Chapter 2

Information Ecosystems: Definition, Functions, and Historical Development

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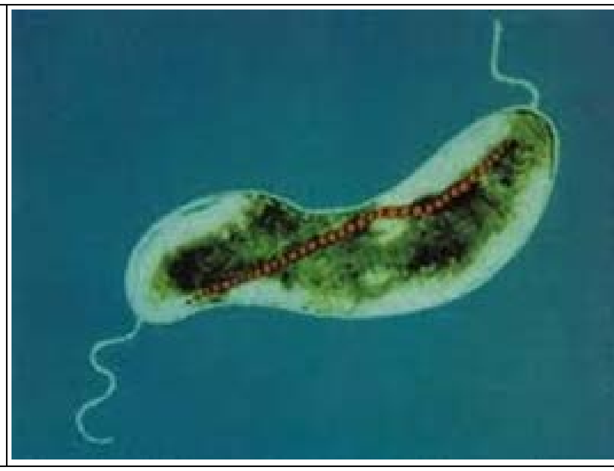
2.1 Carpe Veritas!!

Carpe veritas, seize the truth in rough translation, expresses a little-appreciated insight into the needs of nearly all living creatures. People recognize that in order to survive, and especially to thrive, living creatures need materials from their environment. For instance, plants need light, water, and nutrients or they will wither and die. But, how many people appreciate the extent to which living creatures benefit from gathering information? Organisms often thrive and survive precisely because they have evolved an ability to gather information about their environment and utilize that information to better adapt to their environment. Information allows living things to adapt to and even to alter their environment in ways that enhance their odds of survival and improve the quality of their existence. Organisms utilize information to seek essential or important materials, to avoid or minimize threats, to adapt to changes in their environments, and even to change their environment to better suit them. Consider plants, creatures very unlike us, plants need more than just light, water, and nutrients—plants need information. In fact, though few people suppose that plants have minds or that plants somehow think or cognize, many plants exhibit a number of behaviors driven by information about their environment. For instance, many plants exhibit phototropism. Phototropic plants grow towards a light source. Biologists explain plant phototropism by appealing to a plant's primitive mechanism for sensing light through chemicals called phototropins. Phototropins react to light stimulation, triggering a chemical reaction that guides directional growth.[1-3]

Winslow Briggs who played a key role in developing the biological understanding of plant phototropism. Picture from: Carnegie Science.



(**Above**) Video showing and explaining plant phototropism from created by Britanica.com and posted on youtube. Click on image to play video.
Video showing the orienting of magnetotactic bacteria from: Youtube. Click on image to play video.
Magnetotactic bacteria. Image from: Worldarea.info

Thus, even simple living creatures, like plants need information to thrive—just like they need water, nutrients, and light. Indeed, for most animals the ability to secure life-giving materials, like water and food, from the environment depends upon their capacity to gather and process information in their environment. Likewise, for many living things avoiding predators and other dangers depends upon gathering information. One might call this need for data about the world an **information imperative**. Our very nature as living organisms solving complex problems in a variable and ever-changing environment creates a need for information to promote survival and thriving. As a result, nearly all living creatures operate in accordance with an imperative to gather information and utilize that information to shape their adaptive responses to the environment. Consider another example: In 1975 Richard Blakemore published the first peer-reviewed scientific article describing a simple kind of anaerobic bacteria he called magnetotactic bacteria. Magnetotactic bacteria use information about the Earth's magnetic field to survive and thrive.[4-7] Magnetotactic bacteria, like many anaerobic organisms, thrive in environments that have lower oxygen concentrations; many will actually perish if the oxygen levels rise too high. As a result, these magnetotactic bacteria actively seek deeper waters or silt since oxygen levels drop as one travels from the oxygen-rich surface zone downward to more oxygen-starved zones. But how do these bacteria determine which way is down? Magnetotactic bacteria generate small iron-like crystals that act as a compass, pointing to the earth's magnetic field. These internal compasses allow magnetotactic bacteria to use information about the Earth's magnetic field to move away from the higher oxygen levels on the surface of a body of water or in silt. Orienting themselves using the Earth's magnetic declination—the Earth's magnetic field lines pointing towards the geographic north pole--magnetotactic bacteria then use flagellum (small, hair-like structures) to move away from the oxygen rich surface areas towards the more hospitable oxygen-poor regions of water and silt. These minuscule, mindless creatures illustrate both the need that living creatures have for information about the world and the way in which such information helps creatures to survive and thrive in an otherwise hostile or indifferent environment. On a cautionary note, students should be careful not to equate information with truth, belief, or knowledge. Information as used in the ecosystems chapters refers neutrally to data regardless of its truth or evidential basis. Thus, representing an aardvark as an aardvark and misrepresenting an aardvark as an anteater both constitute examples of visual information.

2.2 Information Ecosystems

Given the important role of information in the lives of organisms one should not feel surprise upon discovering that evolution often selects creatures with enhanced information gathering capacities. Indeed, evolutionary selection often functions to create creatures capable of employing ever more complex and efficient versions of what I call **information ecosystems**. Information ecosystems provide creatures with powerful tools for gathering and verifying information about their world. In the case of modern humans, for instance, an information ecosystem consists of a set of sources (senses, artifacts, organizations, and individuals) one regularly consults to gather information, evaluate claims, estimate likelihoods, or when pondering the adequacy of one's worldview. Nearly all living creatures inhabit an informational environment just as they inhabit a biological environment. The types of information available, the manner of that availability, the ease of access, as well as the spatial and temporal dimensions of information availability define this **information environment**. The generation, consumption, utilization, and exchange of information in these information environments constitutes an organism's information ecosystem.

This chapter begins with a brief discussion of how evolution and human artifice have shaped the uniquely human ability to create and exploit information ecosystems. This brief and superficial history concludes with what one might think of as a new epoch—an epoch in which humans have traveled from a state of information scarcity to a state of information surplus and ultimately have arrived at an age of information superabundance. Living creatures evolved strategies to mitigate information scarcity. Humans, in particular continue to develop strategies that generate and disseminate more information than minimally necessarily for survival and even for thriving. Humans began creating ever increasing information surpluses beginning at least fifty to one hundred thousand years ago. This human information surplus very quickly allowed humans to not merely to adapt to their environment, but to manipulate and transform their environment. As a result, modern humans have created such an enormous information surplus and have so dramatically reshaped their environment that most humans spend most of their time in activities that are unrelated (or at least very indirectly related) to basic their biological existence and needs. Indeed, humans have become so facile and productive in generating information that many people now live in a world of information superabundance.

Most humans now have access to so much information that one of their primary cognitive challenges has become finding relevant information in a horizonless and largely uncharted repository. Sometimes people need information that simply has not been generated or disseminated, but increasingly people struggle to find reliable information stored somewhere in a vast sea of existent data. For instance, considering just the internet, Internet Live Stats[8] estimates the number of individual websites in the internet as rapidly approaching two billion. Maurice de Kunder currently estimates the number of individual pages indexed by Google (based upon his work at the University of Tilberg) at approximately 5.39 billion.[9] Furthermore, the contexts in which people encounter information has become increasingly anonymous and bereft intellectual context further exacerbating difficulties posed by the sheer volume of information.

The next chapter and lectures focus upon a critical examination of the adaptive strategies that have emerged to manage information superabundance as well as the cooptive strategies that have also evolved. These cooptive strategies seek exploit information ecosystems or defeat the advantages that ecosystems create for individual participants. The chapter discusses both individual and institutional countermeasures adopted to limit or otherwise undermine the success of information ecosystems. The exposition of individual cooptive strategies illustrates the variability in resources, training, and intent characteristic of individual strategies. The mechanisms employed predominately by organizations and institutions potentially limit information, distort information, disseminate misinformation, and/or undermine an individual's effective use of and confidence in information ecosystems.

These critical examinations of contemporary ecosystems lay the groundwork for the final discussion on this topic; the final ecosystems chapter urges two interrelated approaches to gathering and evaluating information. First, one of the best ways for someone to accomplish the goal of information gathering and evaluation is to create, refine, and maintain a personal information ecosystem. Second, an effective critical thinker counts research skills among their set of critical thinking tools, and cultivates the habit of regularly seeking out information. Effective thinkers develop the skills and the infrastructure necessary to proactively find and verify information that augments, corrects, and renders their belief systems and worldview consistent, systematic, and comprehensive.

2.3 A Brief History of Information Gathering and Information Ecosystems

Returning to the focus of the current chapter and lectures, an information ecosystem consists of a set of senses, artifacts, places and/or people one regularly consults to gather information, evaluate claims, or when pondering the adequacy of one's worldview. One can think of an information ecosystem as an artificially augmented sensory system. Just as one's eyes gather visual information from the world, other elements of an information ecosystem allow one to gather information and verify information over a wide range of topics and through a variety of sources. Thus, each element of an information ecosystem (ideally) provides one with a reliable conduit for information just as sight, hearing, and touch provide one with reliable conduits for information. Similarly, an information ecosystem allows one to crosscheck the veracity of information in much the same way one can use one's sense of touch to verify information from the visual system.

One might find it odd to think of humans as needing to actively search out or verify information in the same way that they seek food and water. Nevertheless, humans need information just as they need water and food. Indeed, competent, effective, and literate critical thinkers constantly and actively inform themselves regarding a wide range of important topics. Critical thinkers seek information actively because success across a wide variety of activities and goals requires (or benefits from) taking an active role in gathering, organizing, and evaluating information. Evaluating information facilitates avoiding false and poorly-evinced beliefs. Correspondingly, seeking information allows one to cultivate true or highly-evinced beliefs. True and highly-evinced beliefs help one to get the most out of one's life. Indeed, being responsible in one's dealings with other people [even other animals] requires one to reason and make decisions based upon obtaining and using the best-evinced beliefs possible in a given situation. Furthermore, mere procreation cannot explain the rise of human civilization during the last 12,000 years—information seeking and information sharing played and continues to play an enormous role.

