Chapter 8
Learning, Imitation, and Memes

Contents

8.1 Evolution of Complex Organisms

In the course of evolution, complex organisms arose as effective survival machines for genes. This is not to say that complex organisms replaced simple ones; rather the building of complex structures turned out to be another successful path of survival. Thus humans and bacteria coexist and are both successful, so far.

Once cells aggregated and formed cooperating complex structures, the genes for the structures coevolved to meet the demands of changing environment. Thus the structures changed with time, attaining greater complexity. The evolution of such complex organs as the mammalian eye is thus a result of eons of gradual modifications of primitive light-sensitive collection of cells – and it turns out the eye is a result of design compromises because it started out from a transparent organism and thus the retina being inside out was not a problem in the beginning, but now is! (Nesse and Williams, 1994). The marvels of evolution have been achieved through laborious work of cranes rather than miraculous "sky hooks" (Dennett, 1995). Sometimes the cranes would put up pillars on the wrong side of the skyscraper, and the whole edifice would fall, the end of an evolutionary line. Evolution occurs through trial and error, with successful trials continuing the line.

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8.2 Trial and Error

Trial and error is a basic process of evolution and occurs from the beginning in the sense that replication with variation is in fact trial and error. Trial and error became more organized, however, when cells acquired mobility. In plants, increased photosynthetic cell replication on the side facing the sun provided survival advantage. Eventually, movements of the multicellular organisms we call animals became directed and the incipient forms of sense organs and nervous systems appeared as it is more advantageous for the animal to move in the direction of food. In order to find food, it developed sensors that describe the state of the external environment in all directions (sense organs) and information channels for communication between these sensors and the motor apparatus, i.e., the nervous system.

Early nervous system was quite primitive. Sense organs simply distinguished a few situations to which the animal must respond differently. During the process of evolution the sense organs became more complex and transmitted an increasing amount of information about the external environment. The motor systems also made increasing demands on the nervous system for coordination. Special formations of nerves appeared – nerve centers which convert information received from the sense organs into information controlling the organs of movement, i.e., the brain.

8.3 Learn or Perish

As the primitive brain evolved, it developed the capacity to store prior experience as a shortcut to trial and error. If you have already done the trial and error, then you can cut down on the error rate by remembering what worked. This storage of past experience, memory, will be discussed in the next chapter; we will focus on learning itself for the present. It is important to remember, however, that learning and memory form an intrinsic whole.

At a very basic level, experience modifies organisms through habituation and sensitization. Repeated neutral stimulus results in habituation, i.e., a reduction in the animal's reaction to it. On the other hand, repeated noxious stimulus may cause sensitization, i.e., an exaggeration of response. Phenomena like learning has been demonstrated even in bacteria (Bruggeman et al., 2000). By studying the sea snail, *Aplysia californica* that has only 6 motor neurons and 24 sensory neurons, Kandel and colleagues demonstrated long-term habituation and sensitization at the level of a single synapse in response to repeated stimuli, mediated by functional changes in calcium channels and neurotransmitter release (Kandel, 1979).

Associative learning increasingly conferred serious survival advantage to those who were good at it. Both classical (Pavlovian) conditioning and operant (Skinnerian) conditioning are forms of associative learning. As with the Pavlovian dog who associated the ringing of the bell with food and salivated, animals increased the efficiency of finding food and avoiding danger through association of stimuli. In operant conditioning, animals who became ill with certain vegetation learned to avoid plants that had similar shapes and learned through experience what fruits were good to eat and what sorts of animals were easier to hunt. Such survival advantage selected for animals with better and better capacity for learning, i.e., better equipped brains.

As the brain became more complex with better capacity for association and memory storage, a new type of learning began to appear. Why go through the process of strenuous trial and painful error yourself if you can watch others? Why not just imitate the behavior of the successful one? Of course, the animals did not reason this out, it just happened that animals that happened to imitate the successful ones were able to survive better and reproduce better.

8.4 Imitation, Shortcut to Learning

Imitation occurs in nature at the gene level without necessarily involving the brain. Nonpoisonous mushrooms that resemble poisonous ones are not readily eaten by animals and thus have a survival advantage. So with nonpoisonous snakes that resemble poisonous ones.

