the process of inserting mitochondria from one egg into another. The process is used to correct problems in a woman's eggs if she wants to use her own eggs for IVF.
    - Recall that there are two different kinds of DNA in all cells: the nuclear DNA inside the nucleus of the cell and the mitochondrial DNA outside of it. Although the nuclear DNA is the result of contributions from both parents, the mitochondrial DNA is passed completely from the mother to the child.

- With cytoplasmic transfer, the nuclear DNA is partially from Woman 1 and partially from the father, but the mitochondrial DNA is from Woman 2 (the mitochondrial mother). The availability of this process introduces yet another potential "parent" into the development of a child.

Cloning

- The most radical version of IVF, however, occurs when the genetic code is hollowed out of a donated egg and replaced with another genome; the zygote is then implanted to be brought to term. This procedure is *cloning*.

- When an animal is cloned, the entire internal instruction manual from one being is implanted into the egg of another so that the offspring will be genetically identical to the donor in terms of nuclear DNA. Without a cytoplasmic transfer, the mitochondrial DNA will be that of the egg donor. In this way, the clone will be slightly different on a cellular level than the being that was cloned, but this is not a difference that will express itself in the observable properties of the clone.

- To great fanfare, Dolly the sheep, the first cloned mammal, was born in 1996, and many believed that the age of cloning had begun. But cloning has proven to be much more difficult than scientists originally thought. Only about 3% of cloning experiments succeed, and serious problems are observed in those that are successful. Obesity, enlarged organs, undeveloped lungs, developmental delays, kidney problems, joint and liver issues, and brain and immune system malfunctions have all been observed at significantly higher rates in cloned animals.

- Ordinarily, an egg has months to assimilate its genetic code, but when cloning occurs, a rapid taking in of the DNA by the egg causes problems. The egg gets the new internal instruction manual, but in trying to flip through it much more rapidly than it is programmed to do, pages get ripped out and the instructions are unable to be followed. This may be indicative of the cloning process, or it may just be a technological speed bump that can be navigated.

- Some people contend that even if the wrinkles are ironed out, there is something inherently problematic with cloning. The process removes the chance associated with the combining of genetic information from parents. It refuses unique genetic identity to the offspring, and some believe that we have a right to be genetically unique. To refuse this is to play God in some way, to dictate the terms of life to a being who should have the right to determine his or her own path.

- Although these arguments may or may not be cogent in the end, there remains a most interesting case: What about situations in which humans have made it impossible for some animals to reproduce without our assistance? What about animals that are extinct? If there are animals that are genetically similar enough to animals that have gone extinct, should we use cloning to reintroduce them into the ecosystems in which they had been embedded and which developed to include them?
    - The dodo, the auk, and the wooly mammoth were all hunted by humans to extinction, but the systems of which they were a natural part—their prey, predators, and so on—still exist. Do we owe it to the larger system to replace the part we carelessly subtracted?

    - Do we have a responsibility to restore species and, thereby, complete the deprived ecosystems of their missing parts if we were the ones who caused the destruction? We surely think so when it is simply a matter of conservation, as with the American bison, but is re-creating a species a step too far?

Suggested Reading

Macintosh, *Human Cloning*.

Questions to Consider

1. Given that multiple people who may not be involved in raising a child can participate in creating the child, how much of a parent should we consider donors and surrogates? They not only act to bring about the child but are enshrined in the child's biological state; should they, then, have responsibilities toward the child's well-being after birth? Is it morally appropriate to think of their acts as mere contractual work?

2. Given the effects of environment on epigenetic factors and biography, how similar could we expect clones to really be? If you had yourself cloned, how like you would the clone be? How much has your firsthand experience shaped you, and how much is the result of genes?

Genetic Engineering

Lecture 31

We have long manipulated the genetic code of organisms to our benefit. Champion racehorses are put out to stud because their offspring are more likely to be fast. We have selectively bred myriad kinds of domestic dog. But this is a slow process of breeding members of the same species and hoping for the best. We now have several techniques by which we can take genetic code from the same or radically different species and splice it into the genome of an individual. We can make glow-in-the-dark rabbits, plants that turn red when they detect a land mine, and mice that grow human ears on their backs.

The Beginnings of Genetic Engineering

- In one sense, we have been doing genetic engineering on plants and animals for centuries. We call it selective breeding or, in animals, husbandry. But this process takes time and has limitations. Selective breeding allows us to accentuate properties that occur naturally, but it doesn't allow us to radically alter them or to introduce new aspects. In the field of modern genetic engineering, rather than waiting for random mutations to appear in a population, researchers seek to create particular mutations themselves.

- For centuries, artists have imagined the types of entities they wanted to create in nature. The ancient Greeks, for example, crossed the horse with the bird and got Pegasus. The Europeans put wings on a lizard and created dragons. But this sort of thing was well beyond the capabilities of science until the late 20th century, with the invention of the polymerase chain reaction and the development of recombinant DNA techniques.

- The idea here is that we could create cross-species hybrids if we had a means of cutting and pasting bits of the genetic sequence from one organism's DNA into that of another. In this way, we could begin with the desired portion of the genome of one organism and insert it into another. We can now do this with genes of organisms of the same type, called *cisgenic organisms*. We can also add in genes from quite different sorts of organisms, called *transgenic organisms*.

Bacteriophages

- The first organisms into which we planted *transgenes*, or genes from other life forms, were bacteria. This experiment was undertaken because it had already been done—by nature itself in the form of bacteriophages.

- Bacteriophages are a kind of virus that preys on bacteria. They resemble a lunar landing module with six legs supporting a bulbous pod. The pod is full of DNA. The phage lands on a bacterium and hooks its landing gear into it, then drops the pod, piercing the bacteria's cell wall and injecting its DNA into the cell.

- Some bacteria have two kinds of DNA that are separated in the cell. First, there are the bacterial chromosomes that contain the DNA, with the internal instruction manual for the cell to carry out its basic functions. In addition, there are rings of DNA completely separate from this, called *plasmids*. These code for proteins that may be offensive or defensive; they might have the information for the dirty work that makes the host of the bacterium sick, or they may hold the information for how to fight off antibiotics.

- The reason bacteria develop immunities to antibiotics is that the information about how to neutralize the antibiotic is stored in the plasmids. Because the plasmids are distinct from the bacterial chromosomes, they copy themselves. As such, there may be a number of copies throughout the cell, and they are entirely distinct from cell division. Sometimes, the divided cell splits up the plasmids, sometimes not. As a result, the daughter cells may or may not share the resistances of the progenitor cell.

- The phages inject their DNA into the cell in such a way that it becomes part of the plasmid. The instructions that get inserted are, of course, directions for constructing more phages. The bacterium is tricked into creating multiple copies of its own parasite.

- Eventually, either the phage construction depletes the resources of the host cell, in essence starving the bacterium to death, or so many phages get produced that they explode the bacterium's cell wall. Before antibiotics, phages were the most effective treatment for bacterial diseases.