One might suppose that information ecosystems are relatively new phenomena. In fact, humans and other living creatures have used information ecosystems for a very, very long time. Indeed, during the course of the evolution of living organisms, information ecosystems have repeatedly expanded to include new sources of information and to refine old sources. For instance, human beings learn to gather information from other creatures, such as hunting dogs, thereby adding animals to the set of sources incorporated within their information ecosystems. The development of microscopes and telescopes enhance the human visual system, extending the range and discernment of this sense. With the rise of the written word and then the printing press humans add books, newspapers, magazines, academic journals, etc. to the sources within their information ecosystem. Society likewise creates conduits of information specifically designed to accrete and disseminate information efficiently. Thus, telegraphs, radios, telephones, televisions, and libraries become information hubs in the 19th and 20th century. The development and expansion of the of the internet and the World Wide Web allows your computer, cell phone, and tablet to become one of the primary information conduits of the 21st century. The brief history of ecosystems that follows gives a simplified outline of how information gathering and information sharing leads to increased thriving for living organisms focusing particularly upon humans. It also serves to help students better understand the kind of information environment that they currently inhabit—an environment of information superabundance.

2.3.a Biochemical and Biomechanical Sensory Structures

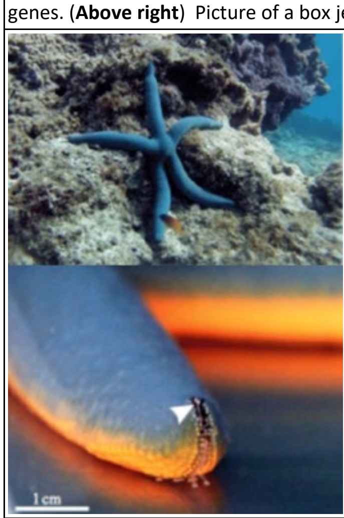
The first elements of information ecosystems in living organisms lack a clear date of evolutionary origin. However, dinoflagellates, mobile creatures like magnetotactic bacteria, appear in the fossil record as early as 1.1 billion years ago. Such simple information gathering structures as the magnetotactic bacteria's ferrous compound and the Euglena's (see below) eyespot and paraflagellar body surely represent the oldest means for organisms to gather data about their immediate environment.[10] As discussed above, the ability to gather even rudimentary information about the environment and use that information to adapt to the environment affords organisms an increased ability to survive and thrive. The introductory discussion above might suggest to students that one finds such comparatively primitive information gathering mechanisms exclusively in lower life forms. However, such structures exist in all almost all organisms. In more evolved creatures these mechanisms are often imbedded in highly specialized sensory organs and/or sensory systems. For instance, eyes evolved as increasingly complex and refined compound structures containing collections of simple photosensitive cells. Human thermoreception[11] (the ability to sense hot and cold) involves rather primitive hot and cold sensing structures in the skin called "C-fibers" and "A delta fibers." Such primitive nociceptive structures in the skin use simple chemical and mechanical operations to sense information about the environment. However, simple biochemical and biomechanical structures tend to be rather rigid, easily fooled, and non-specific. For example, body heat also registers as light under some conditions in some photosensitive cells.

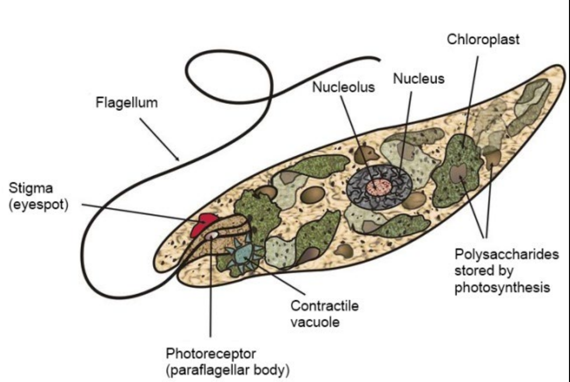
2.3.b Sensory Organs and Sensory Systems

Sensory organs and sensory systems collect and refine basic sensing mechanisms to create more sophisticated information gathering and processing structures. Scientists theorize that sensory organs and ultimately sensory systems first evolve during the Cryogenian Period (850-635 million years ago).[12-14] Olfaction and gustatory sensory systems started to emerge about 700 million years ago. The arrow worm (see below) has no brain or olfactory organ. However, arrow worms do have olfactory sensors along their sides. These sensors share some of the genes active in human olfaction. Arrow worms diverged from vertebrate evolution about 700 million years ago. What we think of as the modern eye emerged during the Cambrian Period (540-485 million years ago) roughly 530 million years ago.[15, 16] Sensory organs, particularly eyes, provide a dramatic increase in the size of the environment from which an organism can gather information.

While simple individual biomechanical and biochemical structures allow organisms to sense features of their environment, these elementary structures suffer from severe restrictions. The range of most biomechanical and biochemical structures often extends no farther than the organism's surface. Simple biomechanical and biochemical structures tend to be relatively non-specific and insensitive to more complex information. Finally, these mechanisms tend to be rigid and easily fooled rendering them relatively unreliable information channels. In contrast, sensory organs increase the range, reliability, and complexity of the information collection dramatically. While magnetotactic bacteria can orient themselves by sensing magnetic north, they cannot detect objects or the properties of objects. Indeed, magnetotactic bacteria cannot actually sense oxygen—the toxin they need to avoid. The information gathering advantage resulting from the evolution of sensory organs certainly helps to fuel the Cambrian explosion—a period during which life evolves from simple, single-celled animals into almost all of the different Phyla found today.[17-19]

(**Above left**) Picture of Amphioxus lanceolatus (arrow worm) from The Marine Biological Association of the UK. Arrow worms and humans likely have common ancestor because they share some olfactory genes. (**Above right**) Picture of a box jellyfish from Livescience. The black dots are two of its 24 eyes.





(**Above left**) Picture of a starfish from Japan (above) together with a close-up of one of its eyes from Physorg. (**Above right**) Diagram of the Euglena indicating its photorecetor. From: Wikipedia

Human sensory systems, of course, do not represent a single endpoint along a single line of progressive evolution. Many creatures—like houseflies--have compound eyes. Some creatures have many more eyes than humans; the starfish has an eye on each of its five arms.[20] Likewise, animals without brains, such as the box jellyfish, have eyes.[21] The Euglena is a single-celled flagellate much like the magnetotactic bacteria. However, instead of a ferrous compound the Euglena relies upon a primitive eye spot and paraflagellar body for phototaxis (light-oriented movement).[22] Indeed,[15]

> most of the types of eye that we recognize today arose in a brief period during the Cambrian, about 530 million years ago. The development of better eyes coincided with increases in size, speed, and armour, as visually guided predation became a common way of life. Opsin-based light sensitivity evolved in a common ancestor of all animals. (p.21)

Likewise, by some estimates, eyes have evolved anywhere from 50 to 100 different times.[15] The prevalence of eyes, the repeated emergence of eyes in the evolutionary record, and the association of the advent of eyes with the explosive proliferation of life forms provide evidence for the advantages conferred by sophisticated information gathering. Additionally, the commonly cited five human sensory systems do not exhaust the possible sensory systems—even in humans. For instance, many sea animals use electroreception[23] to sense electrical fields. Humans also sense pain (nociception)[24], balance and relative orientation (equilibrioception)[25], relative body position and motion (proprioception)[26], was well as temperature (thermoception)[11].

2.3.c Small Groups and Information Pooling

The development of specialized sensory systems increases the range, reliability and complexity of information gathering. The next big jump in information gathering comes through social cognition. By living together in small groups, creatures can actively or passively pool the information they gather with one another. Such pooling effectively expands the range and sensitivity of their individual sensory organs and systems. Today many animals live in groups and communicate information using signal systems of movements and/or sounds. Probably the earliest and simplest example of this strategy can be found in fish schools and shoals.[27] By swimming together and responding to each other's movements fish can pool the information gathered from their sensory organs to detect predators, find food, and explore their environment.[28, 29] Fish first evolved during the Cambrian explosion and are the oldest vertebrates.[30, 31] Scientists believe that schooling evolved as a behavior in fish.[28, 32, 33] No one knows when schooling and shoaling behavior first evolved, however, it likely dates back at least to the Devonian Period, often called the age of fishes, some 400 million years ago.[31, 34] With the advent of information sharing social creatures can benefit from a larger and more diverse information ecosystem leading to greater potential to thrive. Social information sharing likewise introduces greater potential for mutually beneficial cooperative action by allowing exchange of information regarding the mental and physical states of other members of a social group. As a result, social information exchange facilitates increased coordination of action as well as decreasing and/or defusing potential conflicts.

2.3.d Spoken Languages

With the exception of human beings, social animals tend to share only small amounts of relatively simple information. In the case of humans, however, the advent of **spoken language** dramatically magnifies the amount of information as well as the complexity of information that humans can share with one another. Increases in information complexity together with the long-term memory capacities of humans also expand the timeframe for information exchange. For instance, with language humans can communicate about the past and future--not just the immediate moment. Spoken languages allow individuals to communicate much more complex experiences and ideas from sources that transcend the confines of their current time and location. Language likewise facilitates the pooling of cognitive resources beyond the exchange of sensory information. Importantly, spoken language allows communities to partially pool their long-term memories creating a distributed network of long-term memories.