Female fireflies of the Photuris species imitate the flash of other species of fireflies to lure the males and eat them. Furthermore, by eating them, they acquire chemicals from the victims that render them less attractive to their own predator spiders (Eisner et al., 1997).

Cephalopods such as octopuses and squids can imitate the coloring of their surroundings to blend in and avoid predators. Unlike the mushrooms and snakes that resemble the poisonous ones from the beginning, the cephalopods' imitation probably involves rather sophisticated brain activity (Wood and Jackson, 2004). Songbirds imitate their parents and "learn" to sing. Monkeys are of course well known for their imitations of humans. With songbirds and primates, the brain is clearly in charge in imitative learning. With the development of complex nervous systems, imitation became the basis of many repertoires of behavior that are added to those inherently encrypted in the genes.

Before imitation, the only way a new behavior could be passed on from one generation to another was purely by mutation, i.e., if the new behavior happened to be based on a mutation that passed on to the offspring. No learned behavior, such as those acquired by conditioning, could be passed on. With imitation, new generations can learn behaviors from their elders. Imitation, then, may be seen to be a new mode of cross-generational informational transmission that complements traditional genetic transmission.

Imitation replicates the behaviors and emotional expressions that are generated by another organism's experience, i.e., memory. Through imitation, memory is replicated in another brain. For example, monkey A happens to crack a nut with a stone, memory is formed, and remembers the action and uses a stone the next time he obtains a nut. Monkey A's son, monkey B, observes his father successfully cracking a nut with a stone, forms a memory of it, and when he (monkey B) obtains a nut, he copies his father's behavior that was stored in his own brain and cracks the nut with a stone.

Social learning is, of course, not based solely on imitation, though trying out what someone else does form its foundation. It is also not necessarily cross-generational – in fact, imitating peers is the norm both in humans and animals. For example, a young female Japanese macaque discovered that she could wash the sand grains off her sweet potatoes in water, and this behavior spread throughout the troop (Heyes and Galef, 1996). Chimpanzees learn from others how to insert stalks and twigs into an ant nest and harvest them to eat (Goodall, 1964; Sugiyama, 1995).

At a certain level of complexity of the brain, ideas or concepts arose. An idea is a brain code based on processed memories, i.e., an abstract meme. Ideas can be communicated to another either through imitation, emotional expression, or other means of communication. For example, an animal may cry out at the sight of a predator, and others who have not seen the predator may get the idea that there is danger and flee. Some ideas spread, i.e., ideas became infectious, i.e., they replicated themselves in other brains as memes. Some ideas are gene derived within an individual's brain, others are memes from outside that took up residence in the individual's brain.

Eventually, with the advent of language, memes could be propagated through words (which are themselves memes) instead of the action the words represent.

8.5 Coevolution of the Brain and Memes

It is well known that humans have the largest brains among all animals. The brain size of early hominids up to about 2.5 million ago was not much larger than present day chimpanzees, but it grew rapidly with the transition from *Australopithecus* to *Homo*. By about 100,000 years ago, human brain size achieved that of modern *Homo sapiens* (Blackmore, 1999).

The modern human brain volume is approximately 1,350 cm^3, about three times the size of existing apes of comparable body size (Jerison, 1973). With this large brain, humans have developed civilizations and technologies quite unlike any other animal. Clearly, from the point of view of pure genetic survival, such large amount of brain activity is quite unnecessary. Brain is an expensive organ to keep – it consumes 20% of the body's energy, weighing only 2% of the body's weight. To quote Steven Pinker, "Why would evolution ever have selected for sheer bigness of brain, that bulbous, metabolically greedy organ? Any selection on brain size itself would surely have favored the pinhead" (Pinker, 1994).

In addition to being expensive to maintain, the brain is an expensive organ to build, requiring much resource during early life for myelination and growth, more than tripling in size in the first few years. It is also a dangerous organ for reproduction as it is often too big for the birth canal. And it is getting bigger! What might be the evolutionary selection pressures that resulted in the large brain?