- If phages can inject their DNA into bacteria, researchers believed that we could do the same. If there was something we wanted the bacterium to do for us, we could copy the process. In this way, we can get bacteria to produce substances that are usually produced by the body.
  - Insulin, created in the human pancreas, allows us to digest sugars. But some people have malfunctioning systems that do not produce enough insulin, resulting in diabetes. We have now been able to do what phages do: take the section of the human gene that contains the instructions for insulin production and inject it into bacteria, thereby creating a low-cost, nonhuman source of a human hormone.

  - We have also been able to modify bacteria to also produce interferon (necessary for immunity) and human growth hormone. We have transgenic bacteria that produce what will hopefully be cures for hepatitis B and Crohn's disease.

Large-Scale Genetic Engineering

- The first step in attempting this same process with large, complex animals is to determine what genes in the two organisms are responsible for the desired and undesired properties. If we want to change the color of an organism, we see what parts of the genome in each is responsible for color. This sort of genetic mapping has been done for decades.

- The second step is trickier. Here, we need to be able to remove just the desired stretch of genetic information from the target DNA. We want to isolate the replacement code to be inserted from the organism whose property we are adding. The DNA molecules in the chromosomes are long strands of base pairs. We need to know exactly where and how to snip the chromosome.

- The key here was the discovery of restriction enzymes. Bacteria use restriction enzymes in their fights with bacteriophages. The restriction enzymes cut up the invader's rogue DNA before it can get inserted into the plasmid. The restriction enzymes find and destroy the stray genetic material, rendering the phage attack harmless.

- The great discovery made by the Nobel Prize–winning microbiologist Hamilton O. Smith was that some restriction enzymes are programmed to cut an invader's DNA only at specific sections. These enzymes are triggered only by particular bits of genetic information. They look for certain sequences of the nucleotides, and when they see a specific pattern, they cut. These enzymes could be used more carefully by us to snip out exactly the segments we want from a given genome.

- Having the gene we want to insert and having the restriction enzymes remove the bit we don't want from the target chromosomes, we now need to get the new DNA into the target. For this, we need to copy it, using the polymerase chain reaction.
    - The polymerase chain reaction is a cyclical process for which the American Kary Mullis received the Nobel Prize. It uses heat to separate the strands of DNA. Next, a primer is added that sticks to the separated strands in a way that creates a template for the reconstruction of the full DNA molecule.

    - A polymerase is added that provides the nucleotides needed to complete the process, and the separated strands are made into two completely different strands of the same DNA.

- The last step is to insert copies of the desired gene into the target genome.
  - The process of cutting target DNA by restriction enzymes leaves a few nucleotides hanging off the end, like a frayed pair of jeans. These unpaired bases protruding from the missing segment of DNA are called the “sticky ends.”

  - We know what bonds with the sticky ends because the bases in DNA pair up specifically; thus, we make sure that the DNA we want to add has the complement of the sticky ends. These bond together, but the result is not quite stable. We need to smooth out the DNA. For this, we use a ligase enzyme, whose purpose is to repair DNA.

- Following these steps, we are able to take genes from anywhere and insert them anywhere else. We can create plants and animals with properties they never would have otherwise had.

Applications of Genetically Engineered Organisms

- Mice make useful models in medical research; they are enough like humans that observing how diseases progress in mice and how medicines affect them allows us to make reasonable inferences about the same factors in humans. Despite these similarities, the poliovirus does not affect mice. But researchers have been able to create transgenic mice with the appropriate genes to make them susceptible to polio, giving us another weapon in the battle to eradicate this disease from the planet.

- We can also use recombinant DNA technology to create transgenic plants and animals that will act as pharmaceutical factories. We can splice into the genome of a banana tree the genes for producing vaccines to protect people from hepatitis B or cholera. We can splice genes into chickens so that the white of the chicken’s eggs contains an antibody that will fight skin cancer.

- Aside from medical uses, we can alter animals to make them more environmentally friendly. For example, we can use recombinant DNA technology to create less flatulent cows, cutting down on the methane they produce, which is one of the leading causes of global warming.

- Genetic engineering technology has also been used with plants. We now have plants that have been engineered to trap more carbon, the idea being that these plants could make some small difference in the fight against climate change. There are also plants whose leaves change color when the plant is exposed to explosive chemicals, allowing the plants to be used to detect land mines.

- Many uses of genetic engineering are commercial. Crops have been genetically altered to make them cheaper to grow. Corn and soybeans have been genetically altered to make them immune to certain herbicides, giving farmers confidence that if they spray their fields with a particular product, it will kill only the weeds, not the crop.

So far, studies have tended to show that genetically modified organisms do not have significant health effects on the population at large.

- With recombinant DNA technology, the genome is opening up as a blank canvas. We can make adjustments that nature would never make and create combinations that nature would never develop. But our ability to make life forms of our own choosing prompts us to ask: If life is the result of natural processes, and we can now use artificial means to create forms with no natural history, is the nature of life itself changed?

Suggested Reading

Mehlman, *Wondergenes*.

Wingerson, *Unnatural Selection*.

Questions to Consider

1. Genetic engineering uncouples the genetic code of an organism from its evolutionary path. Organisms before genetic engineering were all members of a species and came from common ancestors whose traits developed in response to selection pressures. Is it now possible to create animals that have no species?

2. Should genetically modified foods be marked regardless of health effects? Should you be able to choose whether or not to eat genetically modified foods if there is no demonstrated harm to the person eating them?

Medically Enhanced Humans

Lecture 32

We can now use medical technology to reshape ourselves in radical ways, both physically and psychologically. The ability to make these changes affects what we think of as "normal" because abnormalities are correctable through surgery or medicine. We are able to use these technologies not only to cure diseases but also to give ourselves competitive advantages in the marketplace and in sports. Indeed, the existence of medical technologies is leading to the labeling of some traits as medical or psychological disorders rather than aspects of one's personality because of the social disadvantage these traits convey. Does our ability to change ourselves mean that we have done away with what it means to be ourselves?

The Human Condition

- The phrase *the human condition* means that to be human is to be limited, to be confronted with a universe that is more powerful than you and more complex than you could ever understand, yet somehow to live a meaningful life.

- The classical approach to the human condition is to embrace our inherent constraints, to admit that we are but small elements of a larger reality. Then, we construct ourselves as beings whose lives can nonetheless have meaning in spite of or, indeed, because of these limitations. We can transcend ourselves through relationships with others, by alleviating suffering, or through a connection with the divine.

- The contemporary approach to the human condition is different. We are now technological beings. If we are defined by our limitations, then our job is to redefine our own reality, to break down those limitations.

Medical versus Cosmetic Procedures

- We have looked at both chemical and genetic medicine and their ability to make us better but still maintain some unique human identity. We think of surgery and life-support technology as medical because they are used to restore, preserve, or enhance health. But what should we think about using these technologies for "cosmetic" purposes?

- In some cases, the difference between medical and cosmetic procedures is clear. Quadruple bypass surgery is obviously medical, while an injection of Botox to eliminate wrinkles is obviously cosmetic.
  - Optometrists originally used a diluted amount of botulinum toxin to help people who suffer from blepharospasms, uncontrollable twitching of the eyelid. Injection of an infinitesimal amount of the toxin paralyzes the muscles that control the twitching, bringing about relief from the symptom. In the 1980s, plastic surgeons discovered that this same toxin could be used to smooth out wrinkles.