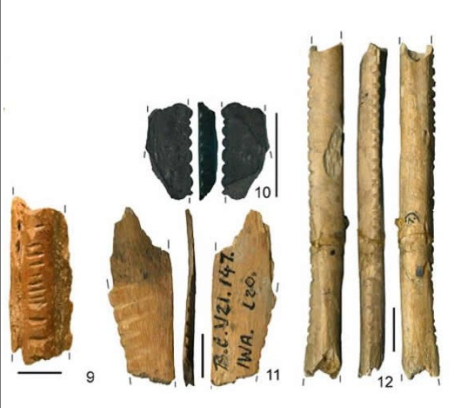
Researchers have no definitive evidence for when spoken language first emerges. Nevertheless, only modern humans appear to have the vocal apparatus required for contemporary languages. Scientists also point to two other factors in estimating the evolutionary origins of language. First, scientists note that sometime beginning in the African Middle Stone Ages[35] humans began to create symbolic artifacts suggestive of the sort of abstract thought necessary for language. These artifacts include body pigments, ornaments like beads, and cave paintings.[36, 37] Second, a gene associated with language in humans, the $FOXP_2$ gene, seems to have first appeared approximately 50,000 to 100,000 years ago.[38] Thus, scientists believe spoken language emerged after the appearance of Homo sapiens (modern humans), probably 100,000 to 50,000 years ago.[39-41]

The advent of spoken language allows for a dramatic increase in the amount and complexity of information that humans can potentially share with one another. It likewise expands the timeframe for such communications, making it much easier to share information about the past or concerns about the future. Language facilitates the pooling of cognitive resources beyond the exchange of sensory information, by allowing communities to partially pool their long-term memories creating a distributed network of long-term memories. However, spoken language must still operate within the limitations of native human cognition and the medium of spoken language. For instance, humans can only share information among people with whom they can speak (both in terms of distance and shared language), information must be heard and understood during communication, and to persist, information must be remembered.

2.3.e Written Number Systems and Languages

The development of written language and number systems constitutes the next significant milestone in human information ecosystems. Modern written languages and number systems probably emerged no earlier than 44,000 years.[42-46] The first known instances of the recording of numbers appear on primitive tally sticks found in Africa and dated between 44,000 and 18,000 years ago (below).[47] Tally sticks function as recording devices (external memories) for the counting and recording of, among other things, quantities. While a number of animals can count—at least to between 2 and 6—tally sticks allow humans to count far, far higher. Using tally sticks, humans could also keep a record of what they counted. No other animal can do these things.[48-50] An additional improvement to tally sticks does not come until roughly 7500 BCE, when archeologists think people began using clay tokens to symbolize individuals (see below). While the shift from notching sticks and bones to manipulating tokens might not seem significant, the use of tokens allows for counting, addition, and subtraction by manipulation of the tokens.[45, 51, 52] People can keep a record of things counted by storing counted tokens in clay envelopes. However, the real benefit to humans comes from richer and more systematic number systems. These number systems do not emerge until around 3200 BCE at roughly the same time that early writing systems emerge.

Scholars now recognize many categories of writing systems. This brief exposition relies upon a slightly expanded version of the popular tripartite scheme of logogram, syllabary, and alphabet, adding only proto-writing (especially) ideography.[53, 54] Within each general category one finds gradients of sophistication placing such individual instances farther from or closer to the next category. What most researchers classify as writing systems are preceded by proto-writing, systems of ideographic and/or mnemonic symbols.[54] Ideographic systems represent ideas with graphic symbols (stylized pictures) that communicate information without necessarily having any direct relationship to any specific language. For instance, countries often adopt ideographic symbols in airports and similar places where people may or may not speak the same language. In other words, just like early counting systems use scratches to represent individuals, ideographic systems use symbols to represent concepts. Researchers have unearthed evidence of ideographic systems beginning as early as the 7th century BCE and running into the 6th century BCE. Jiahu symbols, (see below) the earliest known ideographic symbols, date back to approximately 6600 BCE. The symbols occur on nine

	 	 
(Above) 9-12 shows notched bones possibly used as tally sticks. Modified from: d'Errico et. al. (Below) The top image is a map of northern China with sites where Neolithic symbols have been discovered. From: Wikipedia The bottom image shows several tablets from found in Tărtăria, Romania. From: Ancient Origins	(Above) On top, front and back of the Ishango bone. From: African Heritage[55] On bottom, a clay envelope and accountancy tokens. From: Accountancy to Writing (Below) On top, a picture of a tortoise plastron found in Jiahu. From: America Pink.[56] On bottom, the Dispilio ideographic tablet found in Greece dating to 5600BCE. From Wikipedia	(Above) Two examples of cave paintings from El Castillo Cave in Puente Viesgo, Spain currently dated at approximately 40,000 years. From: Puente Viesgo[57] (Below) The symbols on the top are depictions of several of the 16 symbols found at Jiahu. From Wikipedia The depictions on the bottom come from pottery found at Banpo. Also from Wikipedia
 	 	 

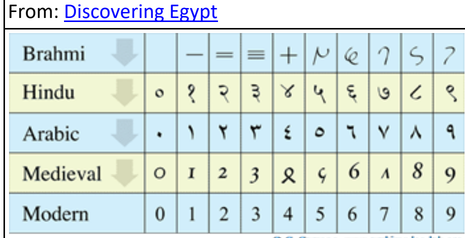
tortoise plastrons (shells) and two bones found at Jiahu, China.[58-61]

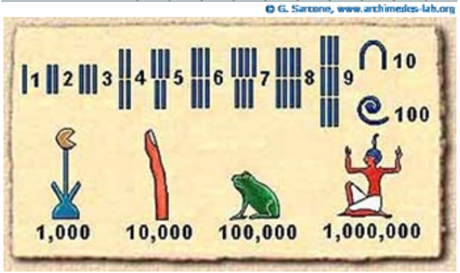
Researchers have also found ideographic symbols inside pottery at Dadiwan, China dating to approximately 5800–5400 BCE as well as carvings in cliff faces of symbols in Damiadi, China dating between 6000 and 5000

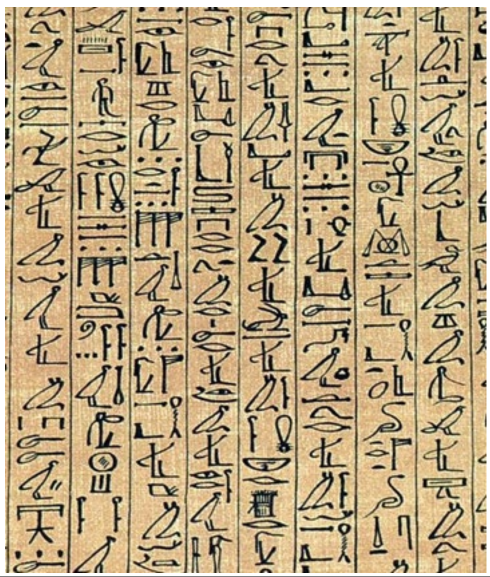
BCE.[60, 62] More sophisticated artifacts emerge from sites at Banpo and Jiangzhai, China (see above). Nicolae Vlassa discovered other ideographic symbols dating to approximately the same period (5300B CE) in Romania on what are often called the "Tărtăria Tablets" or the "Vinča signs".[63] (see above) Likewise, the Dispilio Tablet (see above) and related finds in Greece date to approximately 5260 BCE and represent more complex, language-like symbols and symbol arrangements.[64]

Since ideographic symbols function without direct links to language, researchers do not classify ideographic symbol systems as instances of written language. The first symbol systems categorized as written languages fall under the second category: logograms. A logogram is a single written character which represents a complete grammatical word.[65] One can find examples of logographic symbols even today in contemporary Chinese and Japanese (see below), though researchers estimate that only about 4% of contemporary Chinese characters function as logograms.[66] Scientists identify Sumerian archaic cuneiform script and Egyptian

(**Above**) An excerpt from a primer of Chinese characters. From: Wikipedia (**Below, top**) Chart comparing iterations of hindu-arabic number systems From: Archemedes-lab.org (**Below, bottom**) The Egyptian hieroglyphic number system. From: Discovering Egypt

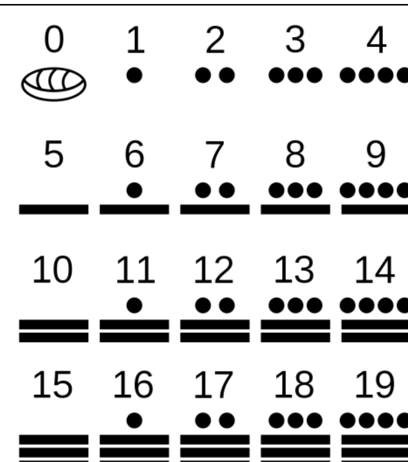






(**Above**) Some Egyptian hieroglyphs on a page from the *Papyrus of Ani*. From: Wikipedia (**Below**) A picture of the rock inscriptions in the cave at Naneghat, India. From: Wikipedia

(**Above, top**) Picture of clay tablet inscribed with early cuneiform found at Jemdet Nasr and dated between 3100 -2900 BCE. From: U.S. DD (**Above, bottom**) 7th century Mayan logosyllabic glyphs found at Palenque, Mexico. From: Wikipedia (**Below**) Mayan number system. From: Wikipedia



hieroglyphs as the earliest logographic languages (see below). These languages are generally considered the earliest writing systems; both emerge out of their ancestral proto-literate symbol systems sometime between 3400 to 3200 BCE.[67, 68] The Sumerians also adapt cuneiform to create several, incompatible, topical number systems at about this time. For example, there were systems for counting grain, counting land, etc..[45] Ultimately, the different Sumerian systems for counting consolidate into a single place-value number system around 2100 BCE. Interestingly, the Sumerian system is a sexagesimal number system in which places were multiples of 60. Thus, a modern hour is still 60 minutes and not 10 or 100 minutes. At approximately 3000 BCE the Egyptians develop a base-10 hieroglyphic number system (see above).[46, 69] The modern Hindu-Arabic number system also uses places for multiples of ten—except for time, angles, and geographic coordinates.

