The Information: A History, a Theory, a Flood Study Guide

The Information: A History, a Theory, a Flood by James Gleick

Contents

Plot Summary

"The Information" is an examination of the history of information theory as well as an essay on how computers and the internet have changed the way in which people interact with and approach information. Information now floods our society, Gleick explains, requiring us to filter and search it to find what we want to know.

Gleick traces advances in information technology from the two-tone drums used by sub-Saharan Africans to communicate over long distances through the development of the telegraph, telephone and internet. The author traces the development of the alphabet to represent language and form words and the transformation of the alphabet into codes to make it transferable along telegraph lines.

Alongside these technological developments, the concept of information as a measurable quantity also developed, beginning with the early attempts of Charles Babbage to construct a mechanical machine that would solve mathematical equations. Gleick describes the theories of the American mathematician Claude Shannon, who was among the first thinkers to propose a way to look at information as something apart from the meaning of a message. Gleick finds the influence of Shannon's information theory extending through to modern computing methods.

The concept was so powerful, Gleick explains, that scientists from other fields such as psychology, biology, and physics took it as a model within their own fields. The brain could be imagined as an immense series of binary switches that affected thought and behavior. The human genome was really a code for the construction of an organism and could potentially be deciphered using information theory. In physics, the theory could be applied to infer the states of quantum particles and to examine the nature of space and time.

Gleick also looks at the relationship between language and mathematics, exploring the ideas by thinkers such as Leibniz that complex thoughts could be represented by symbols and calculated. George Boole expanded on this idea and introduced a system of logic that is now used in computer programming. Bertrand Russell constructed a theory of numbers from the ground up that was plagued by the presence of certain paradoxes. Kurt Gödel proved that these paradoxes were necessary.

After a complete discussion of the history of information technology and theory, Gleick turns to the modern flood of information that has resulted. He looks at the rise of Wikipedia, a collaborative encyclopedia that exists only online and the ways in which modern people cope with the glut of available information. Everything is being saved somewhere. It would seem that there is so much information now that it is hopeless to find anything useful or true, but Gleick is optimistic that we will find new ways to search and filter and continue to learn and create.

Prologue and Chapter 1

Prologue and Chapter 1 Summary and Analysis

In the prologue to "The Information," Gleick identifies 1948 as a crucial year in the history of information and computing. It was in 1948 that a group of researchers at Bell Laboratories perfected and named the transistor, a small device intended to replace bulky vacuum tubes. Also in 1948, Claude Shannon, a mathematical researcher at Bell Labs, published an article in the Bell Labs in-house journal called "A Mathematical Theory of Communication." It was this article that introduced the word "bit" into the vocabulary of communications and set the stage for what would come to be known as information theory. At the time, the telephone was the primary means of communication in the United States, but nobody had really thought about how to quantify the amount of communication that took place.

Information came to be considered as something independent of the actual meaning of a message, Gleick explained. He briefly summarizes the development of this idea as it stemmed from Shannon's work. It was found that information theory was not only useful in practical communications, but had applications in psychology, biology, and physics. Information became more and more important and continues to grow in importance today, in an age where we have more information than ever and are sometimes left feeling overwhelmed by it. Gleick presents his intention to trace the growth of both the concept of information and information itself by identifying the key people and thinking that contributed.

Chapter 1 is called "Drums That Talk (When a Code is Not a Code)." While it was well known that sub-Saharan African tribes could communicate over long distances by drum, for a long time nobody bothered to investigate exactly how the communication worked. Finally, in 1949, an English missionary named John Carrington published a short book called "The Talking Drums of Africa." He explained that the language Kele, spoken in what is now Zaire, is a tonal language with the meaning of words depending partly on whether a syllable has a high or a low tone. The two drums used to communicate had similar varying tones, of which one was high and the other low. To communicate by drum, the drummer replicated the tones of speech with the tones of the drums.

This was not sufficient, however, because many words shared the same tones but had different spoken syllables. To differentiate between words, the drummer added short descriptive phrases. The word for "moon" for example was "Songe," which had the same tones as the word "Koko" which meant "fowl." To indicate "moon," the drummer would beat out the tones for the phrase "the moon looks down at the earth" rather than just the single word. Other similar words had contextual phrases added as well. Gleick notes that in classic Greek literature there are similar contextual phrases that are added, which persisted from the time before writing when Greek legends were memorized and spoken. The extra information was in place to help a speaker and listener remember and identify the elements of the language.

In the 1840s, about the same time that Westerners discovered the talking drums of Africa, Samuel Morse was working on the electric telegraph code and the method for efficiently transmitting messages using only a few symbols. After a few experiments with other methods, he eventually hit upon the idea of assigning each number and letter of the alphabet a distinct sign made up from dots and dashes, which were relayed by shorter and longer pulses of electricity over the telegraph wire. This was a different solution to the same problem the Africans had solved on how to communicate over long distances using only basic signals.

Chapter 2

Chapter 2 Summary and Analysis

Chapter 2 is called "The Persistence of the Word (There Is No Dictionary in the Mind)." Prior to the invention of writing and even for a long time after, there was no concept of "looking up" something as we might do in a dictionary or online. Language and the knowledge it described were contained in the mind until the technology of writing became widespread enough that language could be written down.

The earliest known method of writing language was the use of pictures to represent things. These pictures were stylized by the Chinese between 4,500 and 8,000 years ago into a collection of characters which could be combined to create new meanings. The next stage in writing was to use characters to represent phonetic sounds that approximated the spoken language. The last stage in the development of writing was the alphabet.

An alphabet is the "most reductive, the most subversive of all scripts," Gleick writes. (p. 33). It uses one symbol to represent one "minimal sound." All known alphabets are based on the original alphabet that emerged about 1500 B.C. in the Mediterranean region and spread widely.

The introduction of the alphabet and writing changed the way that Western peoples thought about language and knowledge. Oral legends such as those attributed to the Greek poet Homer were now written down. Written language provided a permanence that allowed for literate thinkers such as Plato to construct new philosophies. Aristotle developed a system of logic that would not have been possible without writing.

Mathematics also became possible and Gleick provides examples of early numerical tables created by the Babylonians as well as a Babylonian written formula for building a cistern of a desired size. In these instructions, Gleick sees the first signs of what is now called an algorithm.