  - The ability to remove signs of aging means that aspects of our bodies that were once unavoidable facts of life became choices. By selecting to have or not have wrinkles, we turn biological processes into fashion. We can now make a cultural statement by allowing our bodies to age naturally or by arresting the appearance of these changes. Experience once implied wisdom, and displays of age gave one respect and standing. But now, displays of youth imply vitality; a different cultural value system is advanced with advancing technology.

- The first move we make in distinguishing medical versus cosmetic procedures is to say that a procedure is medical if it restores something to its natural state and cosmetic if it takes one intentionally out of a natural state. Wrinkles are a natural part of the face; thus, the use of Botox to make one better than natural is cosmetic. But its use to deaden the muscles controlling the eyelids returns the body to its natural state; thus, that treatment is medical.

- The problem here is that sometimes blepharospasms are natural, and sometimes they are brought about by environmental causes. The same is true, of course, of wrinkles. If we try to use natural or unnatural to draw the line, we can't separate the two uses of Botox because wrinkles and eye spasms are equally natural.

- There is, however, a difference. Although both eye spasms and wrinkles may be natural in that they are a part of what nature had in store for a person based on genetics and environment, in one case, the treatment returns the person to a state where he or she can live a normal life, and in the other case, the treatment isn't necessary for living a normal life. Perhaps, then, the difference between medical and cosmetic use is defined by what we mean by *normal*.

- Let's consider another example. Macromastia, abnormal enlargement of the breast tissue, is a medical condition that can result in pain, ulceration of the skin around the breasts, and back problems. Breast reduction surgery for such cases is considered medical.
    - Interestingly, the American Society for Plastic and Reconstructive Surgeons has argued that breast enlargement should be considered medical treatment for micromastia (having small breasts), which can cause psychological or emotional difficulties in some women.

    - The society has justifiably been mocked for this self-serving argument, but it raises a question we need to consider: Should psychological distress or cultural harm be considered in deciding whether something is a disorder that requires a medical response?

Cultural Definitions of *Disorder*

- A more recently classified diagnosis is attention deficit disorder (ADD). Without question, there are physiological reasons that some people have shorter attention spans than others. This in itself has no adverse medical effects. But in a culture that emphasizes schooling of young children in preparation for college attendance, a short attention span can seriously limit an individual's options.

- Knowing that the use of certain amphetamines allows those with shorter attention spans to concentrate better alleviates potential social harm in many cases. The combination of the cultural disadvantage and its ability to be treated has caused us to classify ADD as a recognized disorder requiring a medical response.

- However, there is a great deal of disagreement about ADD. One significant question is this: In what ways is the diagnosis of a disease an objective feature of reality, and in what ways is it determined by cultural and historical factors?

- Another example of this question of objective reality versus a cultural or political matter is the removal of homosexuality from the *Diagnostic and Statistical Manual of Mental Disorders*.
  - This move was political in the sense that it was influenced by a change in beliefs among the community at large, but it was also a reflection of changes in psychology's thinking about the brain and human sexuality. The shift from Freudian and behaviorist views to a more neurologically based picture was a factor.

  - Whether a given person is homosexual is a feature of reality, but whether homosexuality is classified as a disease or a disorder is a matter of politics.

- We create such classifications by considering people's ability to live what we think of as a normal life. We create a notion of what it is to be healthy—to have the physiological conditions for human flourishing—and deviations from this idea are considered situations requiring medical intervention. But this definition—a disorder is something that interferes with the conditions for human flourishing—is cultural.
  - Weber would argue that this definition comes from the Protestant work ethic. In *The Protestant Work Ethic and the Theory of Capitalism*, Weber shows that deeply entrenched in Western thought is the idea that human goodness is equated with the willingness to work hard and to suffer.

    - We see the fingerprints of this cultural value in our notions of disease and disorder. In America, a person is considered "disabled" and eligible for Social Security benefits if he or she is unable to work because of a physical ailment. The ability to be gainfully employed is the defining characteristic of a healthy human body.

    - In this definition, human health is not a feature of the body but a function of humans as relational beings. We are healthy if we can be of use to the economy, and we require medical attention if we cannot.

- The ability to work includes not only physical abilities but emotional and psychological ones, as well. For example, people suffering from clinical depression are unable to interact well with others and suffer a loss of motivation.
    - One of the ways that depression is treated is with selective serotonin reuptake inhibitors (SSRIs). Serotonin is a neurotransmitter that is associated with feelings of well-being. When the body experiences something positive, it releases serotonin, and we enjoy the moment.

    - SSRIs stop the serotonin that was released from being reabsorbed, making us feel happier than we otherwise would. In people who are depressed, the levels of serotonin are diminished, and treatment with SSRIs often brings them more in line with the average.

    - One result is that people on SSRIs are better employees. They do more work, are happier while doing it, and may achieve better outcomes—happier customers, higher sales numbers, and more motivation.

- In his bestselling book *Listening to Prozac*, Dr. Peter Kramer considered a situation in which a patient wasn't depressed but simply shy, which resulted in reduced performance at her job. When she took Prozac, however, she became more assertive, and her job performance improved.
  - In this case, the patient's personality was hampering her ability to work. According to our 21st-century cultural norms, would that make her natural state a disability? Would taking drugs to change her personality be medical or cosmetic?

  - Kramer contends that such use would be cosmetic but argues that it is morally acceptable to use psychoactive substances in a cosmetic way if it serves our desires. We can change our brains by getting additional education if we think that doing so will better serve our life goals. Why, then, can we not also change our brains with medicines to achieve the same end?

- Similar questions arise relating to the use of steroids by athletes.
  - Steroid use doesn't result in instant muscles but allows muscles to heal quicker than they otherwise would. It allows someone who is lifting weights vigorously and usually requires a three-day rest between sessions to be able to lift again in two days; thus, people who use steroids actually work harder than those who don't.

In breaking records, athletes also break the definition of what it is to be human; the human condition is the grappling with our limitations, but athletes strive to make us less limited.

  - If we celebrate people who work the hardest and get the greatest results out of increased dedication and effort, why do we condemn our sports heroes who are found to have used performance-enhancing drugs? We seem to want our sports heroes to extend the bounds of what it is to be human, but we limit their ability to transcend our limitations.

- Our technology has raised the possibility of remaking the human being in radical ways. Should these routes be open to us? Can we use technology to wipe the slate clean and rethink ourselves completely?

Suggested Reading

Kramer, *Listening to Prozac*.

Marschall and Maran, *Pluto Confidential*.

Naam, *More Than Human*.

Rothman, *The Pursuit of Perfection*.

Questions to Consider

1. As society changes, what we consider to be a medical or psychological disorder changes. Are illnesses and disorders really just socially undesirable states, or are they something objective, a problem with biology or neurological makeup that is independent of how the culture wants us to be?

2. If our bodies become a blank canvas that we can use to create the self we want, both in appearance and in psychological proclivities, is there really a self present at all? If we can make ourselves as we want, would the result be a truer instance of ourselves or an inauthentic misrepresentation of who we really are?