Historians date the earliest known instances of written languages in the Americas to between 1100 BCE and 900 BCE.[70-72] Scholars believe that writing and number systems developed independently in the Americas starting with the Olmecs who flourished between approximately 1500 BCE and 400 BCE.[71, 73] Mesoamerican civilizations likewise developed a base twenty number system that included a symbol for zero. The earliest known instances of such a system come from the Mayans and date to 36 BCE.[74-76]

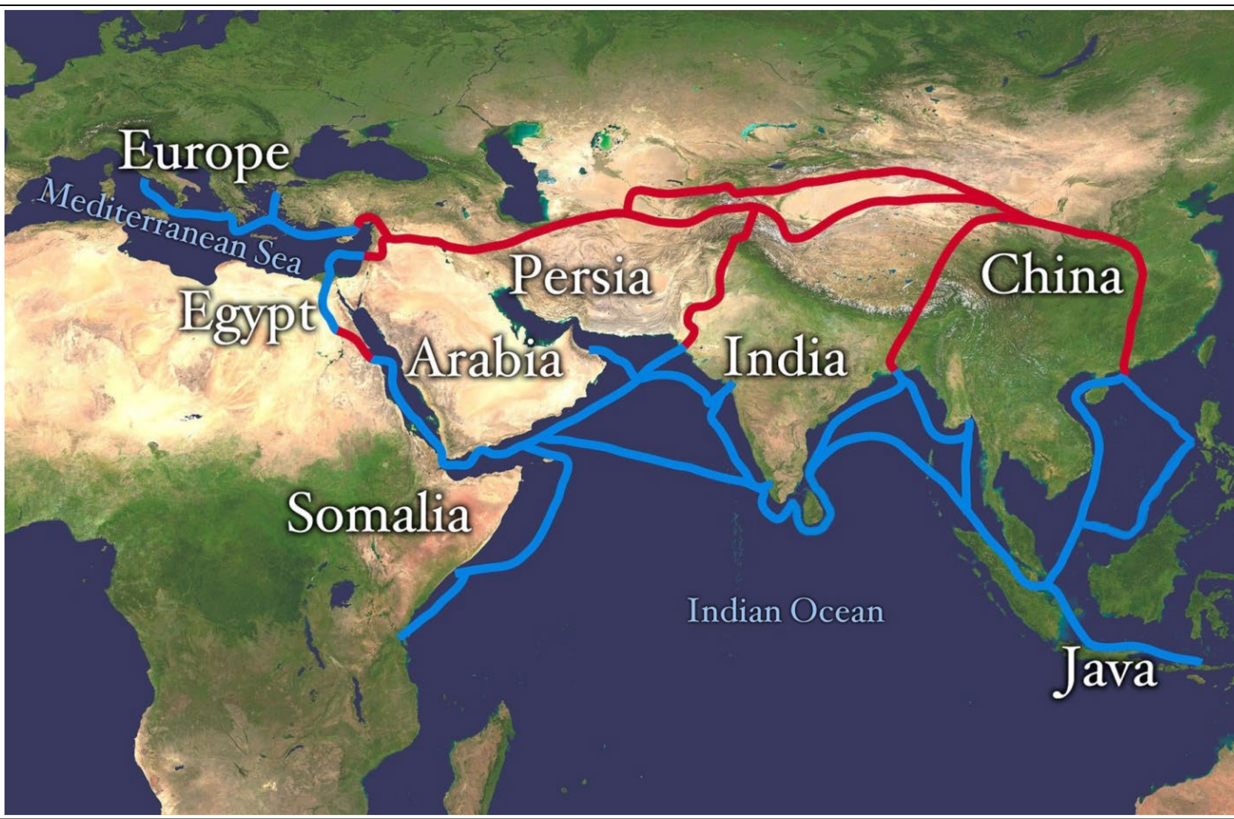
Languages and number systems continue to evolve in ways that increase their ease of learning and use as well expressive robustness in the centuries that follow the emergence of proto-languages and number systems. For example, while logographic writing systems allow one to record words from spoken language, they prove rigid as well as difficult to learn and use. Every word must have a logogram that one must learn. Likewise, one must create a new symbol for any new words. Syllabary languages use a set of written symbols that represent (or approximate) the syllables which make up spoken words. For instance, the oldest version of Greek, Mycenaean Greek, uses syllabary and dates back to approximately 1600 BCE.[77, 78] Within a syllabary system one can use its basic symbols to write any word expressed in the phonemes of that language. Thus, syllabary languages prove more flexible and dynamic. Syllabary languages also prove easier to learn and use in that they have a dramatically smaller number of basic symbols. Like syllabary languages, alphabetic languages use a set of basic symbols to indicate sounds, though alphabetic symbols usually symbolize component sounds of spoken syllables. Specifically, an alphabet is a small set of letters (basic written symbols), each of which roughly represents (or represented historically) a phoneme of a spoken language. The word alphabet derives from alpha and beta, the first two symbols of the Greek alphabet. Alphabets provide an additional robustness over syllabary systems in that alphabets can serve as the basis for writing multiple languages. For instance, modern English uses a 26 letter alphabet derived from Latin alphabets, which in turn are a variant of the Greek alphabet, which developed from the Phoenician alphabet.[79-81] Researchers identify the Phoenician alphabet as the first alphabet and date its emergence at around 1050 BCE.

The first evidence for the beginnings of the modern Hindu-Arabic number system dates to the 3rd century BCE. Specifically, the symbols for the numbers 1-9 appear in royal Buddhist edicts carved into cliff faces, pillars, and caves starting around 265 BCE.[52, 82-84] Perhaps the most famous edict is found in a cave at Naneghat, India. (See above) The full positional number system does not appear in the historical record until the publication in 458 CE of an Indian religious cosmological text called *The Lokavibhaga*.[45, 52, 82, 84, 85] The oldest existent copy of this text, written in Sanskrit, mentions both zero and the positional number system.

The development of written languages and number systems again expands the amount, duration, and complexity of information that one can communicate. But, the real value of written languages and number systems lies in their ability to allow humans to record enormous amounts of information of staggering complexity in a precise and relatively permanent medium. Once recorded, such information can remain available for centuries. Written language and number systems not only externalize the storage of mass amounts of complex information, they thereby allow for much more efficient and extensive manipulation of that information—for instance, through analysis, revision, and search.

2.3.f Expansive Trade

Written language and number systems allow for dramatic increases in the amount of information, the complexity of information, and the efficient and extensive manipulation of that information. But the power of an information ecosystem also derives from the number and diversity of its sources. Greater numbers of participants in an ecosystem and greater diversity among of those participants results in an increased potential within that ecosystem for new and innovative ideas to emerge and spread. Researchers have found little evidence that humans and proto-human had a contact range (trading or otherwise) of more than 60 miles until the Neolithic era.[86] However, beginning in the Achaemenid Empire (first Persian Empire) in approximately 500-330 BCE trade between the Mediterranean and more distant areas in the Middle East increases significantly. The construction of the "Royal Road," connecting the coast of present day Turkey to Persepolis in present day Iran greatly facilitates trade.[87-90] The military campaigns of Alexander the Great extend the reach of trade from the Mediterranean to present day Tajikstan in central Asia. The Seleucid Empire pushes towards China itself by 200 BCE. By approximately 114 BCE the trade routes collectively referred to as the Silk Road connect China, the Indian subcontinent (India, Pakistan, Bangladesh, Nepal, Afghanistan, Bhutan, and Sri Lanka), Persia, Arabia, the Horn of Africa, and Europe. This expansive network of trade also facilitates the exchange of information between the large and diverse group of cultures it connects. Today, of course, information and trade occurs at a global level, making information from anywhere on Earth available—at least potentially.



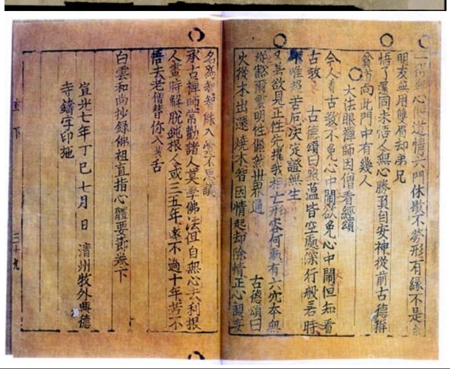
A map showing the major land and sea routes collectively called the Silk Road circa 114 BCE. From: Wikipedia