Chapter 3

Chapter 3 Summary and Analysis

Chapter 3 is entitled "Two Wordbooks (The Uncertainty in Our Writing, the Inconstancy in Our Letters)." The two wordbooks that Gleick refers to are "A Table Alphabeticall" by Robert Cawdrey, published first in 1604 and the Oxford English Dictionary, which was started in 1879 by James Murray.

Cawdrey's book, as he explained in a subtitle, was to provide the meanings of words that people were likely to encounter so they might better understand them and use them themselves. It was a milestone, Gleick explains. It was the first English dictionary at a time when the language was undergoing rapid change as travel and conquest introduced new words. One of the remarkable things about the book, Gleick points out, is the the 2,500 words in it are arranged alphabetically. This arrangement, taken for granted today, was something so new that Cawdrey felt the need to explain the method to his readers.

Prior to Cawdrey, catalogues and word lists in other languages were usually arranged by topic. A Chinese example grouped characters in categories such as tools, weapons, plants, animals, and buildings. An alphabetical list did not take the meaning of the word into account at all, but mechanically placed it in a slot based on the order of the letters. Words were treated as "tokens," Gleick writes, really no different than numbers.

Gleick moves four hundred years after the publication of Cawdrey's book to the near present to visit John Simpson, the sixth editor of the Oxford English Dictionary. The OED, as it is called, was started by James Murray in 1879 with the intention of cataloguing the entire English language. It was a monumental task that Murray did not live to see completed. Simpson's job, like that of the editors that came before him, was to oversee the continual updating of the dictionary to represent the changing and growing language. These decisions are made based on the printed word, Gleick explains. The OED includes with its definitions examples taken from published sources documenting the use of the word and providing context. Even after a word appears in print, the editors wait several years to determine if the word gains regular usage and then votes on whether to include it as an entry.

The stated purpose of the OED is to document the language, not dictate how it is to be used, Gleick explains. However people have grown accustomed to looking to dictionaries to find a definitive meaning or spelling of a word. Documenting the language has the dual effect of "crystalizing" it at the same time. The job of documentation has been made even more daunting by the spread of the Internet.

The Internet has rapidly increased the rate of new additions to the language, Gleick explains, by allowing for both the widespread broadcasting of information and the facilitation of specialized communication between small groups. It is the first technology that provides such access for all levels of communication. Gleick writes that he intends to examine its rise and the foundation on which it is based, beginning with numbers.

Chapter 4

Chapter 4 Summary and Analysis

Chapter 4 is called "To Throw the Powers of Thought Into Wheel-Work (Lo, the Raptured Arithmatician)." In this chapter, Gleick looks at the career and inventions of Charles Babbage, a brilliant Englishman who lived in the 19th century. Babbage had wide interests, including mathematics, engineering, cryptography, railroads, and industrial machinery.

Babbage was fascinated with compiling information into tables. From his own research, he created statistical lists about livestock, fabric, letter combinations in various languages and other facts. He was also fascinated with machinery.

In the 17th century, a Scotch mathematician named John Napier devised a way to multiply and divide numbers by adding or subtracting their logarithms. Tables were calculated and printed so that a person could easily look up the logarithm of any number. At the time, calculations were performed manually, with ample opportunity for error especially in the more complex operations of multiplication and division. By reducing these complex operations to addition and subtraction, Napier's method cut down on errors and allowed for quicker calculations.

The tables of logarithms had to be calculated themselves, however, and the published tables often had mistakes in them, sometimes from calculations, sometimes printing errors. According to one story, Babbage and a colleague were calculating logarithms when he wondered aloud if it might not be possible to construct a machine that would do the work.

Babbage did construct just such a machine, which he called a difference engine. The difference engine was made up of many specialized brass and pewter gears, wheels and levers, powered by a hand crank. While he received government backing for his project, acceptance of the machine as a practical device was weak. Babbage also quarreled with the engineer who helped him construct it. Babbage began to plan for an even more elaborate machine that would do more than compute numbers but would be able to solve complex equations.

While working on plans for this "analytical engine," Babbage struck an acquaintance with Ada Lovelace, a young woman who was the daughter of Lord Byron, the celebrated poet. Lovelace had a deep understanding of mathematics and was extremely intelligent. The two of the them corresponded over mathematical issues and she offered her opinions and ideas on Babbage's new design. Greatly impressed with her insight, Babbage encouraged Lovelace to publish her mathematical arguments, which she did, although anonymously. It was a time when women were not expected to engage in scientific or academic efforts.

Babbage traveled and lectured about his idea for the more powerful analytical engine, but it was never built. His difference engine was long forgotten after his death, but was rediscovered many years later in the computer age. Babbage has since been recognized as an early pioneer in computing.

Chapter 5

Chapter 5 Summary and Analysis

Chapter 5 is called "A Nervous System for the Earth (What Can One Expect of a Few Wretched Wires)." By the 1840s, the technology of the telegraph was starting to gain a foothold in the larger cities of the world such as New York and London. Electricity was seen as a wondrous force and was little understood at the time, but all kinds of possible uses were imagined after the telegraph became established.

Prior to the electric telegraph, there was the French invention by the same name created by Claude Chappe and his brothers during the French Revolution. These were towers built in the line of sight of other towers with an apparatus at the top with arms that could be arranged into various positions according to a code. Backed by the French government, these telegraphs were built across the whole of France in a network, allowing messages to be passed from station to station. They worked as long as weather conditions were clear, but in rain or fog that obscured the line of sight, communication was disrupted. Passing the message between so many operators also introduced errors such as in the children's game of "telephone."

Electricity opened up a new field of possibility in communication. Wires were more reliable than the visual telegraph system that depended on weather and several inventors came up with devices that would turn the electric current into readable signals. Gleick describes some of these early and complicated devices that used bubbling gasses, magnetic needles, and other methods for sending messages over electric wires.

Samuel Morse and Alfred Vail finally hit upon a system that was based on opening and closing the electric circuit, which was used to control a relay switch at the receiving end. Morse created an alphabet code made up of short pulses, called dots, and long pulses, called dashes, with each letter and number represented by a unique combination. Looking at the arrangement of type in a printer's type case, he determined what he thought were the most common letters in English and gave these shorter combinations in order to make the transmission of messages shorter and more efficient.