Susan Blackmore proposed that a turning point in evolution occurred with the advent of memes, i.e., memes changed the environment in which genes were selected, and that the direction of change was determined by the outcome of memetic selection (Blackmore, 1999). She argues that genes were selected for bigger and bigger brains in humans because of the selective advantage of imitation, i.e., memes.

Blackmore suggests that there are three skills needed for imitation – making decisions about what to imitate, complex transformation from one point of view to another, and the production of matching bodily actions. The skills needed in imitation, i.e., putting oneself in another's shoes and then imagining oneself doing it to achieve the same end, she argues, are exactly the skills needed in advanced social skills known as Machiavellian intelligence or theory of mind (TOM). Machiavellian intelligence involves the ability to manipulate and deceive others as well as to form and dissolve alliances to achieve social or political success, and involves exactly the skills of putting oneself in the other's shoes and taking the other's point of view, and imagining what it would be like to be the other. This intelligence is most prominent in humans, but has been demonstrated in other primates such as rhesus monkeys (Chicago, 2007).

Homo habilis, which means "handy man," some 2.5 million years ago first started using stone tools. Tool making probably spread through imitation, with further refinements and changes in styles, which also spread. With tool making, the better imitators of better tool makers obviously had better chance of success. And more successful imitators of more successful people had better chance of success in survival and mating (Blackmore, 1999). The escalation in skills for making better tools and the skills to imitate the successful ones who were skillful or had high Machiavellian intelligence led to an escalation in increase in brain size in humans. And with increased brain size came increased complexity both in tools and in social structure, i.e., memes that are the basis of culture and civilization. Memes and genes for brain size and complexity must have coevolved.

Another example of gene–meme coevolution is that of lactose absorption and dairy farming. There is a correlation between lactose tolerance and history of dairy farming in populations, i.e., over 90% of populations with history of dairy farming are lactose tolerant, while only about 20% of populations without the history of dairy farming have sufficient lactase activity (Leland and Odling-Smee, 2000). A population genetics analysis revealed that the allele for high lactase activity depends on the probability that the children of the milk users will adopt the meme for milk consumption (Feldman and Cavalli-Sforza, 1976). Furthermore, they found a broad range of conditions under which the lactase allele does not spread in spite of fitness advantage, demonstrating that memes complicate the genetic selection process.

The "Machiavellian intelligence" or the "social brain" hypothesis posits that large brains and distinctive cognitive abilities of humans have evolved through intense social competition in which the competitors developed increasingly sophisticated "Machiavellian" strategies as a means to achieve higher social and reproductive success. A mathematical model was constructed in which genes control brains which invent and learn strategies (memes) which are used by males to gain advantage in competition for mates. In that model, Gavrilets and Vose found that the dynamics of intelligence had three distinct phases (Gavrilets and Vose, 2006). During the dormant phase only newly invented memes were present in the population. During the cognitive explosion phase the population's meme count and the learning ability, cerebral capacity (controlling the number of different memes that the brain can learn and use), and Machiavellian fitness of individuals increased in a runaway fashion. During the saturation phase natural selection resulting from the costs of having large brains checked further increases in cognitive abilities. The results suggest that the mechanisms underlying the "Machiavellian intelligence" hypothesis can result in the evolution of significant cognitive abilities on the timescale of 10–20,000 generations. They showed that cerebral capacity evolves faster and to a larger degree than learning ability. Their model suggests that there may be a tendency toward a reduction in cognitive abilities driven by the costs of having a large brain as the reproductive advantage of having a large brain decreases and the exposure to memes increases.

Memes arose when genetic evolution reached a certain complexity of the brain and facilitated the brain's growth, which in turn helped the spread of memes. The relationship between genes and memes is not, however, always facilitative. Certain brains may be wired to reject memetic spread, and memes can interfere with the spread of genes through such practices as celibacy, birth control, and suicide.

From the gene's point of view, our bodies are just vehicles or containers for their perpetuation. From the meme's point of view, our brains are just vehicles or containers for their perpetuation. Genes have evolved to make better, sturdier, and more efficient containers for themselves, and so have the memes in producing better and bigger brains. Memes have, in addition, evolved a means of existing and replicating outside of brains, in electronic media, books, DVDs, and computers. Eventually, memes might not need brains at all to survive and replicate. Would this mean the end of genes? Not necessarily. Genes are packets of information encoded in DNA consisting of four nucleotides. Seen in this light, genes are nothing but memes encoded in nucleotides. Although the concept of memes as we currently use the term arose from imitative learning and storage and transmission of information at a fundamental level, memes invented genes, invented bodies, brains, and computers. The evolution of memetic containers will go on, relentlessly trying out different materials and forms.