2.3.g Printing and the Printing Press

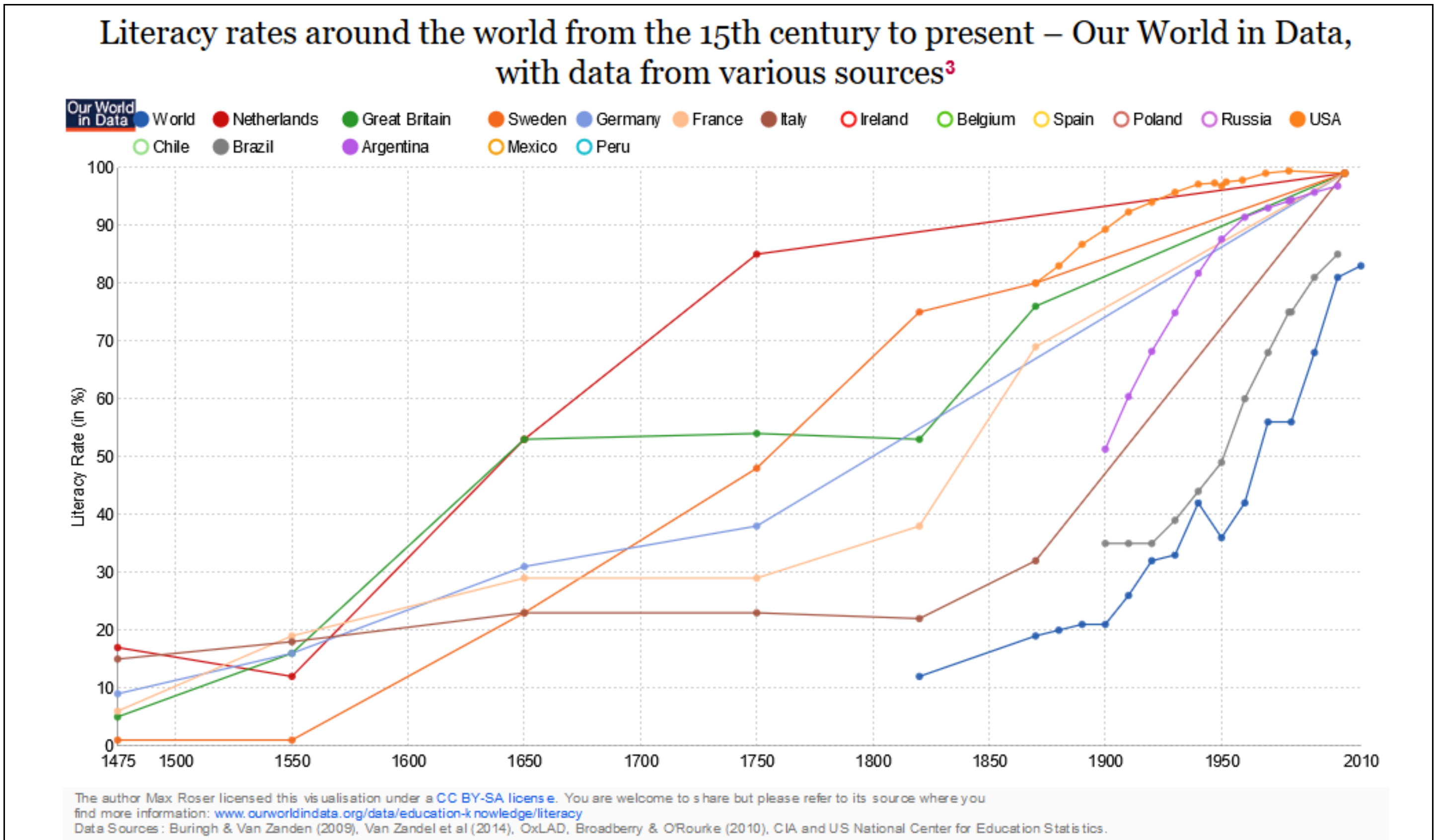
By 114 BCE written/spoken languages and number systems together with trade make tremendous amounts of information potentially available. However, only a small percentage of people participate in a meaningful fashion in this large and diverse information ecosystem. Most people of this time cannot read, write, or use number systems. Likewise, producing written information still requires labor-intensive hand writing and/or copying. The invention of printing, particularly of movable type printing, dramatically increases the availability of written information and literacy.

Historians date the origins of printing to approximately 220 CE in China.[91-94] The Chinese originally used wood blocks to print designs on cloth. A combination of the appearance of paper and the Buddhist mandate to create and disseminate religious texts leads to wood block printing of documents on paper in Japan, Korea, China, and eventually India. Scholars general recognize the *Diamond Sutra*, a copy of which dates to 868 CE, as the first intact, known printed book.[95]

Though wood blocks allow for making multiple copies, creating the blocks proves quite labor-intensive. Researchers generally credit a Chinese inventor named Bi Sheng for the invention of movable type printing between 1040 and 1048 CE.[91, 93, 96] Bi Sheng uses both wood (early) and porcelain characters in his printing. The invention of movable type dramatically increases the ease with which one could print a given text and lowers the price of such texts commensurately. However, printing and movable type spread at a surprisingly slow pace. The Islamic world, for instance, resists the introduction of printing for religious reasons--mostly, the importance assigned to memorization of the Qur'an and the tradition of artful calligraphy. However, printing and movable type slowly spread from Asia move towards Europe. Koreans, for instance, develop bronze movable type around 1230 CE. Bronze type proves much more durable than the porcelain used in

	 	
Image of a page from a Chinese play printed using a carved wood block during the Yuan dynasty. From: Wikipedia	On top, a picture of a page from the *Diamond Sūtra*. From: Wikipedia On bottom, an image of the Jikji, the earliest known book printed with movable metal type in 1377. From: Wikipedia	Picture of a replica of Johannes Gutenberg's printing press. From: Wikipedia

China. As a result, Korea produces the first book known to have been printed using movable type, the Jikji.[97] Many people in the Western world have been taught that Johannes Gutenberg, a German goldsmith from Mainz, invented the movable type printing press between 1438 and 1444 CE.[98] Gutenberg is the first person to build and use a movable type printing press in Europe. He also deserves credit for having executed the task of printing to a high standard. Gutenberg's most famous project, a copy of the Bible, served to fuel the printing revolution in Europe. The movable type printing press brings relatively high-quality and high-speed document duplication to Europe just as the European Renaissance begins to dramatically increase the information production of Europe. Movable type printing helps to trigger an explosion of literacy in Europe and the rest of the world. Literacy rates go from a range of between 1% to 17% in 1475 to 83% worldwide in 2010.[99]



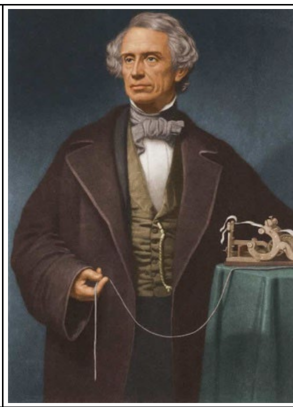
Graph showing literacy rates from 1475 to 2010. From: Ourworldindata.org

2.3.h Early Electronic Communications

Printing technology adds to the number of literate participants in the information ecosystems that it reaches. It likewise allows for the relatively cheap creation of fairly high quality copies of documents. The 19th and 20th centuries bring innovations that dramatically increase the speed with which information travels within an ecosystem. Historians generally assign the origins of the first such invention, the electronic telegraph, to the work on English inventor Francis Ronalds in 1816.[100-102] Others make significant contributions to the development of telegraphy prior to Ronalds. The idea of an electronic telegraph seems to have first been suggested in 1753 by an unknown author in a Scottish Magazine. In 1837 William Fothergill Cooke and Charles Wheatstone introduce the first commercial telegraph in England.[103-105] That same year in the United States,

(Top Left) Picture of an example of a Cooke and Wheatstone electric telegraph. From: Wikipedia. **(Above Middle)** Map showing the main telegraph lines in 1891. From: Wikipedia. **(Top right)** Picture of a portrait of Francis Ronalds. From: Emaze.com

Picture of a Morse Telegraph Key. From: Wikipedia



Portrait of Samuel Morse. (1791 - 1872) From: Time

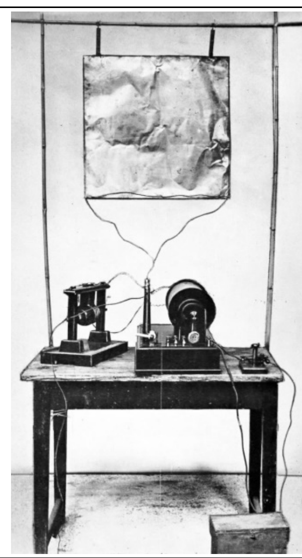
Picture of William Fothergill Cooke (1806-1879) From: The Telegraph

Picture of Sir Charles Wheatstone (1802-1875) From: BPH

Samuel Morse independently developed and patented a recording electric telegraph.[106] Together with his assistant, Alfred Vail, Morse developed what came to be called Morse Code.[107, 108] Though the use of electric telegraphy requires significant infrastructure, the ability to transmit information almost instantaneously across the world drives investment until telegraph cables connect every major land mass on Earth in 1891.

Portrait of Alexander Popov (1859-1905). Adapted from a commemorative Russian stamp: Сьогодні в історії

Photo of Guglielmo Marconi (1874-1937). From: History.com



Picture of Marconi's first transmitter. From: Wikipedia

Portrait of Karl Ferdinand Braun (1850-1918). Adapted from: Biography.com

Radio improves upon telegraphy in that it requires much less infrastructure and delivers reproductions of sound that travel at a nearly instantaneous rate. Russia and some Eastern European countries attribute the invention of radio to Alexander Popov, who presents a paper on his radio wave lightening detector on May 7, 1895.[109, 110] Indeed, beginning in 1945 and continuing to today Russians celebrate "Radio Day" on May 7th to commemorate Popov's discovery.[111] However, most scholars believe that Popov did not actually transmit information via radio waves until 1896. Most historians recognize the Italian inventor Guglielmo Marconi (perhaps together with Karl Ferdinand Braun) as the inventors of radio.[109, 112-114] Marconi successfully transmits messages for a distance of about two miles in the summer of 1895, and goes on to found The Wireless Telegraph & Signal Company in 1897.[115] By 1902 Marconi radio transmissions cross the Atlantic. The Nobel Foundation jointly awards Marconi and Braun the Nobel Prize in Physics in 1909 for their contributions to radio.