The telegraph had a widespread effect on society, Gleick explains. Businessmen quickly realized the advantage of being able to transmit orders quickly over long distances and to receive market information from far points. It led to advances in weather forecasting as people began to realize through quick communication the larger patterns of weather.

The technology was so new that many people did not understand exactly how it worked. Gleick relates a story of a woman in Germany who had heard of troops being sent to the front "by telegraph" and asked an operator to send a dish of sauerkraut to her son over the telegraph. One man in a telegraph office in Maine wrote out the message he wanted to send on a paper. The operator transmitted the message and then put the paper on a hook on the wall. The man argued with the operator that his message had not been sent because he could see it still hanging there on the wall.

Gleick points out that before the telegraph, there was no separation on most people's minds between a written message and the physical form it took. Like the man in Maine, people thought of a message as a physical thing. The telegraph extracted the meaning from a message and turned it into its most basic elements, its letters, then transformed those letters into electric impulses. The information was separate from the physical writing.

Telegraph messages were priced by the number of words and regular users soon realized they could save money by compressing their messages. Another method to shorten messages and also to ensure privacy was for the sender and receiver to use prearranged codes. Businesses would issue code books to their representatives with commonly used phrases represented by short words. This removed the meaning of the message one more step away from the actual impulses sent over the wire.

A new interest in cryptography arose following the rise of the telegraph, Gleick explains. Words and letters could be replaced by symbols or other words and letters to conceal the meaning of a message or to make it more efficient to transmit. A mathematician named George Boole took this concept even further and proposed that complex thoughts and relationships between things could be represented by symbols and manipulated like any other mathematical symbols to create a logical representation of thought. Boole's system, which came to be called Boolean logic, was to become an important part of the development of computers.

Chapter 6

Chapter 6 Summary and Analysis

Chapter 6 is called "New Wires, New Logic (No Other Thing Is More Enswathed in the Unknown)." The chapter outlines some of the first steps in creating a formal system that merged mathematics and logic.

Claude Shannon was a brilliant young man who grew up fascinated with cryptograms. After studying electrical engineering, he took a position at the Massachusetts Institute of Technology working for Vannevar Bush who had created a "Differential Analyzer." This was a machine similar to the one that Charles Babbage had envisioned, which used mechanical methods to solve complex equations. Shannon learned a good deal about the relay switches that were part of the analyzer and used them as the subject of a graduate paper in which he applied the binary logic of George Boole to a system of relays. Relay switches can either be open or closed. They have two possible states, which Shannon represented as 0 and 1.

Bertrand Russell and Alfred North Whitehead were mathematicians who attempted to construct a complete system of mathematical logic from basic principles. The work they produced was a classic in mathematics called Principia Mathematica. By introducing a formal system of proofs and integrating concepts from formal logic, Principia Mathematica aimed to describe a complete system that could be used to prove or disprove any statement. One problem faced by Russell and Whitehead, however, was that their system sometimes led to apparent paradoxes. Statements such as "This statement is false" could not be addressed in the logic of Principia Mathematica, for example. If the statement is true, then it must be false, but if it is false, then it must be true. Statements like this that refer to themselves are called "recursive." Russell addressed the problem of these recursive paradoxes by simply making them against the rules of his formal system.

A young mathematician named Kurt Gödel was excited by Russell's concept of a complete formal system, but felt that ruling out the possibility of paradoxes was not an elegant solution. He formulated a proof that showed that such paradoxes would exist in any formal system of logic. There were statements, Gödel showed, that could never be proved and could never be disproved.

The time was now the 1930s and the telephone had replaced the telegraph as the height of communication technology. The telephone had several advantages over the telegraph. It was easier to use, as no encoding of the message was required, and its availability grew rapidly. To handle the increasing amount of telephone traffic, switchboards that were operated mainly by women handled the connections between callers. The next stage in handling telephone traffic was to partially automate the system using relay switches that were operated by impulses that represented unique numbers. This was the birth of the telephone number.

Telephone callers were used to a certain amount of "noise" on the line as they talked. Crackling and popping were a result of external effects on the electric lines as well as fluctuations and imperfections in the signal. A man named Harry Nyquist, who worked for Bell Laboratories began to examine the noise in the 1920s and developed a theory that predicted the maximum amount of signal that could be transmitted over a medium of a certain size. Although he did not use the word "bandwidth," Gleick explains, this is the concept that he had started to define.

Nyquist's approach to the problem of noise on telephone lines drew the attention of Claude Shannon. Nyquist's theory did not depend on the actual message being spoken over the telephone. It simply separated the meaningful part of the signal from the "noisy" part of the signal. This was an important early shift in the way information was thought of, Gleick argues, and set the stage for Claude Shannon's information theory.

Chapter 7

Chapter 7 Summary and Analysis

Chapter 7 is called "Information Theory (All I'm After Is Just a Mundane Brain)." During World War II both Claude Shannon and Alan Turing were working on separate cryptography projects. Although they could not speak to each other about their secret work, they often met and talked about ideas that had arisen from their work, including the question of whether it might be possible to create a machine that could think. In defining the question, Turing said he was not interested in trying to find a machine that could approach the intelligence of a human, but simply a "mundane brain."

Turing began to write about an imaginary machine that could process information. His machine consisted of an infinite tape made up of individual squares and a machine that could read the tape and act on the information on it. Each square would have either a 0 or a 1 in it and one square would be in the machine at a time. The machine would have "states" that directed it to perform an operation based on the information it read. It could move left, move right, print, erase, or change states. The states would be indicated in a table of instructions for the machine to follow. In essence, the machine was a programmable computer, Gleick explains. Turing had reduced the logic of thought into its basic elements.

Shannon had been working on defining information in a similar way. He coined the term "information theory" in a secret paper he wrote while working on cryptography. Later he published an article in the journal of Bell Laboratories, where he worked, entitled, "A Mathematical Theory of Communication."