Transhumans: Making Living Gods

Lecture 33

It is one thing to use technology to help make us better, but it is a completely different matter when we begin to incorporate technology into our bodies, making us human/technology hybrids, or cyborgs. Researchers have implanted chips in their bodies to enable them to control the computer, lights, and thermostat without touching them. Implanted chips have allowed two people miles away to both experience the same sensations undergone by one of them. Researchers have been able to implant chips into the brains of mice that allow for the insertion or deletion of specific memories. At what point do we lose our humanity if we technologize our senses and brains?

Prosthetic Devices

- For decades, certain individuals have been human/technology hybrids, but traditionally, this was restricted to those who had medical conditions. Pacemakers, for example, are inserted into those with heart problems to check the rhythms of the heart's beating and provide an electrical kick when needed to ensure proper functioning. Prosthetics have been developed for those who were born without limbs that function in the usual way or for those who have lost limbs as a result of accidents or disease.

- In the case of prosthetics, two quite different approaches to design have been developed. One approach is based on the idea of replacement. If a human has lost an arm, we need to restore that arm artificially to bring the individual back as closely as possible to having the bodily experience he or she had before the accident.
    - Many prosthetic arms, for example, included hooks that allow the wearer to pick up objects. The mechanism controlling the hook is engaged by using other functional muscles, such as the shoulder above the limb or the opposite shoulder. Movements on a mechanical or electrical trigger connected to the artificial limb allow the wearer to open and close the hook at will.

- Advances have led to hand-shaped appendages instead of metallic hooks. These are much more complex because they allow a large number of subtle movements, but they require a better triggering system.

- The optimal trigger for the prosthetic, of course, would be the human brain. The greatest advance in replacement prosthetics is to have them connected in such a fashion that they are controlled just as a biological limb would be.

- Targeted muscle reinnervation uses the nerves that are designed to control functions in, say, the hand in order to control the prosthetic. The nerves are connected to the prosthetic in such a way that their electrical signals activate the artificial hand. The artificial hand reacts to thought in almost exactly the way that the biological hand would.

- This replacement approach to prosthetic design is based on the idea that the job of medical technology is to restore functionality in the form of usual human usage.

- However, a second approach to prosthetics takes a different view on the matter. The enhancement approach is based on the view that prosthetics are an opportunity for humans to augment themselves with superior abilities or additional functions. In this view, the human body is not ideal or perfect but is unnecessarily limited, and when we use prosthetics to replace broken parts, we can do so in a way that upgrades the body.
    - Prosthetic legs, it was long thought, should mirror the structure of biological legs. But the American biomedical engineer Van Phillips chose to design a more efficient version. The result was the Flex-Foot Cheetah, a leg with a springy blade design at the foot. These are more efficient than biological limbs and allow for running at speeds and jumping to heights that are beyond the capacity of those without them.

- The idea behind Phillips's approach is that we need to think of humans as detachable from our biologically given bodies.

Human/Technology Hybrids

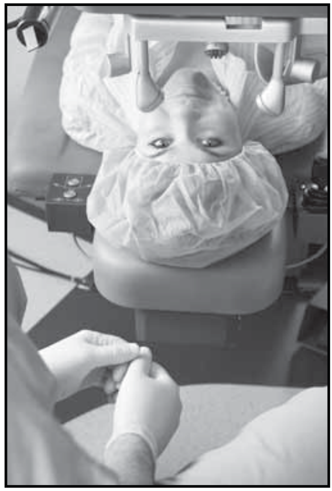
- In recent years, nanotechnologies have opened the door for fascinating applications in human/technology hybrids.
  - For example, nanosensors can be packed into a capsule and swallowed by a patient; they can then transmit details about the person's bodily functions from inside the body.
  - Nanochips may also be used to deliver chemotherapy directly to tumors in patients with cancer. Equipped with lasers, nanochips could eventually be used to conduct surgical procedures inside the body with no need for an incision.
- The British engineer Kevin Warwick had an expanded view of the uses of this new technology. Instead of nanotechnology working independently within the person, his goal was to fully enmesh it into his own body, making his anatomy seamlessly organic and technological.
  - At first, Warwick had a silicon chip transponder—a radiofrequency transmitter—inserted into his arm. He programmed objects in his laboratory, such as the lights, the door, and the computer, to respond to the transmitter, enabling touchless operation.
  - Next, Warwick and his wife had chips inserted into their forearms connected to the nerves used to sense touch. These chips were connected by radio frequency transmitters that communicated with a computer connected to the Internet. When his wife touched something with her hand in one location, Warwick would have the same sensation in another location. The two literally shared sensory experiences of the world from different bodies.

- Warwick then went a step further. He had chips inserted into his forearm, again connecting them to nerve endings that were programmed to respond to outputs from the computer and other electronic devices. When these devices executed various functions, they sent Warwick a signal that registered in his brain through the electrical signal sent into his nerves from the chips. He could not only control the machines from afar, but he could feel what they were doing; they were extensions of his body. In this way, Warwick gave himself a new sense.

Augmenting the Senses

- Some of the most interesting work in creating hybrid biological/technological humans has involved extending the senses we already have. People who wear eyeglasses already use sense-altering technologies. But these days, laser in-situ keratomileusis (LASIK) surgery allows for vision correction without wearing an aid. This surgery can also be used to give people superior vision.

- Other advances allow the human eye to interpret a greater portion of the electromagnetic spectrum. One relatively simple technology for this interpretation is night vision goggles, which use the same techniques cats do for seeing in low light. These techniques increase the amount of light brought in to the eye and increase the range of viable wavelengths. Such capabilities can be built into wearable glasses.



LASIK surgery uses a laser to slice open the cornea and, in many cases, can reshape the eye to restore 20-20 vision; this surgery has also been used by athletes to enhance their vision.

- In the future, we might be able to choose to wear glasses that would let us see as an insect does or wear artificial ears that allow us to hear radio waves. The human brain is incredibly plastic. Not long after wearing these sensory enhancers, we will probably develop the brain structures for interpreting them as naturally as the way we connect with our surroundings now.

- Perhaps the most radical advance in our senses would be computer augmentation.
    - When we see, light passes through the cornea and lens of the eye, is focused on the retina, and is converted into electrical signals sent through the optic nerve to the brain.

    - There, it is processed by several areas that separate out objects, place them in geometric relation, scan them for humans and other recognized objects, compare them with past visual experiences, and store the image in memory. But the memory is flawed. It is limited in how much detail it stores, and we are limited by having access only to our own stores. Further, the memory regularly makes mistakes.

    - All these drawbacks could be helped if the internal brain worked in concert with an external brain to help it interpret what we see. Digital glasses function in two ways: as glasses to see the world and as a monitor for a built-in computer. The computer is connected to a camera that projects content onto the monitor in the glasses. Wearing these glasses, you could search for directions and have a map with street names and directions imposed on the streetscape ahead of you.

Implanting Memories

- We know what we experience and have experienced because we remember it. But we are now arriving at a place where memories themselves can be constructed and implanted or erased. Researchers have recently done both with mice.