The invention of television adapts broadcast technology to the encoding, transmission, and decoding of streaming images as well as audio. Early television cameras use electromechanical components and the picture quality and reliability of these systems remains very low. The eventual invention of electronic components makes reliable, higher quality broadcasts possible. Though many people develop the various theories and components necessary to create electronic broadcast television, historians generally identify the American inventor Philo Farnsworth as the person who combined the technologies of image encoding, transmission, and image decoding into one functional system.[116-119] Farnsworth demonstrated his complete system prototype in 1927. Despite creating the first complete electronic system, Farnsworth fought patent lawsuits stemming from patents for a television system filed in 1923 by Vladimir Zworykin and eventually purchased by RCA.[116, 118-120] The devices described in Zworykin's application were demonstrated for

			
Picture of Philo Farnsworth (1906-1971) From: Keelynet.com	Picture of Farnsworth and his prototype broadcast system. From: Messy Nessy	Picture of Vladimir Zworykin (1888-1982) From: History of Telecommunications	Vladimir Zworykin demonstrating electronic television in 1929. From: Wikipedia

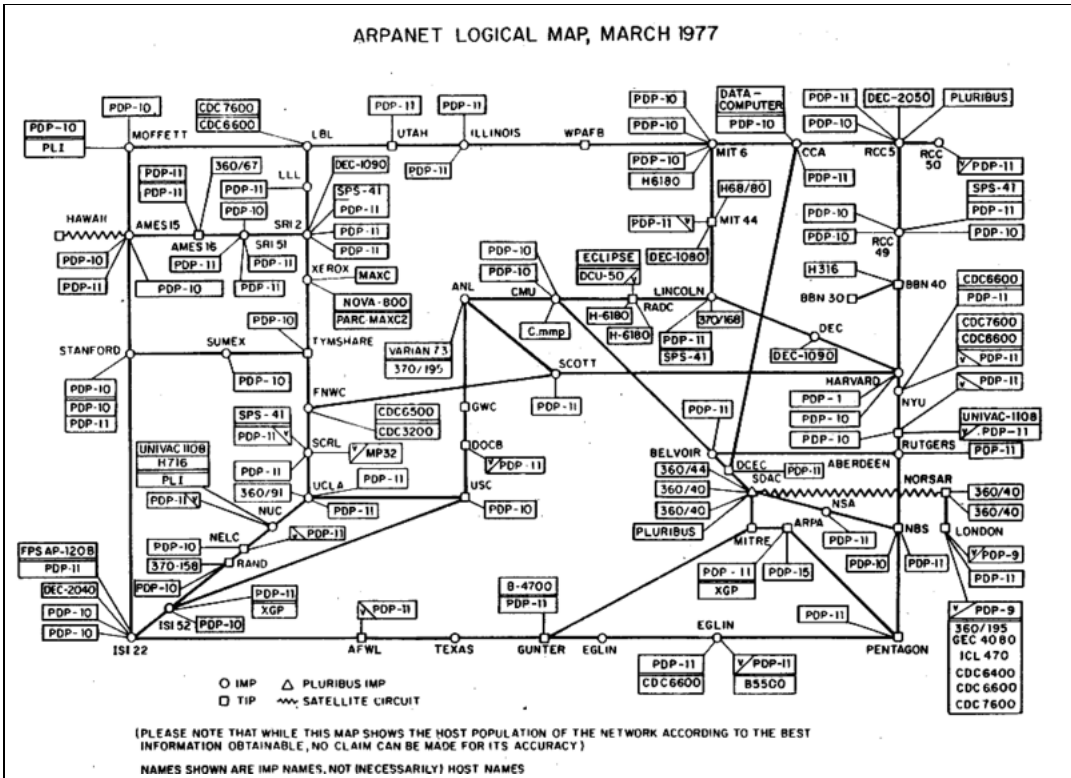
Westinghouse in 1925/1926 but they were not deemed successful enough to warrant further development. Germany began the first public electronic television broadcasts in 1935. The Berlin service was soon joined in 1936 by the British Broadcasting Corporation (BBC). In the same year NBC/RCA began broadcasting in New York City. Interested students can view a video of the original 1936 NBC/RCA broadcast here.

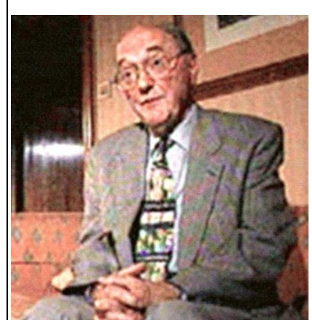
Many other inventions contribute to an ever increasing size, diversity, and richness of information ecosystems. However, this extremely superficial history jumps to (and concludes with) the development of the internet and the World Wide Web.

2.3.i The Internet and the World Wide Web

The development and expansion of the of the Internet and the World Wide Web has allowed your computer, cell phone, and tablet to become the one of the primary (and arguably, the most powerful) information conduits of the 21st century. Today the parts of the internet commonly accessed by most users contain something like 60,000,000,000,000 (60 Trillion) pages. Normally the sheer enormity of this informational leviathan would render it nearly useless, but users can navigate this expanse of information to find relevant information using powerful and fast search tools. But, how did such an unprecedented information ecosystem conduit come about?

What people now think of as the Internet has its beginnings in 1960 with the work of Paul Baran, a RAND corporation engineer. A Welsh computer scientist named Donald Watts Davies further develops Baran's work in 1968. [121-124] These men develop and introduce techniques for packet switching—a technique for grouping data into regular sized packets making efficient transmission across interconnected networks possible.[125] The first packet switching computer network, Advanced Research Projects Agency Network (ARPANET), connected UCLA, Stanford, UCSB, and the University of Utah in 1969.[126]



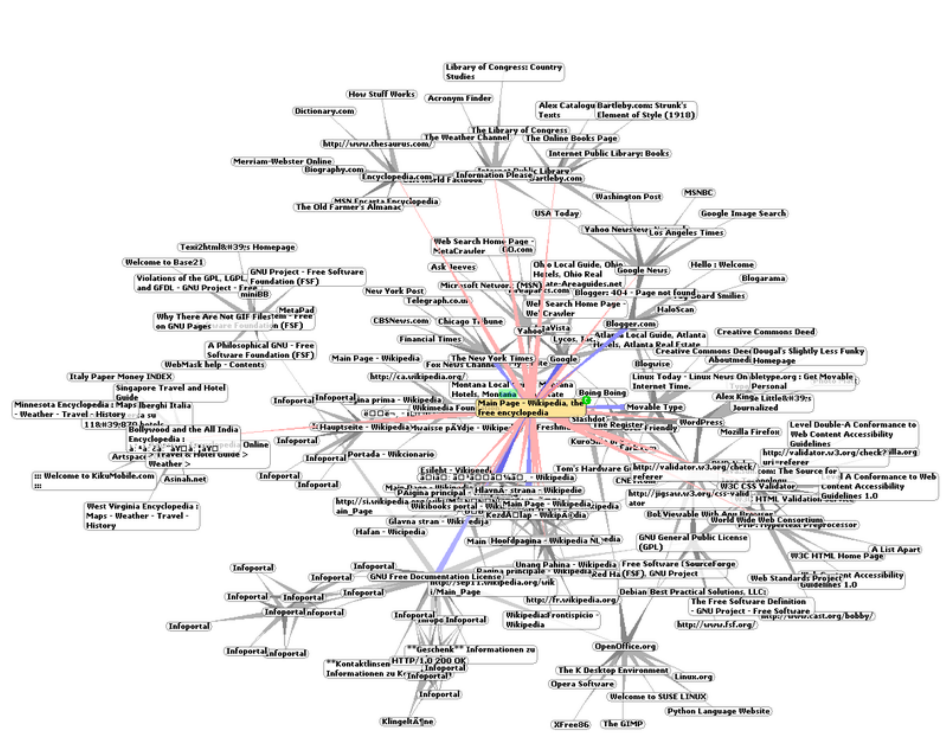


(Top Left) A diagram of packet switching computer network, ARPANET, from 1977. From Wikipedia (Top Right) A picture of Paul Baran. From Wikipedia (Bottom Right) A picture of Donald Watts Davies. From wbglinks.net

The defense department created ARPANET for military use. Widespread, user-friendly civilian packet switching networks do not appear until the 1990s and the introduction of the World Wide Web. The web has its origins in the work of Tim Berners-Lee, a British computer scientist.[127] In 1980 Berners-Lee, then at CERN (European Organization for Nuclear Research), developed a hypertext language, ENQUIRE, and set of protocols allowing different computer systems running different hardware and operating systems to exchange information.[128] Together with Robert Cailliau, a Belgian computer scientist, Berners-Lee submits a proposal to

CERN to develop a large network hypertext database publically accessible through the internet. The two men name this database the "worldwideweb".[129] Berners-Lee posts the first document in August 1991.

The development of personal computing and the internet represents perhaps the most dramatic change in humanity's ability to create and utilize a powerful information ecosystem since the advent of the written word. The internet has become a primary source of information for many people in many societies. Indeed,




(Top Left) A diagram depicting just a small part of the World Wide Web centered on Wikipedia. From [Wikipedia](). (Top Right) A photo of [Robert Cailliau](), Jean-François Abramatic (the current chair of the World Wide Web Consortium), and [Tim Berners-Lee]() at the 10th anniversary of the World Wide Web Consortium. From [Wikipedia]() (Bottom Right) A picture of the Berners-Lee's first Web server for the World Wide Web--a NeXT workstation (a NeXTcube). From [Wikipedia]()

the United Nations' International Telecommunications Union estimated that 48% of the then 7.4 billion people on Earth used the internet, which carried an estimated 97% of all electronic communications.[130, 131] The internet vastly expands both the number of the sources available to the average person and the ease of access to those sources. Today users can gather information on a mindboggling array of topics, through a variety of media including television, radio, print media, and personal communication. Individual people as well as institutions all around the world generate, contribute, and access information in this network—all without leaving the comfort of their living rooms and offices. Such a powerful and far-reaching information ecosystem only became possible in the last thirty or so years.