Shannon began with a simple model for communication. At one end was the information source which gave a message to a transmitter, which produced a signal. At the other end was a receiver that received the signal and delivered the message to the destination. In between the transmitter and the receiver was a noise source that affected the information.

Shannon proposed overcoming this noise by using extra symbols to correct errors, much in the way the African drummers used extra beats to provide context for their messages, Gleick explains. Doing this meant looking at language in terms of probability. In English, some letters appear more often than others. The letter E is much more common than the letter Q for example and thus more likely to occur in a message. There are also two letter combinations that are more common than others. In most English words the letter Q is followed by a U, for example. When a Q occurs, there is a very high probability that the next letter will be a U and a very low probability that it will be something else. Looking at the combination "qu" for its information content, the U is really extra. The information is held in the Q.

By examining the statistical makeup of English, Shannon was able to determine how much of a typical message was useful information and how much was extra. He devised a way to measure the amount of information in a message, expressed in a new unit he called "bits." By measuring information in bits, he could theoretically compute the maximum amount of information that could be transmitted through a given channel. He also showed that it was theoretically possible to overcome any amount of signal noise by sending corrective bits of information.

A bit was simply the smallest amount of useful information. It was a coin toss of a zero or a one. Shannon imagined that a machine might be created that could represent bits of information using a relay switch that was either open or shut. His idea was only a theory at this time, Gleick explains, but the technology that would make it practical was soon to arrive in the form of the transistor.

Chapter 8

Chapter 8 Summary and Analysis

Chapter 8 is called "The Informational Turn (The Basic Ingredient in Building a Mind)." Shannon's information theory drew little attention at first, but received some note in scientific and philosophical journals. One review was written by a man named Norbert Weiner, who claimed that he had developed a similar theory independently of Shannon. In Weiner's view, the theory had implications for the understanding of the human nervous system which might be thought of as a system of switches and signals.

Weiner produced a book in 1948 that coined a new word, "cybernetics" by which he meant a philosophical field that studied communication and control as well as the relationship between humans and machines. Weiner's book was a collection of philosophical musings, Gleick explains, but it came at a time when the first large computers were being unveiled after World War II and curiosity about them was peaking. The book became a best seller.

Both Weiner and Shannon were among a group of scientists from all disciplines who were invited to attend and present a series of talks given at a New York City hotel. Shannon fascinated the group with a presentation of his theory and the idea that English has a specific "entropy." By "entropy," Shannon referred to the predictable redundancy of a language, like the meaningless U after a Q in the earlier example. He claimed that this entropy could be computed.

At one of these gatherings, Shannon arrived with a robot. It was a device that used relay switches as a logic processor and learned to navigate a maze by trial and error. Once it learned the maze, it could be placed back at the beginning and it would travel through it without any mistakes. Shannon used his information theory to create other devices that could solve specific problems and he set his mind to imagining a machine that could be taught to play chess. The technology at the time was such that he soon realized that using only relay switches it would take an impossibly long time to teach such a machine all the possible combinations and moves in a chess game, but it was theoretically possible.

Meanwhile, scientists from other disciplines were grabbing on to Shannon's ideas and applying them to their own fields. A psychologist named George Miller had already noticed that people seem to be able to easily remember up to seven items at a time, such as the digits in a phone number. Beyond seven items, people made mistakes in memory. There seemed to be a limit to the amount of information and that limit could be measured using information theory. While seven items seemed to be a limit on short term memory, people can also recall thousands of faces and words and can memorize long passages, so it seemed to Miller that some kind of simplification of information was taking place in the mind. Information theory addressed this as well. Soon physicists and biologists would find that information theory and the idea of entropy had applications in their fields as well.

Chapter 9

Chapter 9 Summary and Analysis

Chapter 9 is called "Entropy and Its Demons (You Cannot Stir Things Apart)." "Entropy" was a term that was not widely understood when Shannon used it in his theory of information. The word had first been used in thermodynamics to describe the availability of energy in a system. A closed system made up of a hot part and a cold part would eventually reach an equilibrium as the heat passed from the hot part to the cold part. As the energy moved from one part to another, it had the potential to do work, but once everything became the same temperature, no work could be done. "Entropy" was first used by Rudolf Clausius in 1865 to describe this unavailability of energy.

James Clerk Maxwell suggested that the meaning of the word be reversed, to describe instead the part of energy which was available to be converted into work, but later agreed with Clausius' usage. "Entropy was not a kind of energy or an amount of energy," Gleick writes (p. 271). It was instead an abstract measurement of the unavailability of energy.

The study of thermodynamics had noted that energy seemed to travel in one direction. Heat could travel from a hot thing to a cold thing, but not the other way around. It was not impossible for heat to travel in the opposite direction, just very improbable. The most probable state for an arrangement of molecules in a system is in a jumble and the least probable is that they will be highly ordered, with, say, all the hot molecules on one side and all the cold molecules on the other. A highly ordered state has a higher availability of energy and thus low entropy. It was realized that entropy was a "physical equivalent of probability" (p. 275). It reflected the uncertainty of a given state.

Shannon used the same word to mean the uncertainty about a message. Erwin Schrodinger used the concept to describe living organisms, which create orderliness out of a disorderly world in apparent contradiction to the laws of thermodynamics. Living organisms escape entropy.

Chapter 10

Chapter 10 Summary and Analysis

In Chapter 10, called "Life's Own Code (The Organism Is Written in the Egg)," Gleick explains how information theory came to play a role in the modern understanding of genetics. The existence of the "gene" as a basic element of genetics had been theorized before the mechanics of genetic reproduction was fully understood, Gleick writes. It had long been noted that physical traits were inheritable and that they had something to do with the chromosomes, which had been examined. Schrodinger and others theorized that genes were a kind of code for constructing an organism and went looking for insight into how many there might be and how they might actually work.

In 1953, James Watson and Francis Crick published their now famous paper in which they describe their discovery of the role of deoxyribonucleic acid, or DNA, a substance that was found within the cells of every living thing. The acid was made up of four different nucleotides, each represented by a letter. These elements came in predictable proportions in the shape of a double helix, which allowed it to split and replicate.

A cosmologist named George Gamow immediately recognized that DNA was a code and proposed that it could be deciphered mathematically. It was information, passed from generation to generation. Genes, it was theorized, were not something physcially separate from DNA, but were given sections of this code that were expressed in certain ways.