8.6 Empathy and Mirror Neuron System

We saw in the previous section that what is required in imitation is an ability to put oneself in the other's shoes. When it comes to feelings, this is exactly what we call empathy; empathy is imitation of another's feeling. Empathy is usually achieved through a reading of the other's facial expression, body language, as well as verbal communication and an understanding of the person's situation. What is the neural substrate of empathy?

Mirror neurons were first described in the ventral premotor cortex of the rhesus macaque brain and later in the inferior parietal lobule. These neurons fire when a monkey performs a goal directed hand and mouth actions as well as when it observes the same action being performed by others (Ferrari et al., 2003; 2005a; b). This mirror neuron system (MNS) may form the neural substrate for understanding others' actions as well as intentions via a simulation mechanism whereby observing others' actions elicits neural activity in neurons that would be activated if the animals were actually engaging in the same activity. Thus, the mirror neuron system may form the basis of imitation in primates.

Mirror neuron system has been demonstrated in humans that encompasses the pars opercularis of the inferior frontal gyrus and adjacent ventral premotor cortex and the anterior inferior parietal lobule (Iacoboni and Dapretto, 2006; Rizzolatti and Craighero, 2004). The MNS, in concert with activity of the anterior insula and amygdala, is considered to be involved in the decoding of others' emotional states (Carr et al., 2003; Gazzola et al., 2006; Lenzi et al., 2008; Schulte-Ruther et al., 2007).

Observing facial muscles denoting a particular expression elicits firing of mirror neurons that are fired when one has similar expressions oneself. The frontal component of the MNS then modulates the activity of the amygdala and the limbic system to match the expression through connection to anterior insula. MNS activity in response to nonemotional stimuli has been associated with cognitive aspects of empathy, such as perspective-taking abilities (Gazzola et al., 2006), as well as with empathic concern (Molnar-Szakacs et al., 2006). As for emotionally laden stimuli, personal distress and, to a lesser extent, perspective taking have been associated with MNS activity in response to disgusted and pleased emotional expressions (Jabbi et al., 2007). Emotional empathy and empathic concern have also been linked to MNS activity in the right inferior frontal cortex while viewing angry and fearful facial expressions (Schulte-Ruther et al., 2007).

It seems thus that, with the development of mirror neuron system, imitation is built into the brain which reciprocally reinforces the theory of mind (TOM, Machiavellian intelligence), or the ability to think and feel like the other.

8.7 Meme Generation and Meme Infection

We discussed how our brains may have evolved to accommodate increasing memes. Are all memes in our brains then parasites? Not necessarily. Some memes obviously arose de novo in certain individuals, then, spread through imitation, and in humans, through symbolic communication, i.e., language. The mirror neuron system provides a direct example of how memes may arise in the form of motor expression before they have been fully assembled with emotion and meaning, i.e., before connections have been made with neurons in the limbic system and association cortices.

The activity of the mirror neuron system may later be connected with the cortex and the limbic system, especially if the activity is efficacious.

Some memes arose from plain trial and error – like the first monkey who happened to crack a nut with a stone. Then, “crack a nut with stone” meme spreads throughout the troop by observation (infection).

Memes are essentially memories that skip brains and infect other brains. When these memories are recalled and reassembled to meet current needs, we have *information.* Existing information is compared with incoming information leading to appropriate action.

Then, is all information memes? Yes to an extent. The “crack a nut with stone” idea would be a successful meme within the monkey as it would be replicated over and over again when he found a nut. If the “crack a nut with stone” idea stayed in one monkey’s brain without being transmitted to other monkeys, it is not a successful meme in terms of longevity across generations. On the other hand, most likely, other monkeys would see the monkey cracking a nut and imitate it, and then the meme would spread successfully horizontally. Just as certain RNA’s and DNA’s are potential but not successful genes, memes may arise and fall without ever becoming successful, success being defined as the ability to infect and replicate.