On the downside, as we will see, while almost anyone can create content on the internet, a great deal of content available on the internet lacks sophistication, proper source citation, and/or what one might call "commitment to the truth." As a result, one must exercise care in the formation and maintenance of internet-based elements of one's information ecosystem. Again, the reliability of information sources has been a perennial challenge for humans. Rumors, gossip, and urban legends represent examples of unreliable sources that exist long before the internet. However, because one now has access to information that can appear and disappear in a matter of minutes generated by people with whom one has no connection and who do not necessarily have any stake in the betterment of other individuals or their societies, the need to choose one's information sources carefully becomes even more important than in the past. Unfortunately, as the following chapter discusses, internet users and portals both exhibit several tendencies that vitiate the tremendous potential of the internet. Moreover, even today one cannot access all of the information potentially available through the Internet. By some estimates the search-indexed accessible Internet constitutes a mere .0018% to .0025% of the Internet.[132, 133]

2.4 Seven Significant Developments in Information Ecosystems

Students might wonder, why bother with this schematic history of information ecosystems? What does it teach us? Most obviously, it helps to illustrate the link between the quality of an information ecosystem and the ability of organisms to live complex and adaptive lives. This history also highlights seven features that can significantly improve the quality of an information ecosystem falling into roughly four interrelated categories. (1) Increasing the amount, complexity, and disparateness of information available within an ecosystem as well as the diversity of modalities through which information is stored and accessed dramatically affects an ecosystem's usefulness. (2) Increasing the number and diversity of participants and sources augments an ecosystem and tends to increase those features like the amount, complexity, variety of information. (3) Reliable sources and mechanism for rapid dissemination of information further enhances the system's potential to provide timely and useful information. (4) Finally, increasing the spatial and temporal dimensions of the information environment from which an ecosystem draws information further strengthens an ecosystem. For example, the sections on biochemical and biomechanical sensory structures, sensory organs, and sensory systems discuss the slow evolution of embodied ecosystem elements, evolution promoting four of our seven features. Sensory organs and sensory systems collect and refine basic sensing mechanisms creating more sophisticated and powerful information gathering and processing structures. Adaptive mechanisms in sensory organs and systems act to reduce noise and error in sensory information. **As a result, the transition from isolated sensory structures to sensory organs and on to sensory processing systems represents a dramatic increase in the reliability, volume, and complexity of information available to an organism.** In many cases sensory organs and processing systems also extend the range of an organism's informational environment. For example, using olfaction sharks can detect even a small drop of blood in a volume of water approximately the size of an Olympic swimming pool. Depending on the species and current and other conditions, sharks can detect blood from about a kilometer away.[134]

The discussion of fish schooling and shoaling likewise illustrates how pooling of information between individuals extends the range of each participant's informational environment thereby increasing the amount, and in some cases, the kinds of information available to each participant. The advantages of information pooling have proven significant enough that bacteria, fungi, and plants have evolved mechanisms for exchanging information. For instance, "once a single bacterium mutates to become resistant to antibiotics, it can transfer that resistance to other bacteria around it through a process known as horizontal gene transfer."[135] In similar fashion, researchers have established "in studies of Arabidopsis thaliana, also known as mustard weed, … that when a leaf was nicked, the injured plant sent out an emergency alert [airborne chemical signal] to neighboring plants, which began beefing up their defenses."[136]

Some animals such as birds have evolved more nuanced signal systems, but only humans have evolved more elaborate information ecosystems. The development of human spoken and written language dramatically increased the amount and complexity of information available to individuals as well as extending both the temporal and spatial limits of the human information environment. Blossoming trade and technological developments further increased the both the number and diversity of participants in human ecosystems as well as the modalities and speed of information transmission within ecosystems while extending their temporal and spatial ranges to the beginning of the universe and far beyond the limits of our galaxy. Indeed, contemporary human ecosystems—an only contemporary human ecosystems—exhibit all seven features to a high degree. No other animal or historical epoch approaches the power and reach of the contemporary human information ecosystem.

2.5 Chapter Summary

Beginning with the discussion of an information imperative common to living organisms, this chapter and lectures emphasize the important role that information gathering plays in the survival and thriving of living organisms. The chapter explores the development of biological and artificial channels for information collection and dissemination as well as cooperatives for gathering and verifying information, calling the networks of such channels developed and utilized by a given individual their information ecosystem. The chapter continues by discussing the evolution of information ecosystems from simple chemical and mechanical sensory structures through the advent of sensory organs and systems. It discusses the development of cooperative information exchanges, noting how the emergence of spoken languages as well as the creation of written languages and number systems further supercharge human information ecosystems. It concludes by outlining how the accelerated development of information storage and communication mediums make possible almost instantaneous transmission of information across great distances and the accretion of nearly unimaginably vast collections of information.

The next chapter and lectures turn towards a discussion of personal information ecosystems. Importantly, the chapter begins by refocusing the history given above. Early life suffers from and information deficit; an organism's access to information proves unreliable and inadequate to its basic needs. As life evolves more and more organisms begin gathering larger, more determinant, and more complex bits of information. For instance, the emergence of sensory systems allows organisms to gather complex and systematic information about features in their distal environment. Living creatures likewise improve the reliability of their information gathering sources and the range from which they gather information. At some point, organisms begin to enjoy an information surplus; they can reliably gather more information of greater complexity than proves necessary for mere survival.

But, as the next chapter suggests, humans have proven so adept at crafting ever more elaborate and sophisticated information ecosystems that they have created an age of information superabundance. As characterized in the next chapter, information superabundance occurs when so much information becomes available within an ecosystem that finding information within that information ecosystem becomes as cognitively challenging as collecting information from the environment itself. The next chapter looks at how humans have sought to adapt to information superabundance. After discussing the limitations of internet search and personalized news feeds, the chapter focuses on threats to robust and transparent information sharing. Specifically, the chapter and lectures differentiate five different kinds of so-called "fake news"; comedic news satire, amateur reporting, counterfeit news, disinformation, and propaganda.

2.6 Key Terms For The Ecosystems Chapters

Accuracy: Accurate news sources exhibit the twin virtues of reliable reporting and integrity. In other words, accurate information sources regularly offer veridical, highly evinced reports, **and** on those occasions when these sources misreport, they identify and acknowledge their mistakes. Thus, one ought to understand accuracy in terms of two dispositional properties; reliability (the tendency to deliver true and/or highly evinced information) and integrity (the commitment to reliability).

Amateur reporting: Amateur reporting constitutes the second class of "fake news." Unlike news satirists, amateur reporting consists largely of people who post information that they collect or witness. For instance, people will often post videos, pictures, and/or written accounts of events that they research or witness. Amateur reporters generally intend to report facts. However, like comedic satirists, even conscientious amateur reporters often have no training in journalism. Such reporters are often unaware of and need not adhere to any journalistic practices, nor do they have a codified set of professional ethical standards. Amateur reporters tend to lack not just training, but the resources and motivation necessary to investigate and verify their reports.

Anti-social Restrictions on Information Sharing: Anti-social restrictions attempt to undermine or limit information exchange in order to benefit some members or groups of society at the expense of others. Anti-social efforts to undermine or limit information flow come in a number of forms. The most chilling anti-social measures combine two or more of these three deliberately malicious techniques to undermine information flow in an ecosystem: information suppression, disinformation and propaganda.

Availability Cascade: Timur Kuran and Cass R. Sunstein use the term, "availability cascades," to refer to a self-proliferating process of information exchange. Specifically, the ease of information sharing together with the social pressures to conform combine to fuel a rapidly spreading acceptance of an idea or belief. As, Kuran and Sunstein note, "An availability cascade is a self-reinforcing process of collective belief formation by which an expressed perception triggers a chain reaction that gives the perception increasing plausibility through its rising availability in public discourse. The driving mechanism involves a combination of informational and reputational motives: Individuals endorse the perception partly by learning from the apparent beliefs of others and partly by distorting their public responses in the interest of maintaining social acceptance." (Timur Kuran and Cass R. Sunstein p.683)

Belief Perseverance: Belief perseverance names a human tendency to resist changing one's belief or modifying the confidence that one assigns to a belief once that belief has been formed. Belief perseverance works to render one increasingly resistant to new information—even highly reliable and predictive evidence.

Censorship (or Information Suppression): Information suppression or censorship has long been a staple of repressive governments and societal institutions. Information suppressors intend to deprive people of information in order to repress, control, or otherwise manipulate them. The typical tools of information suppression include; a dominant state-run media, prohibiting independent media, imprisoning journalists, murdering or allowing the murder of journalists, restricting internet access, monitoring and censoring the internet, and government harassment.

Comedic News Satire: Comedic news satirists produce one variety of "fake news." Satirists usually make no pretense of providing objective, serious news. Though often written by very well-informed people and extensively fact-checked, satirists intend to produce comedic entertainment rather than news. Even conscientious news satire comedians often have no training in journalism. Such comedians need not adhere to any journalistic practices, they have no codified professional ethical standards, and they do not even have to believe their own material. Likewise, news satirists generally lack the resources to conduct independent investigative research on the topics they cover. They must rely upon primary news sources for the vast majority of their information.

Confirmation Bias: Confirmation bias is an innate disposition shaping human thought. Conformation bias works to shape how humans gather, remember, and utilize information. Specifically, human beings exhibit confirmation bias when they preferentially seek out (or interpret) information to confirm their existing or potential attitudes or beliefs. One can think of confirmation bias as serving a useful purpose insofar as it leads someone to look for information that will provide additional evidence for their beliefs. Nevertheless, confirmation bias also acts to reinforce one's beliefs--even in the face of strong disconfirming evidence.