- Scientists at MIT have taken DNA from animals whose cells are photosensory—that is, cells that turn light it into electricity—and spliced it into neurons in mice. The researchers could then trigger those specific cells by shining light on them. This made it possible to manipulate specific neuronal function in the mice, for example, memories, because the light shone into the brain would trigger those and only those photosensory cells.

- The researchers could have a mouse experience something in a certain context, say, getting a painful shock immediately after seeing a flash of red light. The mouse remembers the shock when it sees the red light and exhibits behaviors associated with fear. But by getting the right neurons to be photosensitive, researchers could now trigger them, flash the red light, and have the mouse behave with no fear response. The mouse forgets the shock it experienced. That specific memory can be turned on or turned off based on the flashing or non-flashing of the light influencing those brain cells.

- Similarly, and perhaps more frighteningly, researchers have been able to implant a memory in a mouse's brain.
  - Mice were created with certain neurons that could be activated with light signals. These optogenetic mice were put into a black room and allowed to explore. They behaved normally and roamed throughout the room. Then, the mice were put in a red room, where they were given a shock. This created the conditioning that led them to be afraid of the red room when placed there.

  - The mice were later placed back in the black room. Again, they behaved normally until the neurons associated with the conditioned fear response to the red room were activated. Then, the mice behaved exactly as they did in the red room, with a conditioned fear response.

  - The researchers had created in these mice a false memory of having been shocked in the black room, which caused them to behave exactly as they do with authentic memories.

- The hope is that these insights into memory could lead to treatment for people who have undergone traumatic experiences. Other research is exploring the potential of neuroprosthetics to improve or inhibit memory. Some scientists envision *neural dust*, tiny chips that could be spread throughout the brain to record and transmit its activities.

Suggested Reading

Hughes, *Citizen Cyborg*.

Warwick, *I, Cyborg*.

Questions to Consider

1. Is there a difference between taking probiotics to increase the number of good bacteria in the gut in order to achieve better health and using nanosensors to aid in our health? In both cases, we intentionally add something to our systems that we know will make us healthier, but is there a difference if that thing is natural or manmade? Is this situation any different from taking vitamin C from oranges or synthesized vitamin C that was made in a lab?

2. If we can develop technology to implant memories and technologies to send sensory stimulation to someone other than the person who sensed it, could we live someone else's life? Could we feel and think everything another person thinks and feels? If the brains were connected, would the result be two people living the same life or one person with two bodies?

Artificial Intelligence

Lecture 34

Computers can do many things, but can they think? The idea of creating a machine that thinks goes back to the 17th century, with the invention of mechanical calculators. If machines can mirror our logical processes, aren't they thinking? With the move to electronic computers, we have been able to model neural structure and create increasingly more complex algorithms that can beat our best minds at strategic games, such as chess, and make novel scientific discoveries. But do these machines think? What would it mean to have a computer that became sentient, that had an internal life and feelings? Would such a machine become human?

Pre-Electronic Artificial Intelligence

- The idea of artificial intelligence (AI) is interwoven in the contemporary mind with computers, but it pre-dates electronic computing. Possibly the most important name associated with AI is the British mathematician Alan Turing.

- At the beginning of his career, Turing was fascinated by Kurt Gödel's incompleteness theorem.
    - Gödel opposed the logical approach of British philosopher Bertrand Russell, who contended that a mathematical statement is true if it could be proved. But proof must occur within a system; thus, Russell and his former teacher Alfred North Whitehead created what they believed to be the logical foundations on which mathematics could be completely constructed. Gödel showed that Russell's project failed.

    - Gödel determined a method for mapping true sentences about mathematics onto true equations and false sentences about mathematics onto false equations. He then asked what would happen with the sentence "This sentence is not provable." If it is true, then it can't be proven, but if it is false, then it would be provable. It is a contradiction if we adopt Russell's view that mathematical truth and provability are the same thing.

- ○ Because sentences about mathematics are mapped onto mathematical equations, then there would be truths of mathematics that are unprovable. No mathematical system could be both complete—contain all truths—and sound—contain only truths. Gödel showed that logic wasn't enough to justify mathematical truth.

- Turing took Gödel's work and crossed it with what Blaise Pascal and Wilhelm von Leibniz had done in the 17th century with computing machines. Turing believed that if there was a rule, then a machine could be built to follow the rule. In this way, he came up with the idea for what we now know as *Turing machines*.

- If Gödel had succeeded in translating talk about math into mathematical equations and we had machines that could solve mathematical equations, then we could develop machines that could do proofs. On the basis of this reasoning, Turing believed we could have machines do the abstract work for which we think we need human mathematicians.

- Just as this question became interesting, the British declared war on the Germans. The British were able to intercept German radio transmissions, but the Germans had developed the most complex encryption code ever created, the Enigma code. It was widely thought to be unbreakable.

- The code, however, was a translation problem similar to what Turing had seen in Gödel. Turing had worked on the question in terms of abstract machines. All he had to do was actually build one and make it focus on this problem. It was an extremely difficult task, but he built it, and it worked. Turing's machine cracked the German code.

- After the war, Turing reflected on his machine and its ability to run through possibilities, reject incorrect ones, and find the possible right answers. The machine certainly seemed to think as well as a human, indeed, possibly better and faster. This prompted a philosophical question: How will we know when a machine can think?

The Turing Test

- The answer to this question is what is known as the *Turing test*. According to Turing, the true test of AI is to play a sort of game with a computer. A player types questions into a computer and tries to determine whether the responses received come from another human or a computer. If the respondent is a computer but the player is incapable of determining that fact, AI will have been achieved.

- We can never get inside of other people's minds. The only way we know that other humans are people like us is by the way they react to us and to the world. If a machine could do the same, then just as we attribute a mind to other people, we would have to attribute a mind to the machine.

- The first generally accepted passing of the Turing test was ELIZA, a computer program written in 1965 by Joseph Weizenbaum. ELIZA was a complex program that allowed for conversational exchanges in natural language. It was set up to simulate the conversation between a patient and a psychiatrist, and it was so successful that many of those who interacted with ELIZA were convinced that it could not be a computer program.

The Chinese Room

- For many, the Turing test seems insufficient because it looks only at stimulus and response. The American philosopher John Searle reintroduced the mind into the AI question with his famous Chinese room example.

- In this scenario, Bob, who speaks only English, works in a room filled with books. Slips of paper with Chinese writing on them are slid through a slot in the door, and it is Bob's job to write responses. He does this by locating the written Chinese characters in one of the books. The book then tells him what to do; for example: If it is raining, draw this character. Bob writes the appropriate characters on the paper and slips it back through the slot.

- The Chinese speakers who wrote the questions and received answers are engaged in a conversation, but with whom? It's clearly not Bob, who speaks no Chinese. And it seems silly to think that the room understands Chinese because rooms cannot be intelligent.

- Searle uses this example to draw a distinction between strong AI and weak AI. *Strong AI* is intelligence as we experience it internally, that is, having thoughts, feelings, and experiences. *Weak AI* is having a machine that is capable of doing the sorts of things we do with our intelligence, such as solving problems, making discoveries, interacting with the environment, and being strategic.