DNA forced molecular and evolutionary biologists together, Gleick explains, resulting in some interesting ideas. One was that of Richard Dawkins, a zoologist. Dawkins turned evolution around and proposed that DNA was the source of life. Organisms had not evolved DNA since DNA had evolved organisms as a way to more effectively replicate itself. Humans, he wrote in a book in 1976 called "The Selfish Gene," are "survival machines - robot vehicles blindly programmed to preserve the selfish molecules known as genes." (p. 301). Genes were thus simply information. They were not physical particles or elements. They were made of bits.

Chapter 11

Chapter 11 Summary and Analysis

Chapter 11 is called "Into the Meme Pool (You Parasitize My Brain)." One of the concepts that Dawkins proposed in "The Selfish Gene" is the idea of a meme. Memes take many forms, but are ideas or other bits of information that pass from person to person and are replicated through imitation.

Gleick gives some examples of memes. They might be ideas. Dawkins suggested that the belief in God is a meme that has survived by replication for many generations. Tunes might be memes, such as the opening bars of Beethoven's Fifth Symphony. Catchphrases like "Survival of the fittest" and "Read my lips" are memes. Images can be memes, too, such as the Mona Lisa.

Memes can mutate and be manipulated, Gleick explains, but they are messages that are independent of the people who propogate them. With the Internet, they are stored in databases and preserved and passed along. It would seem, Gleick suggests, that memes, perhaps like genes, are the master and the humans who propagate them the slaves.

Chapter 12

Chapter 12 Summary and Analysis

Chapter 12 is called "The Sense of Randomness (In a State of Sin)." Much of the chapter discusses the work of Gregory Chaitin, a mathematician who was fascinated with Gödel's proof that all formal logic systems must be incomplete, which Gleick explained in Chapter 6. Chaitin was also familiar with Shannon's work on information theory and his concept of entropy as uncertainty. He proposed that the concept was related to what mathematicians called randomness in numbers.

Random is a word that everyone seems to understand, Gleick writes, but he asks what it truly means. A number may appear to be random to one person, but another might recognize a pattern in it or devise a way that the number could be calculated. Certainly random numbers could not be based on the knowledge of the observer, Chaitin proposed. He defined random numbers as numbers that could not be computed.

By a "computable" number, Chaitin meant a number that could be expressed in a simpler form by use of a Turing machine. This theoretical machine could be given instructions, for example, to "print 45 and repeat it one hundred times" resulting in an integer of two hundred digits. The number can be compressed into an algorithm, which is a set of instructions for arriving at a certain result. To be computable, however, it must have an algorithm that is smaller, in bits, than the number itself. The size of the algorithm indicated the "complexity" of the number.

Chaitin determined that most numbers are not computable. There were simply far too many positive integers for there to be enough algorithms to describe them. Furthermore, while it might be possible to prove that a given number is computable, it might not be possible to prove that a number is incomputable, or truly random. A stream of numbers that looks "chaotic" may in fact have a simple algorithm, but it may be impossible to work backward from the number to discover it.

Chaitin also concluded that complexity, based on the size of the algorithm to compute a number, was the same thing as entropy in thermodynamics. He had made a crucial connection between the two fields and contributed to the study of unpredictable dynamical systems in physics.

The amount of information in a message can be expressed by the algorithm that produces it, Gleick explains. In a message that is made up of a string of bits, each bit can be either a 0 or a 1. A simple algorithm might be "print 1 followed by 0 and repeat it 50 times" The result is a long string, but the amount of information is actually very small. At the other end of the scale of complexity is a string that is infinitely long where each bit is determined by a random coin flip. This has the maximum amount of information, but is essentially meaningless.

In the real world, Gleick explains, messages that are truly interesting lie in the middle of the range of complexity. He gives the example of a piece of music written by Bach that has several short passages that are repeated and layered over one another. There is a simple pattern that contains relatively little information, but it is arranged in a surprising way that becomes interesting and meaningful. "Everything we care about lies somewhere in the middle, where pattern and randomness interlace," Gleick writes. (p. 353). As an IBM researcher named Charles Bennet wrote in the 1980s, the amount of information in a message is actually not a good measurement of the message's meaningfulness.

Bennet also suggested that complexity include the amount of work required to create information. Up to this point, Gleick explains, information processing was though to be "free." The Turing machine, for example, existed only in though and had a limitless amount of energy. Gleick examines the physical nature of information in the following chapter.

Chapter 13

Chapter 13 Summary and Analysis

Chapter 13 is called "Information Is Physical (It from Bit)." The main title is in reference to a work by Rolf Landauer in which he examined the formula by John von Neumann that described the energy cost of information processing. Von Neumann had theorized that every operation on a bit cost energy. Landauer proved this was incorrect. Flipping a bit from one state to another did not change the entropy, and so had no cost in energy, Landauer showed. Charles Bennet, based on Landauer's theory, showed it was only when information was erased that entropy was changed and heat was dissipated.

This connection of information with entropy and the physical realm proved to have applications in quantum physics. Charles Bennet went on to design a method for passing information using qubits, or quantum bits. A problem in quantum mechanics is that the act of observing a particle interferes with the behavior of the particle. The exact properties of a quantum particle cannot be known, so physicists think of them in terms of probability. Until they are observed, they exist in a cloud of probable states all at once.

This has presented the possibility of using quantum particles in the place of bits in a quantum computer that can have many states at once. It is only a dream at this point, Gleick explains, but the theory is solid. Early experiments have shown that entangled particles, which are particles that are mysteriously linked to one another even over long distances, can be used to send information.

Chapter 14

Chapter 14 Summary and Analysis

Chapter 14 is called "After the Flood (A Great Album of Babel)." Gleick makes reference to a story by Jorge Luis Borges that imagines a "Library of Babel" that encompasses everything in the universe. Everything that has ever been written or uttered exists in this library and is preserved.

Gleick compares the concept with the flood of information that has washed over the world since the rise of the Internet. He describes the famous library at Alexandria, which once held writing from all over the known world but was burned when Alexandria was conquered. He sees a modern comparison to the online encyclopedia Wikipedia, which differs from previous printed encyclopedias not only in that it does not exist in physical printed form, but in that it is collaborative and descriptive, not authoritative as, for instance, the Encyclopedia Brittanica intended to be.