Counterfeit News: The third class of "fake news" is counterfeit news. Counterfeit news sources generally, but not always, seek to profit from fabricating sensational "news" stories. Thus, counterfeit news sources create false news for the same reasons currency counterfeiters create fake money. Counterfeit news creators deliberately deceive in order to make money from advertising revenue that their articles create. Practitioners of counterfeit news tend to adhere absolutely no journalistic practices, generally do not intend to present true accounts, and rarely engage in any fact-checking procedures.

Contextualized (Contextualization): A term used to describe how human reasoning and assessment of one's own reasoning and the reasoning of others is strongly shaped by the content of one's inferences or argument as well as the context of those inferences or arguments. For example, people tend to judge arguments as better when they agree with the conclusion of the argument and worse when they disagree with the conclusion. This particular content effect is called the belief bias.

Diversity of Media: Good information ecosystems incorporate a diversity of media. Different media—kinds of information sources--have different strengths and weakness. One ought to include print, audio, video sources. Print sources ought to include books, newspapers, and magazines. One should draw from the internet, conventional mass media (radio, and television), as well as governmental agencies and professional organizations. Within a form of media—like newspapers—one ought to cultivate a diversity of sources from local, national and international outlets. Taken together diverse media sources help to balance one's ecosystem by introducing different modes of presentation, emphases, timelines, ownership, as well as regulative and professional norms.

Disinformation: Practitioners of disinformation seek to undermine trust in standard information sources and institutions with the goal of supplanting objective, independent information sources, intimidating rivals, and manipulating public opinion. Practitioners of disinformation seek to infect information ecosystems with ideologically biased information as well as false and contradictory information. Practitioners of disinformation are disruptors. They do not wish to convince so much as to confuse. The practitioner of disinformation seeks always to muddy the informational waters, undermine trust in independent information sources, and ultimately to force either a state of general disbelief or a state of dogmatic confirmation bias among individuals.

Fecundity: A news source exhibits fecundity if it provides more than just the bare facts. A fecund information source provides unbiased context and/or analysis along with the bare facts. Such sources a very likely to report significant news in a timely fashion; they call one's attention to breaking news or trends and report news that other sources may not even notice. Fecund information sources prove highly valuable in that they help one to assess the significance of events, to differentiate isolated events from trends, and anticipate potential future developments.

Filter Bubble: Eli Parser suggests that the widespread and unmonitored use of personalization programs in search engines and news feeds acts to create a self-reinforcing bubble of idiosyncratic information around users, sheltering them from opposing viewpoints as well as denying them access to new ideas and perspectives. Filter bubbles potentially turn each of us into unwitting cyber-rubes lost within the biases and idiosyncrasies of our ever more parochial filter bubbles. For Pariser personalization can combine isolation and ignorance with little to no user oversight or insight regarding how their information gets selected. Parser notes that

> the new generation of Internet filters looks at the things you seem to like-the actual things you've done, or the things people like you like-and tries to extrapolate. They are prediction engines, constantly creating and refining a theory of who you are and what you'll do and want next. Together, these engines create a unique universe of information for each of us-what I've come to call a filter bubble-which fundamentally alters the way we encounter ideas and information. (p.9)

Information Ecosystem: An information ecosystem consists of a set of senses, artifacts, places and/or people one regularly consults to gather information, evaluate claims, or when pondering the adequacy of one's worldview. Good information ecosystems should include straight news sources, analysis and commentary sources, fact-checking and debunking sources. These sources should provide information on a range of important topics like history, law, science and medicine, politics, economics and finance, as well as current world, national and local events.

Information Environment: All living creatures inhabit an information environment just as they inhabit a biological environment. The types of information available, the manner of that availability, the ease of access, as well as the spatial and temporal horizons define this information environment. For example, the information environment of magnetotactic bacteria consists only of its relationship to the Earth's magnetic declination—the Earth's magnetic field lines pointing towards the geographic north pole.

The Information Imperative: Even simple living creatures like plants and bacteria need information to thrive. For instance, plants use information about the direction of light to adapt their growth patterns to maximize exposure. Magnetotactic bacteria use information about the Earth's magnetic field to move towards anaerobic environments and to avoid oxygen rich environments. Indeed, for most animals the ability to secure life-giving materials like water and food from the environment depends upon their ability to gather and process information in their environment. Likewise, for many living things, avoiding predators and other dangers depends upon gathering information. One might call this an information imperative. That is, our very nature as living organisms creates a need for information to promote thriving. As a result, it is an imperative of all living creatures to gather information and utilize in adaptive responses to the environment.

Information Superabundance: Most humans now have access to so much information that one of their primary cognitive challenges has become finding relevant information in a horizonless and largely uncharted repository. Sometimes people need information that simply has not been generated or disseminated, but increasingly people struggle to find reliable information that exists somewhere in a vast sea of existent data.

Information Suppression (or Censorship): Information suppression or censorship has long been a staple of repressive governments and societal institutions. Information suppressors intend to deprive people of information in order to repress, control, or otherwise manipulate them. The typical tools of information suppression include; a dominant state-run media, prohibiting independent media, imprisoning journalists, murdering or allowing the murder of journalists, restricting internet access, monitoring and censoring the internet, and government harassment.

Memes: Memes are images, videos, and/or short messages that convey an idea, norm, cultural practice, or perspective in a highly trenchant manner often using comedy. Memes often propagate through push strategies and social media in a manner somewhat analogous to propagation of genes through a population. Richard Dawkins adopts the name meme from the Greek word *mimema* meaning imitated in his 1976 book *The Selfish Gene*.[137] For Dawkins' memes refer to self-replicating units like behaviors or ideas, the spread of which through a population causes human behaviors or culture to change and evolve.

Minimally Adequate Comprehensiveness: The property of minimally adequate comprehensiveness proves a highly desirable property of belief systems. A minimally adequate belief system contains a sufficient amount and variety of information to adequately guide one in one's typical or intended decisions and actions. For example, people without a basic understanding of the functioning of the Federal Reserve System lack a belief system with minimally adequate comprehensiveness to evaluate the need for reform or abolition of the Federal Reserve System.

Personalized Search and News Feeds: Personalization algorithms filter search and news feeds by using information about your location, preferences, internet habits, search and buying history to predict what items best suit you personally. Skeptics worry that personalization's combination excessive customization with little to no user oversight effectively isolates and shields people from other perspectives and experiences—turning each of us into unwitting cyber-rubes lost within the biases and idiosyncrasies of our ever more parochial filter bubbles.

Product Placement: Product placement occurs when advertisers work with content creators so that their products appear in films, television, music, music videos, sporting events, magazines, video games, and even books. Product placement can range from showing or mentioning the product (as in the video above) to integrating the product into the story itself (often called "brand integration").

Propaganda: Propaganda consists of intentionally biased persuasive rhetoric that often evokes fears, biases, and falsehoods to manipulate emotions, opinions, and actions. Propaganda proves most effective in the absence of institutions and contexts that reveal its cynical, excessive, one-sided, and/or false nature.

Pro-social Restrictions on Information Sharing: Societies often codify some limitations on information transfer, arguing that throttling information flow actually serves the greater social good. One might call these measures pro-social restrictions.

Pull Technology/Pull Strategies: Pull strategies deliver content in response to explicit user inquiries. Pull strategies act as more passive or responsive communicators, usually limiting content to the items explicitly requested. For example, if students go to the Main Branch of the New York City Public Library, they can request a copy of Russell's *The Problems of Philosophy*. A library staffer will respond to that request by retrieving a copy of that book from the stacks. The staffers retrieve only the books a person explicitly requests and only when the books have been requested.

Push Technology/Push Strategies: Push strategies initiate contact or provide information actively without a user soliciting that information. For instance, many phone apps now notify users of events; email apps notify users of new mail, operating systems inform users of updates, etc..

Scope: One important property of a good information ecosystem consists in a large scope. Specifically, an information ecosystem with a large scope contains multiple sources providing information on a wide variety of topics. Thus, a good information ecosystem provides one with the resources to gather or check facts regarding topics as diverse as world politics and human anatomy.

Slant: Since one creates an information ecosystem as a tool for oneself, it will naturally contain a certain slant. More conservative individuals will likely develop information ecosystems with a conservative slant. Likewise, more liberal individuals will likely develop information ecosystems with the liberal slant. People who like science will likely have an information ecosystem with more sources about scientific discoveries and theories. People who like technology and gadgets will have more sources about these topics. Sports enthusiasts will have more sources providing them with information about developments in sports. Having a slant proves desirable in an information ecosystem just as modifying one's phone by downloading apps can enhance its usefulness by customizing its capabilities to its user.

Nevertheless, students ought to make a conscientious effort include sources in their information ecosystem that provide them with alternative perspectives and worldviews. One reason why one should strive to include information sources with alternative slants in one's information ecosystem consists in the potential of such sources to temper biases in how human beings process information.

Sponsored Content: Sponsored content refers to advertising that appears in internet searches and media in a manner that closely resembles news and search content. These search and media companies make money every time visitors click on these ads. Most, if not all, legitimate companies indicate sponsored content. However, the ease with which one can identify ads varies significantly among search and media outlets.

Worldview: A worldview consists of those beliefs, values, and practices that constitute a person's understanding of themselves, society, and the universe as well as that person's significance and role within society and the universe. As such, a worldview provides a vehicle through which an individual conceptualizes and interprets themselves and the world. Worldviews likewise facilitate the prediction and understanding of the behavior of ourselves and others and guides expectations as to how the world will change over time.

Yellow Journalism: Yellow journalism involves sensationalism—usually scandals or fear mongering—lavish imagery, and poorly documented, often false or misleading journalism. The term originally came into use to describe the journalism practiced by William Randolph Hearst and Joseph Pulitzer. Yellow journalists tend to be legitimate journalists who present themselves as having high accuracy standards, but who show significant tendencies towards poor accuracy—often to boost revenue. For instance, Hearst and Pulitzer needed high circulation for their papers that often cost a penny.

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