Not only information about facts and behaviors but also emotions can be memes as long as they can be remembered and transmitted. A recent finding from the Framingham heart study social network is that happiness is contagious. In a 20-year follow-up of nearly 5,000 people, clusters of happy and unhappy people were found in the network. The clusters of happiness seem to result from the spread of happiness and not just a tendency of happy people to associate with each other. According to this study, a person’s probability of being happy is increased by 25% if a friend who lives within a mile and becomes happy. Coresident spouses and siblings who live within a mile, and next door neighbors had similar increases in probability to be happy (by 8, 14, and 34%, respectively) (Fowler and Christakis, 2008). Happiness spread even to people who were separated by three degrees of separation and not even known to each other.

What exactly is meme contagion or infection? Does a meme physically enter the brain of the host?

In a sense, the answer is yes. A meme is a packet of information, i.e., an idea, emotion, or behavior, or a recipe to create the idea or emotion or behavior. Information content should not be confused with the carrier or vehicle through which it travels, which themselves are also memes. For example, the information content of the meme of “love” is not the assemblage of the letters l-o-v-e (which are themselves memes), but rather the *idea* that can be expressed as “amour,” “Liebe,” “ 名 爱,” or “hluv.” Because we have in our brains the genetic and memetic apparatus to process memes that associate themselves with various forms of conveyance (languages, images, sounds), we have the capacity to understand, empathize, and influence other brains as they do ours.

Information changes the brain just as a virus (a packet of DNA or RNA, genetic code) changes a cell. The exact mechanism of meme-induced brain changes in the form of memory will be discussed in the next chapter.

When you throw a pebble in a lake, waves are formed that cause all the water in the lake to resonate without the pebble touching all the water molecules. Likewise, a new meme may affect all brains exposed to it. Of course, you can create a counter-wave in the lake to neutralize the pebble waves. The brains may also have counter-memes that may already be there, or newly introduced.

As memes have discovered new carriers outside of the brain such as books, computers, electromagnetic waves, DVDs, memes can now reside independently of human brains. In fact, some such memes have flown out of the planet Earth in space ships. Some such memes may infect nonhuman hosts in other planets and find a separate path of evolution (Fig. 8.1).

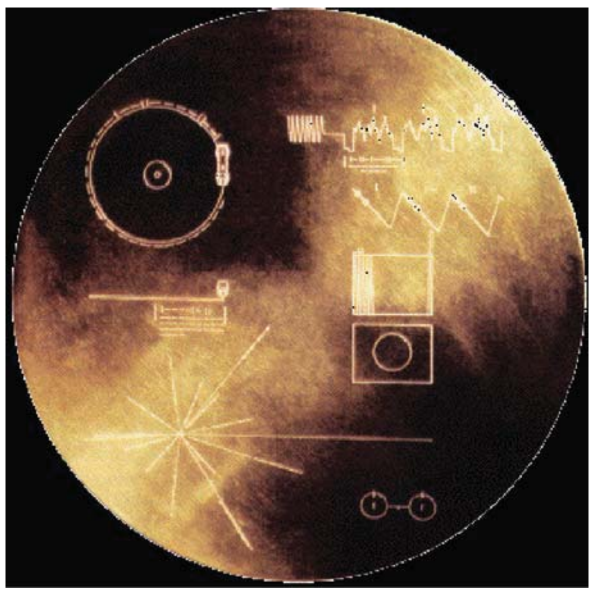

Fig. 8.1 The Voyager Interstellar Record with 2 h of images and sounds of earth. A 33 rpm grooved gold record 1977 (http://www.cedmagic.com/featured/voyager/voyager-record.html)

8.8 What Is a Meme?

A meme is memory that is transferred or has the potential to be transferred. The transfer of a meme may be from one brain to another, from a brain to a medium such as books, recordings, and digital media. Memes may be broadcasted, i.e., dispersed from the brain like seeds or spores. Memes are replicators. Replication occurs either within the brain or outside the brain. Replication occurs in two forms: direct replication as in being copied by a Xerox machine, or through transmission to other brains and then to other brains, etc. Within the brain, replication may occur through direct contact with other neurons and conferring the memory to them, or through reinforcement of the memory within the neuron which results in increased potential for the meme to reach consciousness and thus to be broadcasted or transmitted to other brains or media.