Achieving Weak AI

- Weak AI has been achieved in many ways. The first major advance was Marvin Minsky's stochastic neural analog reinforcement computer (SNARC). Built in 1951, before digital computers existed, SNARC simulated the behavior of a rat in a maze. Amazingly, this computer could learn and, as a result, alter its search strategy; this was the first major step in creating machines that could think in the weak sense.

- Scientists held two other developments as crucial to fully achieving weak AI. One was successful interaction with an external environment; this was instantiated in terms of the development of a self-driving car and was realized in 2005. The other element is strategic problem solving. Scientists believe that we will have achieved weak AI when a computer can outthink a person in a game of strategy, such as chess.

- ○ End games of chess with specified conditions (such as one player having a king and a pawn and the other having only a king) can be thought of as straightforward logic puzzles. In 1912, the Spanish mathematician and engineer Leonardo Torres y Quevedo created an electromechanical robot that could solve such problems. In 1950, Claude Shannon extended the work to a machine that could play passably well in a variety of end-game scenarios.

- ○ In 1957, the American Alex Bernstein developed the first program to play a complete game. Bernstein, who was both a computer scientist and an accomplished chess player, said that the machine played a legitimate beginner's game with the occasional remarkable move. To reach human expert level, it had quite a way to go.

- ○ The invention of fuzzy logic by the Azerbaijani mathematician Lotfi Zadeh in 1965, along with advancements in the power and speed of computer processors, led to the ability to create improved chess programs. Thus, in 1996, a team from IBM pitted their chess-playing computer, Deep Blue, against a grandmaster and former world champion, Garry Kasparov. Kasparov won the first match, but a year later, Deep Blue was the winner.

Achieving Strong AI

- There is little doubt that weak AI—the ability to learn, strategize, and react to the environment—is well within our grasp. But the question of strong AI remains: Could computers ever become conscious, self-aware beings with their own minds? That is, can we create a nonorganic version of a functioning human brain?

Weak AI allows your smartphone to give you directions, but strong AI—real strategic thought—is demonstrated by outthinking a mind we already know to be strategic.

- The attempts to do this can be traced back to 1943, when Warren McCulloch and Walter Pitts took the simplified view of neurons as switches and showed how one could build something like a Turing machine out of them. If we treat neurons as on/off switches, we can start to think about building simplified brains.

- But neuroscience soon showed us that neurons are much more complicated. Real neurons have multiple dendrites that branch off and create incredibly complex webs of interconnections. Any models we make would have to be intricate neural networks or neural nets. This would require computers much faster and more powerful than anything available, and for quite a while, the project lay dormant. But it was revived in the 1980s when technology made it viable once again.
    - Computer models need to have layers of analysis based on both feedback and feed-forward behaviors. A *feed-forward behavior* occurs when a system responds to a context, in this case, a set of values, by doing something. A *feedback loop* is where an algorithm's output is fed back into the program as input.

    - When a program engages in feed-forward behavior, it acts; then, the feedback behavior takes that action into account in reassessing the situation. In this way, the computer can act and learn from the results of past actions. It can improve itself at tasks.

    - Add to this the ability to perform layers of analysis, and you have the ability to not just judge the likely successfulness of a given act but to come to generalized results about classes of similar acts.

    - Having neural nets that are able to achieve results in different frames—having the ability to achieve what we might think of as different perspectives—may be the gateway to strong AI.

- ○ If intelligence or sentience is an emergent property, then this ability to create neural nets that are capable of working on different levels may be the key to having a machine that is capable of recognizing itself as a thing in the world. It perhaps could lead to self-realization—an artificial consciousness experiencing understanding as we understand it.

Suggested Reading

Warwick, *Artificial Intelligence: The Basics*.

Whitby, *Artificial Intelligence: A Beginner's Guide*.

Suggested Viewing

2001: A Space Odyssey.

Transcendence.

Questions to Consider

1. John Searle distinguishes between weak AI—solving problems, successfully playing strategy games, and interacting with the environment—and strong AI—having an interior life with thoughts and feelings. Weak AI is something we are used to, but will computers ever achieve strong AI?

2. Would strong AI make the computer into a person, with the rights, responsibilities, and privileges we grant to fellow humans?

The Internet and Virtual Reality

Lecture 35

Those who worked on the AI project had the dream of creating an alternative to the human brain, a more powerful thinking machine that could replace us. An alternative vision was the augmentation approach, which moved from huge mainframe computers to smaller microcomputers that would not replace users but increase our abilities to create, organize, and share information. The product of this movement was the Internet, an unregulated network of computers, open to all. The development of the Internet has had stunning effects on contemporary culture, including the creation of a new realm, cyberspace, where people can live other lives that are reflective or completely separate from their everyday lives.

AI versus Microcomputing

- The early proponents of AI saw the need for large computers to model the complexity of the human brain. They also believed that once we achieved AI, we would increase the size of computers. The dream was that someday, we would be able to substitute the artificial brain for the human brain to solve problems quicker and more efficiently, without the potential for human error.

- At the time, there was also a different picture of the future of computing and of humanity. This picture did not encompass big companies, big government, and big computers; indeed, it was exactly the opposite. In this view, the idea was to shrink the computer to give power to people.

- The vision was quite different from that of researchers working on AI. It was not to replace people but to augment them. The technology would not only make each one of us better at being who we are and doing what we strive to do, but it would bring us all together, allowing us to become more interconnected. It would enable us to become a global village of symbiotic communities, lifting us all up as a unified human race in peace and harmony. This vision emerged from the counterculture hippie movement in San Francisco.

Information as a Scientific Concept

- In 1948, Norbert Wiener published the book *Cybernetics: Or, Control and Communication in the Animal and the Machine*. The central insight of the book is that information, rather than energy, is the central notion in all of science.

- In the late 1940s, the idea that energy was at the core of science was based on the fact that energy could be transferred; it was the source of all change. "Doing science" meant finding the equations that govern energy transfer in particular systems and showing how energy creates work, light, order, and life.

- However, in looking at quantum theory and relativity, genetics, behaviorism and social psychology, and the project to create mechanical calculating machines and early robots, Wiener arrived at a different view. He suggested that we could reframe the commonalities of all sciences in terms that are not based on the flow of energy but on the flow of information.
    - If nothing can travel faster than the speed of light, including such physical forces as gravitation, then events at points in space sufficiently separated will not be able to influence each other. Cause and effect, the basic notion underlying all of science, is shown by the theory of relativity to be about communication by signals sent between points in space and time.

    - When spin-correlated particles are removed from each other and the wave function collapses as a result of looking at one of them, how does the other one know what property state to assume? Quantum mechanics is about information.

- Evolution is based on the passing on of genetic information. Consciousness is nothing more than a body's ability to take in information from the environment and to adjust the body's actions as a result. Psychology is about information and communication.

- The same is true of technologies aimed at creating more efficient machines to perform human tasks. We need these machines to be able to monitor themselves and modify what they do as a result.