There is an expectation today that all information should be preserved, Gleick argues, which has magnified the amount of information available by a huge amount. It is natural, he claims, that people should start to think of the universe as a computer itself, and from there to wonder how much information it contains. Gleick ends the chapter with some numbers offered by Seth Lloyd, a quantum engineer at MIT, who estimates that based on the speed of light and the age of the universe, the universe has performed something like 10 to the 120th power "operations" and holds around 10 to the 90th power bits.

Chapter 15 and Epilogue

Chapter 15 and Epilogue Summary and Analysis

Chapter 15 is called "New News Every Day (And Such Like)." With the flood of information comes information overload, Gleick writes. It is not a new concept. He quotes from the 17th-century scholar Robert Burton who felt overwhelmed by the amount of news he received every day. The sheer amount of information and the speed at which it travels now is remarkable and presents the problem of finding what is useful among the flood.

We have developed two main strategies for coping with the flood, Gleick explains, filtering and searching. Without indexing that allows for searching, the Internet is just a jumble like unshelved library books. This has fundamentally disrupted the way in which information was organized, he argues.

The Epilogue is subtitled "The Return of Meaning." In it, Gleick presents his optimistic view of the future regarding information. He briefly reviews the history of information as he has presented it and points out how Claude Shannon's theory had to separate all meaning from information in order to treat it as an entity in itself. While this allowed eventually for the enormous expansion in the use of computers, which led to networking and the establishment of the Internet, it was disheartening to think that meaning had become cheapened or somehow made irrelevant.

Tremendous gains in search technology have brought meaning back into our relationship with this flood of information, Gleick argues. Whereas in 1994, search engines would often "time out" on large searches or direct the user to change their search terms to avoid lengthy searches, Google now handles enormous amounts of information that has been automatically ranked for its relevance. The open, collaborative nature of the Internet makes it possible for everyone to act as "librarian" to this new universal library. We have become "creatures of information," Gleick concludes, but we have the tools and capability to take control of it.

Characters

Claude Shannon

Claude Shannon was a mathematician and engineer who worked at Bell Labs in the mid 20th century. He was born in 1916 in Michigan and studied electrical engineering at the University of Michigan, followed by electrical engineering and mathematics at the Massachusetts Institute of Technology. During World War II, Shannon worked on secret cryptography projects for the US government. While he was working on these projects that he first conceived of a way to describe information as an entity separate from the meaning of a message. He developed the idea of the "bit," the smallest particle of information. A bit could have one of two states, which he presented as 0 and 1. He also equated the amount of information in a message with the amount of entropy or uncertainty in the message. By reducing information to its elemental form, he opened up a new field of scientific inquiry that proved to have applications not only in communications, but also in mathematics, thermodynamics, quantum physics, psychology and molecular biology. Shannon devised a simple robot that used relay switches in a logical circuit to learn a maze and then repeat a path through it. He envisioned the possibility of computers complex enough to solve the game of chess and beat a human player, but using the technology at the time it would have required an impossible amount of time to calculate its moves.

Charles Babbage

Charles Babbage was an English inventor and mathematician born in 1791. He was a brilliant child and attended Cambridge University, where he became dissatisfied with a math department that had not moved beyond Isaac Newton's calculus. Babbage was fascinated with math as well as with machinery. According to one perhaps legendary story, he was toiling away with a fellow student computing logarithms when he wondered aloud if it might not be possible to create a machine that would generate them automatically.

Babbage designed and built just such a machine, which he called a difference engine, with the financial backing of the British government. The project became drawn out however, and Babbage had disputes with the engineer who had helped him design the machine. He turned his thoughts to an even more elaborate machine, an analytical engine, that would use the same principles but be able to solve different kinds of equations. He never built the analytical engine, but fully described it, inspiring other mathematicians like Ada Lovelace to theorize on the potential of such a machine.

Babbage's contribution to information theory and the modern computer were recognized long after his death. in his lifetime, only a few people recognized that he had made important strides in the way information is thought of.

Alan Turing

Alan Turing was a contemporary and friend of Claude Shannon. Like Shannon, he worked on cryptography projects during World War II and thought deeply about information and how it was processed. Turing developed an imaginary machine for processing bits of information on an infinite tape using a few possible operations and following a set of instructions. While he did not use the same terms, his machine worked very similarly to the way a programmable computer now works with memory and an encoded program.Turing used this imaginary machine to prove that most numbers are uncomputable.

Ada Lovelace

Ada Lovelace was the daughter of the famous poet Lord Byron, although this fact was kept from her as a child. She showed an early fascination with mathematics and a great ability at grasping difficult mathematical concepts. She was a friend and correspondent of Charles Babbage and at his urging, she published some of her writing on mathematics anonymously at a time when women were not expected to be able to contribute to academic endeavors. She died at a young age from illness.

Isaac Newton

Isaac Newton was an English scientist who developed a system of describing gravity and the physical world. He also devised calculus as a method of measuring change over time. Newton's method of calculus was still the preferred method taught at Cambridge University when Charles Babbage attended, but younger serious mathematicians like Babbage preferred the version invented at the same time as Newton by Gottfried Wilhelm Leibniz.

Gottfried Wilhelm Leibniz

Leibniz is a German philosopher and mathematician who invented calculus at the same time as Isaac Newton. Leibniz also wrote about the nature of language and how words and names can be organized, which Gleick connects to early thinking on information theory.

James Clerk Maxwell

Maxwell is a a scientist well known for what came to be called "Maxwell's Demon," an imaginary intelligent creature that could sort molecules, creating order from disorder.

Bertrand Russell

He is a mathematician who wrote Principia Mathematica with co-author Alfred North Whitehead. This system was a formal system of mathematics built upon basic principles and with a formal logic of proof. Russell's system led to some troubling paradoxes, which were later proved to be inevitable by Kurt Gödel.

Kurt Gödel

He is a mathematician who proved that no formal system of logic could be complete.