Memes need not be consciously transferred to be spread. Imitation is an example in which memes are created by simple observation. Such memes created through imitation may be either transmitted consciously in language or transmitted nonverbally through imitation by others. What is critical here is that the behavior that is imitated is remembered, i.e., memory has been formed that is potentially transferred.

Since Dawkins described memes as an analog of genes, there has been confusion concerning what the relationship between genes and memes is. Before the discovery of DNA, genes were defined purely by the phenotype, e.g., genes for blue eyes, color blindness. Now we know that strands of DNA make up the basis of protein synthesis that underlies the phenotypes. There are, however, many strands of DNA that do not produce protein ("junk DNA") but are faithfully replicated and may affect other DNA strands. DNA replication is dependent, however, on the phenotype's success in mate selection. Genes are a sequence of replicating nucleotides that carry *both* the information and the machinery for replication.

Memory is the precursor and foundation of memes. Memory served to reduce the error rate of trial and error. Out of memory arose *ideas*, interconnection among neuronal clusters containing memories that facilitated learning. As the complexity of the nervous system increased through evolution, imitation became a shortcut to trial and error. When ideas and actions acquired the means of replication through observation and imitation, they became memes, or replicating information. Memes are encoded in the neurons of the brain as "brain codes" as will be discussed in the last section of Chapter 9. As memory and ideas are interconnected, assemblies of memories and ideas formed, which were more convenient to store and retrieve. Some of these assemblies were particularly useful and thus tended to be imitated or learned together. Such assemblies are sometimes called memeplexes. However, it should be noted that when we talk of memes, much of the time we are talking about memeplexes.

The advent of mirror neurons facilitated imitation and a new means of meme manipulation – the Machiavellian intelligence. With the development of language (which is nothing but new containers of memes), memes acquired the means of spreading beyond the brain's immediate proximity of time and space.

Memes, consisting of only information, did not possess the means of replication, which has to be dependent on matter–energy-dependent processes (Crofts, 2007). Memes, as pure information or code, were stored as memory, constructed as thought, schema, knowledge, and emotion, emitted as sound, expression, and eventually in language, none of which carried the machinery for replication. Of necessity, meme replication was done by brains infecting other brains.

What, exactly, is meme replication? Karl Marx wrote *Das Kapital*, which gave rise to the meme, *communism.* It spread from brain to brain, eventually resulting in the meme taking over the governing structures of many countries during the twentieth century. It also evolved differently in different locations, so that the communisms practiced in different countries, e.g., Soviet Union, China, North Korea, Hungary, were very different. One can see that the complex memeplex that is communism consisted of many memes, including ideas concerning economics, equality, fairness, labor, profit, collectivism, ends justify means, authoritarianism, universalism, nationalism, etc. Many of the component ideas were also mutually contradictory while others were mutually reinforcing. Thus a meme complex can be replicated in many different ways through component memes and may mutate rapidly while maintaining the label and some vestiges of the original meme. Memeplexes often organize people or groups of people for their perpetuation and replication – such as political and religious organizations that reinforce the memes, and schools and institutions to replicate themselves in fresh brains.

Memes have been likened to a virus, which can replicate only when it finds a suitable cell. A meme, say an idea written in a book, does not enter the brain and make books in the brain. Memes are more like prions. Once a prion is in contact with a suitable protein, it changes the configuration of the existing protein, which, in turn, changes the configuration of an adjacent protein. So does an infected brain change adjacent brains through communication.

With the advent of computers and the information age, however, memes may have acquired the material means of self-replication, i.e., memes no longer need brains for actualization and replication. In fact, it may be that the achievement of a certain level of information-processing capacity inevitably means the ability to decode memes, regardless of their origin. This would be the hope if the Voyager disk were to be understood by an intelligent being in another part of the galaxy. It is also possible that memes may find that an efficient way of self-replication is encoding themselves with nucleotides in a new environment!

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