- Wiener's ideas in *Cybernetics* deeply influenced the group of computer pioneers who gave us the advances that led to the personal computer and the Internet. The main center of this development was in northern California, in the area now known as Silicon Valley. There, the engineer Douglas Engelbart brought together a group of programmers, engineers, and technicians who were influenced both by developments in technology and by the San Francisco Bay–area culture of the late 1960s.

- ARPAnet, the first computer network that became the Internet, was a military-funded project, but many of those who worked on it did so to avoid serving in the Vietnam War. Indeed, many of these engineers and programmers were working on the development of the personal computer to aid the movement to end the war.

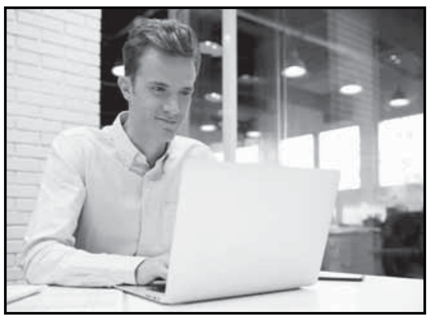
- In addition to Wiener's *Cybernetics*, these computer pioneers read the works of the science fiction writer Robert Heinlein, especially *Stranger in a Strange Land* and *The Moon Is a Harsh Mistress*. These books are notable for Heinlein's weaving together of stories that portrayed a technologically advanced human future that still grappled with social problems similar to those seen in the 1960s. Heinlein's work showed a future in which human abilities were augmented by technology, and it appealed to the anti-authoritarianism that was a significant part of the counterculture movement.

- Another cultural influence was the music scene. Some of the engineers used their technological expertise and equipment to create psychedelic light shows for local rock concerts. Often, the rock musicians would allow their concerts to be recorded by the audience and, later, replicated and distributed.
  - This led to an interesting line of thought: If Wiener is right and everything is information, then everything could be stored on tape, replicated, and distributed. If rock bands were freely allowing the information from their shows to be promulgated, then shouldn't computer data also be free—and freely accessible?

  - In this view, individuals might have their own computers, but they would form a network, a digital commune, with no sense of independent ownership of programs or data.

A New Neighborhood: The Internet

- From this San Francisco–area group of hippie computer pioneers came Apple computers, spreadsheets, word processing, the computer mouse, e-mail, computer music and graphics—everything we now associate with computers. The result is a completely different picture of the world. Indeed, in some ways, the Internet has created a completely new world unto itself. Where the founders hoped it would augment us as real people in the real world, it has actually allowed us to become different people in a different world.



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Although the Internet was conceived of by its founders as being a communal gathering place, it now has online "tribes" with fluid but well-defined hierarchies.

- One of the effects of the Internet is to allow people who are, perhaps, alienated or isolated in their physical space to discover or create online neighborhoods filled with others who are like them. Physically isolated people can find a virtual home, a community that feels comfortable in a way that their actual surroundings do not.

- It's possible to create maps of these neighborhoods, and interestingly, they are quite insular. There are largely self-contained regions of cyberspace where likeminded people link, talk, and refer to others only within their areas of interest. These are intellectually gated communities where users spend time only with people who share their interests and biases.

- One result of this e-balkanization is an increase in *group polarization*.
  - This term describes a phenomenon in which people in a heterogeneous group with differing opinions on a given matter arrive at a moderated consensus. Some people in the group with strong opinions will disagree with one another, but the overall effect will be one of moderation.

  - But in homogenous groups, group sentiment tends toward the extreme, often with the group ending up more extreme than most or all of its members. The resulting positions or decisions will be more risky, excessive, aggressive, or punitive than would be the case if the members were to decide on a given issue before engaging with one another.

  - This has added to a second element of online life: perceived anonymity. One effect of believing that no one knows who you are is *disinhibition*, the idea that when we think we are invisible, we are willing to do things we would never consider doing if we thought people were watching.

  - When we combine online disinhibition with the extremism that comes from group polarization, the results can be disturbing. Indeed, online social interactions are often less civil than those in the face-to-face physical world.

- Another intriguing development on the Internet is the emergence of massively multiplayer online role-playing games, such as World of Warcraft and Guild Wars. In these games, people become characters, meet and interact with others, and work both together and against one another.

- Second Life takes these games one step further. Here, players create avatars, determining every aspect of their online selves, including gender, race, appearance, and behavior. They then inhabit the world of Second Life, interacting with other avatars and knowing them only as who they want to be.
    - Second Life has millions of users who have created electronic versions of everything in this world. There are churches with virtual services, stores where players can shop for virtual items, events and gathering places to visit, and more.

    - Second Life also has an economy. Players have assets and can accumulate debts. They can create goods or exchange services within the game, all of which can be bought and sold. At a certain level, players even own virtual land that they can buy and sell.

    - When we think of the phrase *virtual reality*, what often comes to mind is some sort of goggles or helmet that immerses the wearer in three-dimensional computer-generated graphics. But this is an atomistic picture of virtual reality, one in which an individual person is put in a false world. What we see in Second Life and other online role-playing games is virtual reality in a deeper sense.

- Throughout these lectures, we have seen how views about the nature of reality proceed in a three-step fashion.
    - We begin by thinking of reality as a set of distinct things that we can understand by studying them closely. We then move to the reality of relations among things. This is the step we see with online worlds.

- The third step in understanding reality has always been to move from sets of relations to fields, where what is real is the whole, and the parts are seen as modes of the whole, rather than distinct individuals. This move has been seen as the next step in the development of the Internet.

Suggested Reading

Markoff, *What the Dormouse Said.*

Wiener, *Cybernetics*.

Questions to Consider

1. The early mantra that guided the formulation of the Internet was "Information wants to be free." Given that information is one of the currencies of the Internet, in what ways is this true and in what ways is it not?

2. The rise of social media has seemed to erase any sense of online privacy as people share intimate and mundane details of their every move and every activity. At the same time, the only way that people can maintain separate online and offline lives is behind a shield of privacy. If the online world was completely transparent, then some of the freedoms we enjoy online would not exist. How much privacy should there be with respect to our online lives?

Data Analytics

Lecture 36

In these lectures, we've seen that our picture of reality tends to proceed through a three-step development process. First, we see an atomistic world made up of individual entities. We learn about reality by examining these objects one by one. Then, we move to a relational picture, in which we attribute reality to relations among objects and understand it in the context of those relationships. Finally, we see reality as an interconnected web, in which what is real is the whole, with the seeming individuals being elements of the whole. In this lecture, we'll look at data analytics as the realization of this last step in the realm of technological developments.

Big Data

- With the advent of computers, cell phones, and the Internet, vast amounts of data became available about how people interact in our natural and social environments. And with the increase in processing power, computers could search for relationships that no one would have expected but that were extraordinarily explanatory. This was the birth of predictive analytics, also known as *data mining* and *big data*.

- All major companies now have departments of data analytics to figure out what your purchases mean for them and how they can use this information to get you to spend more money. Police departments and government agencies, phone companies, and Internet search engines all keep tabs on us to collect and analyze data.