Albert Einstein

He is a well known physicist who was troubled by the theory of quantum mechanics, which relied on probabilities. "God does not play dice with the universe," Einstein once said in regard to quantum physics.

Robert Cawdrey

Little is known of Cawdrey or his life, Gleick explains, but he was the 17th-century author of the first English dictionary. His dictionary was also remarkable because it arranged its entries in alphabetical order. This marked a change in the way in which words were thought of, Gleick explains.

Objects/Places

Information

Information is the central subject of "The Information" and it is shown to have a wide-ranging meaning. In the way that information is defined by pioneer information theorist Claude Shannon, information is not the same as meaning. The meaning of a message is separate from the letters or coded signals used to transmit it. Shannon reduced information to its pure signals and developed the concept of a basic unit of information called the bit.

Difference Engine

This is an invention of Charles Babbage that used mechanical wheels, gears, and levers to calculate logarithms.

Analytical Engine

This is a more complex version of Babbage's difference engine that was meant to perform more complex functions. Babbage never built the machine.

Turing Machine

This is an imaginary machine theorized by Alan Turing that processed information based on a set of simple operations and a table of instructions. A theoretical version of a very simple computer.

Maxwell's Demon

This is an imaginary intelligent being that could sort molecules based on some criterion and create order out of a disorderly system.

Entropy

This is the measurement of unavailable energy in a system. Entropy was also shown to be correlated to the amount of information in a message.

Wikipedia

This is a collaborative online encyclopedia that anyone is allowed to add to and edit.

Google

This is a search engine that ranks the importance of search results based partly on how many other links are connected to them.

Relay

This is a kind of electrical switch that can be used to control an electronic circuit. Relays were used in the earliest logic circuits.

Bit

This is the smallest amount of information. A bit can have one of two states, on or off, 0 or 1, etc.

Themes

Entropy

The concept of entropy is one that runs throughout "The Information" and ties information theory to the fields of mathematics, quantum physics, and molecular biology. It is a complex concept and one that Gleick tries to explain in detail.

The term was first used in reference to thermodynamics in the 19th century, Gleick explains. It was noticed that if a hot object was placed next to a cooler object, the heat would move from the hot object toward the cold. As energy moved, it provided potential to do work similar to when steam was released. Eventually, in any closed system, the temperature would stabilize and no energy was available to do any work. Entropy was a term used to refer to this unavailability of energy. A stable system had maximum entropy.

This tendency for energy to move in a certain direction was then defined in terms of probability. It was not impossible for a system to exist with all its hot molecules on one side and all its cold molecules on the other. It was just highly unlikely. Highly ordered systems, which had low entropy, were improbable.

This concept was seen also to describe information. Gleick gives the example of a string of numbers. A highly ordered string of numbers, such as 01010101, does not provide much information. It has an orderly pattern that can be described as "repeat 01 four times." It has a high order, a low entropy, and low information. By contrast, a completely random string of numbers has low order, high entropy, and high information. Information and entropy were the same thing and creating information shifted entropy.

Entropy was also seen as applicable to biology. A living organism is a highly-ordered arrangement of matter. It shifts entropy as it creates order, just as entropy is shifted when information is created.

Theory and Technology

Throughout Gleick's historical account of the development of information theory, he profiles brilliant thinkers who can be seen in retrospect as having had important breakthroughs in thinking about information. In almost every case, however, the theories were not immediately recognized for their importance. This was partly because the technology had not caught up with the theory.

Charles Babbage was an inventor and pioneering mathematician in the 19th century whose difference engine was the first real mechanical computer. He designed an even more versatile machine, an analytical engine, but lacked the funding and support to have it built. Nevertheless, he discussed its functions with other mathematicians and proposed that it would be possible to build such a machine that could solve many kinds of equations based on mechanical principles. He was envisioning a modern computer, although he did not know it then and at the time nobody saw the need for such a machine.

Claude Shannon's development of information theory came in the mid 20th century, at a time when computing machines had become a reality, although they were large and crude by today's standards. He was familiar with relay switches, which could be either open or closed and he recognized that they could be used in a logical arrangement to perform computing tasks. His theory of binary logic preceded the invention of the transistor, which greatly increased the logical capacity of a circuit. The technology of the transistor allowed for the development of larger and more complex systems based on Shannon's theory, eventually leading to modern computers. The theory had preceded the technology once again.

Autonomous Information

One of the more interesting ideas that Gleick presents is that information is autonomous, like an organism that can replicate itself and survive. He cites the work of Richard Dawkins, a zoologist who wrote a book called "The Selfish Gene" in 1976. In his book, Dawkins reversed the relationship between living organisms and the DNA that encoded their cells. The DNA molecule, which is really a string of genetic information, came first, Dawkins argued and that all living organisms are really just machines with the purpose of providing energy that allows these molecules to replicate themselves. In other words, this information is in the charge.

Gleick compares Dawkins' idea to the concept of memes. Memes are pieces of information that get repeated and passed along from person to person by word of mouth, by writing, in music, art and other methods. They can be phrases, ideas, images or any other type of information. They act like organisms in the way that they move independently and are replicated.

Gleick provides some examples of memes. The belief in God is sometimes thought to be a meme that has survived from the earliest days of human existence. In more recent times, the Internet has given memes a rich medium through which they can be propagated widely and quickly. He offers the example of the phrase "Jump the shark," which was propagated by a website of the same name and has entered into common usage.

Style

Perspective

"The Information" is both a history of the concept of information as well as an essay on the modern flood of information that faces us.

Gleick constructs a history of the development of the concept of information theory beginning at the dawn of history with the invention of writing and the alphabet. He looks at these developments from a modern perspective, identifying the major contributions that were made with the benefit of hindsight. Many of the concepts whose origins he identifies were not widely recognized as being important at the time they were articulated, Gleick explains, but by finding the connections between these historical events and our modern flood of information he gives them the recognition that he thinks they deserve. Wherever possible, Gleick provides biographical information on the major figures he identifies, giving an historical background that helps to place them in the line of development of information theory.