- Many of us worry about outsiders reading our e-mail messages or listening in on our phone conversations, but those shouldn't be our concerns. The real information that lets other people know everything about us isn't in what we write or say; that tells others only what we think we'll do. The real truth is in the so-called *metadata*—the when, where, and to whom of our communications. Those facts can tell what we will do even if we don't realize it at the time—and often, we don't.

- Most of us think we are constantly making free choices, but data analytics has shown that we are shockingly predictable.
  - In 2004, 100 students at MIT were given free cell phones on the condition that researchers could keep track of data from the phones. No one would record or listen to the calls or read the text messages, but using GPS and accelerometers, researchers would track users' locations and information about contacts they made.

  - Researchers discovered that by considering only six basic behaviors—termed *eigenbehaviors*—they could predict how a person would behave later in the day with 90% accuracy.

  - By looking at what time users woke up or whether they spent significant time in a place with poor cell phone coverage, researchers could predict, say, who users would spend time with that evening or whether they would sleep somewhere other than their dorm rooms. Such decisions, we would think, are so personal and context dependent that they shouldn't be predictable, but they are—to a shockingly high degree of accuracy.

Metadata

- Metadata can be used for three main functions, the first of which is prediction—how a specific person will behave in the future. This is to some degree a function of personal habits that require keeping track of data on a specific individual, but not always.
  - Facebook used its access to the data of millions of users who announced on the site that they had begun seeing each other romantically to create a profile that predicts when two users will begin a relationship. These predictions are based on how often users visit each other's pages, how often they

leave messages or comments, and when they announce their relationship. Common patterns in these data points repeat themselves almost every time.

- Using metadata, a group of psychologists, neuroscientists, and data analytics experts have developed two video games that give accurate predictions for venture capitalists about the likelihood of success of entrepreneurs proposing new ventures.

- The second function of metadata is diagnosis, that is, giving a description of a person's current state.
  - With wearable monitors that keep track of vital statistics and physical activity, there are ways in which both predilection for disease and evidence of the earliest stages of onset can be determined well before symptoms appear. We can use big data to tell us things about our health that we would otherwise know only much later, often once the condition is more difficult to treat.

Advertisers use data analytics to focus their message to exactly those most likely to be swayed and to do so in the most effective and efficient ways.

  - In addition, there are many interested parties who would like to diagnose us on fronts outside the world of medicine. Advertisers, for example, would like to diagnose individuals to determine if they are in a certain target audience. With this goal in mind, one major retailer used data analytics to diagnose which of its customers was pregnant. The retailer identified 25 products, the purchase of which in various combinations gives a high probability of pregnancy and due date.

- The third function of metadata is forecasting, which provides larger-scale knowledge about social groups.
  - Perhaps the most notable example of data analytics–based forecasting was the joint project among the University of Memphis, the Memphis Police Department, and IBM in developing what was termed Blue CRUSH (criminal reduction utilizing statistical history).

  - By considering crime and arrest data; weather forecasts; economic indicators; maps of occupied, unoccupied, and recently sold housing; calendars of local events and paydays, and several other factors, Blue CRUSH provided Memphis police with unbelievably detailed forecasts about crimes that hadn't yet been committed, predicting them down to the block and to within a four-hour time window.

Data Analytics and Free Will

- The results of data analytics are certainly not failsafe, but the interesting question for us in redefining reality comes from how incredibly successful they actually are: What does it mean that human behavior can be so unbelievably well modeled and predicted with data related to credit card use, cell phone information, and web searches?

- Data analytics experts can determine with great accuracy that you are expecting a child, having an affair, about to have a heart attack, or are part of a terrorist plot based on a digital footprint you don't even know that you are leaving. Is this an affront to free well?

- The fact that your behavior is predictable mean doesn't necessarily mean that you don't choose your actions.
  - Consider mother's intuition—the uncanny ability of mothers to determine when their children are about to do something they shouldn't.

    - This ability of mothers doesn't mean that children aren't free to choose their actions. Rather, it means that the mothers know their children so well that they can predict what the choice will be and can parent in such a way as to try to instill new habits that promote better choices. One can have free will and still be predictable in the way that will is exercised.

- Perhaps the most interesting feature of this discussion is that behaviors are sometimes predictable independent of the individuals involved. The factors and relations that are uncovered using the statistical methods of data analytics show us to be part of a giant web of people, places, and interactions. The determination of our actions isn't based solely on elements of our own profiles but on the interactions we have with others and the properties of their backgrounds.
    - We think that prediction could perhaps follow if we knew everything about someone, but in fact, there are cases where we need to know little if anything to successfully predict future behavior.

    - For example, in the MIT study that kept track of students through the use of their cell phones, some behaviors were shown to be contagious. That is, if a group of students displayed a predictive behavior and another student began to associate with that group, the newcomer would acquire the predictive behavior.

    - It may or may not be true that there are reasons why we do what we do, but there are observable factors that can determine in advance whether or not we will do something, even if we have never done it before. The key is that we become associated with others and, thereby, acquire aspects of them as our own.

Summing Up Our Course

- The central question of this course has been the redefinition of reality as a result of advances in modern science and technology. We have looked at the trajectory of developments in the physical sciences, in the biological and social sciences, and in the development of technology, and in all three, we have discerned a pattern.
    - Our notion of reality begins with an atomistic picture, in which reality is viewed as a collection of discrete objects. Reality is made of pieces, and we learn about reality by looking at each piece, literally or metaphorically, under a microscope.

    - Each time this view was developed, problems emerged because we came to realize that reality isn't well described as an atomistic system. As a result, the picture of reality must be enlarged so that what we held to exist was a set of individuals and their relations.

    - But then in each case, we were forced to make a further generalization, where reality was seen as a unified whole in which the seeming individuals became embedded aspects of a single, coherent, larger existence.

- With advances in data analytics, the combination of social science and technology seems to be forcing us to come to the same conclusions about ourselves and our social world. We aren't the individuals we think we are, living the individual existences we think we are living with our indomitable free will. We know that relationships influence us, but we now may need to take the last holistic step with ourselves: thinking of ourselves as nodes of a larger social web.

- Remember that Einstein won his Nobel Prize for showing that we need to think of light as being both particle and wave. A particle is an entity unto itself, an independently existing thing. A wave is a disturbance in a medium. These seemed to be irreconcilable pictures.

But Einstein showed us that the real world is more complex than our categories, that it had to be a complicated marriage of the two. Perhaps data analytics and our online lives show us the same thing in terms of the self. Perhaps, we, too, are social particles and waves, with a reality as intricate and multifaceted as the world of atoms.

Suggested Reading

Eagle and Greene, *Reality Mining*.

Siegel, *Predictive Analytics*.

Suggested Viewing

Minority Report.

Moneyball.

Questions to Consider

1. If humans are so predictable, does that mean that we do not have free will? Are we just very complicated robots, or do we have free will but choose to use it in entirely uncreative ways? If researchers know that we are going to make a certain decision before we have even considered the question, are we really free to choose?

2. Are we really individuals? Does the effectiveness of data analytics mean that we are just a part of a larger human environment that is embedded in a natural environment? Are we part of a bigger system, or are we our own entities? In the end, what is really real, the thing, the relationships, or the whole?

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