Gleick is a former journalist, and he provides a perspective that is accessible to the general reader. His writing goes beyond the mostly descriptive journalistic perspective, however. He also offers interpretation and explanation from the perspective of someone who is optimistic about technology and its benefits. Gleick completes his book with a forward-looking perspective in which he imagines that we will find new ways to communicate and manage the enormous amount of information available. We will not be overwhelmed by the flood, but will continue to create and thrive, he concludes, casting an optimistic perspective over the entire book.

Tone

It is clear through Gleick's writing that he is dedicated to his subject and that he greatly admires the brilliant people he profiles who made historic contributions to the development of information theory, the computer, and the Internet. He emphasizes the many ways in which most of these thinkers were ahead of their time and explains how their important ideas were often forgotten at the time they were presented but later discovered to be of great significance. He describes the present work of some advanced theorists who are experimenting with quantum computers, which may produce the next wave of advancement in information technology. His emphasis on the continued advancement in this field and its importance in all branches of science creates an optimistic tone that displays his faith not only in the ability of humans to continually find new ways to process information, but also in their ability to cope with ever increasing amounts of information.

Gleick is often writing about complicated ideas that span computer science, biology, physics, psychology, and literature. He simplifies these ideas for his readers while still showing how complex these concepts can be without adopting a pedantic tone. He is respectful of his readers. Gleick maintains a tone that shows he assumes they are as interested in his subject as he is and willing to give it serious attention.

Structure

"The Information" is presented in fifteen chapters with a prologue and an epilogue. It contains endnotes, a bibliography, and index. Each chapter is named with a short phrase or quotation taken from the subject of that chapter, as well as a subtitle. The book is illustrated with photographs, tables and drawings.

For the largest part of the book, Gleick presents a chronological account of the development of information theory, which he attributes to Claude Shannon who wrote in the mid 20th century. Chapters 1 through 6 provide a historical foundation for Shannon's breakthrough ideas. Beginning with the invention of writing, Gleick moves to the first attempts to classify language in the 17th century and to the brilliant inventions of Charles Babbage in the 19th century that mechanized mathematical operations. In Chapters 7 through 11, Gleick introduces Shannon's influential information theory and shows how it led to breakthroughs in other scientific disciplines. Chapters 12 through 15 describe the present age of the Internet and the challenges that such a flood of information present modern society. In the Epilogue, Gleick presents his optimistic view that humanity is still in charge of the flood of information and that the rapid growth in the availability of information is ultimately beneficial.

Quotes

"The raw material lay all around, glistening and buzzing in the landscape of the early twentieth century, letters and messages, sounds and images, news and instructions, figures and facts, signals and signs: a hodgepodge of related species. They were on teh move, by post or wire or electromagnetic wave. But no one word denoted all that stuff." (Prologue, p. 7).

"No such science, no such pragmatism informed the language of the drums. Yet there had been a problem to solve, just as there was in the design of a code for telegraphers: how to map an entire language onto a one-dimensional stream of the barest sounds." (Chapter 1, p. 21).

"With words we begin to leave traces behind us like breadcrumbs: memories in symbols for others to follow. Ants deploy their pheromones, trails of chemical information; Theseus unwound Ariadne's thread. Now people leave paper trails." (Chapter 2, p. 31).

"No one doubted that Charles Babbage was brilliant. Nor did anyone quite understand the nature of his genius, which remained out of focus for a long time." (Chapter 4, p. 78).

"Morse had a great insight from which all the rest flowed. Knowing nothing about pith balls, bubbles, or litmus paper, he saw that a sign could be made from something simpler, more fundamental, and less tangible - the most minimal event, the closing and opening of a circuit." (Chapter 5, p. 143).

"The invention of writing had catalyzed logic, by making it possible to reason about reasoning - to hold a train of thought up before the eyes for examination - and now, all these centuries later, logic was reanimated with the invention of machinery that could work upon symbols. In logic and mathematics, the highest forms of reasoning, everything seemed to be coming together." (Chapter 6, p. 177).

"Few could follow it. It seems paradoxical - it is paradoxical - but Turing proved that some numbers are uncomputable. (In fact, most are.)" (Chapter 7, p. 211).

"That evening Shannon took the floor. Never mind meaning, he said. He announced that, even though his topic was the redundancy of written English, he was not going to be interested in meaning at all. He was talking about information as something transmitted from one point to another." (Chapter 8, p. 246).

"The improbability of heat passing from a colder to a warmer body (without help from elsewhere) is identical to the improbability of order arranging itself from disorder (without help from elsewhere.) Both, fundamentally, are due only to statistics." (Chapter 9, p. 274).

"By now the word code was so deeply embedded in the conversation that people seldom paused to notice how extraordinary it was to find such a thing - abstract symbols representing arbitrarily different abstract symbols - at work in chemistry, at the level of molecules." (Chapter 10, p. 295).

"Memes emerge in brains and travel outward, establishing beachheads on paper and celluloid and silicon and anywhere else information can go. They are not to be thought of as elementary particles but as organisms." (Chapter 11, p. 313).

"A simple object can be generated - or computed, or described - with just a few bits. A complex object requires an algorithm of many bits. Put this way, it seemed obvious. But until now it had not been understood mathematically." (Chapter 12, p. 337).

"The information produced and consumed by humankind used to vanish - that was the norm, the default....Now expectations have inverted. Everything may be recorded and preserved, at least potentially." (Chapter 14, p. 396).

"As the printing press, the telegraph, the typewriter, the telephone, the radio, the computer, and the Internet prospered, each in its turn, people said, as if for the first time, that a burden had been placed on human communication: new complexity, new detachment, and a frightening new excess." (Chapter 15, p. 398).

"In cyberspace, almost everything lies in the shadows. Almost everything is connected, too, and the connectedness comes from a relatively few nodes, especially well linked or especially well trusted. However it is one thing to prove that every node is close to every other node; that does not provide a way of finding the path between them." (Epilogue, p. 425).

Topics for Discussion

How did the invention of the alphabet change language, according to Gleick? What was the significance of this change?

How is information different from meaning? Can the two things be completely separated?

What does the future of information processing hold, in Gleick's view? Is he optimistic?

How does the concept of entropy connect the various branches of science?

How does Gleick connect the technologies of the telegraph and telephone to modern computers?

What role does uncertainty play in information theory> Is it important?

How was the Internet changed our relationship to information? How have we learned to cope with these changes?