Physical Aspects of Cognition and Consciousness, and Unification Thought

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1. Human Cognition and Consciousness

Human cognition is a phenomenon to be understood by physiology, while consciousness is a psychological topic. Nevertheless, cognition and consciousness are intimately related and mutually interacted: cognition provides data to form consciousness and consciousness give directions for cognition to select for human well-being. Recently there has been a great interest in human cognition stimulated mainly by the emergence of NBIC (nano-bio-info-cogno) technologies which is also called converging technologies. The converging technologies refers the synergistic combination of four major provinces of science and technology each of which is developing at a rapid rate: (a) nanoscience and nanotechnology; (b) biotechnology and biomedicine, including genetic engineering; (c) information technology, including advanced computing and communications; (d) cognitive science, including cognitive neuroscience.

We are already experiencing the dramatic changes brought on by computers, communications, and the internet. The combination of science and technology with entrepreneurs and venture capitalists has created a momentum of change which is extraordinary. Following the successful Human Genome project there is an emerging assertion to launch Human Cognome project which is a program to understand the structure and functions of the human mind. Indeed the human mind is the ultimate frontier for human to challenge and unraveling its mysteries will bring tremendous benefits. Cognitive science and neuroscience will continue to advance our understanding of the human information processing system and the way our brains work.

At this point we will digress briefly to appreciate the scale of successful information coding and evolution. People have existed on earth in one form or another for about 2 million years, which is a few hundred thousand generations. Today there are about six billion people on earth. The human body is made up of about 10^{13} cells, the human brain about 10^{10} cells (10^{27} atoms), and the human genome is about 10^9 base pairs. Humans have solved numerous problems over the generations, creating successful civilizations and businesses as well as creating a growing body of knowledge to draw on to solve increasingly complex and urgent problems. In some ways, however, bacteria, the primitive life form, are even more impressive than humans (Howard Bloom 2001). Bacteria have existed on earth for about 3.5 billion years, which is an estimated 10^{14} bacteria generations. Today there are an estimated 10^{30} bacteria (or about one hundred million bacteria for every human cell) on earth living inside people, insects, soil, deep below the surface of the earth, in geothermal hot springs in the depths of the ocean, and in nearly every other imaginable place. Bacteria have been successful "problem-solver", as is evidenced by their diversity and ever-growing bag of genetic tricks for solving new problems. People have made use of bacteria for thousands of generations in producing bread, wine, butter, cheese, soy sauce, and kimchi etc., but only in the past couples of generations have bacteria become both a tool kit and a road map for purposeful gene manipulation. Bacteria and viruses are both an ally and a threat to humans. Among our best new allies in this flight are the advances in life sciences technologies enabled by more powerful digital technology. Most recently, electronic transistors have been around for less than a century, and at best, we have only a few dozen generations of manufacturing technology. Today there are more than 10^{18} transistors on earth, and very roughly 10 million transistors per microprocessor, 100 million PCs manufactured per year, and 10 billion embedded processors. Nowadays the digital technology is also growing exponentially. Internet traffic doubles every 6 months, wireless capacity doubles every 9 months, optical capacity doubles every 12 months, storage doubles every 15 months, and chip performance (per Moore's law) doubles every 18 months.

Although we are fascinated by the technological achievements in such areas as computers and communication systems, the efficiency and complexity of sensory systems far exceed even the most sophisticated man-made such systems. Sensory systems not only interpret physical stimuli such as those carried by light, sound, odors and flavors but they also provide input to our emotional brain either consciously or unconsciously. Sensory organs contain sensory receptors and structures that conduct the physical stimulus to the receptors and which ultimately provide conscious awareness of physical stimuli. The main function of sensory receptors is to transform physical stimuli into trains of nerve impulses in the afferent nerve fibers that innervate the receptors. The properties of the receptors and the media that transmit the physical stimuli to the receptors determine the range of stimuli that are coded in the discharge pattern of the afferent nerve fibers. The wavelength range of visible light, the frequency and intensity range of hearing, and the range of vibrations that can be sensed by skin receptors, along with the range of chemicals that can be sensed by the chemical senses (olfaction and gestation), depend on the properties of the receptors and the media that transmit the physical stimuli to the receptors. Sensory organs that respond to innocuous stimulation perform two important kinds of tasks for the organism: (1) detect a physical stimulus that reaches one of its sensory organs, and (2) communicate that information to the sensory nervous system where extraction of useful information occurs. The sensory receptors of the five primary senses are located in the special sensory organs of vision, hearing, olfaction, and taste and in the somatosensory receptors that are distributed in the skin over the entire body. In what follows we will provide a brief description of the five sense organs and their receptors, which is followed by discussions of the basic physiology of the sensory organs and the mechanisms of sensory transduction.

A. Vision

The visual system has been studied extensively, and in many ways its function is better understood than any other sensory system. The visual system has been studied in great detail in the cat and monkeys. It is assumed that the visual system of monkeys is similar to that of humans, and the visual system of the macaque monkey seems to be most similar. There are considerable differences, however, among the visual systems of mammalian species, and the eyes of diurnal animals differ from those of nocturnal animals. Some species have color vision, while others see only black and white. In fact, few mammals other than primates can distinguish colors. Birds, which are also diurnal animals, have color vision but use different mechanisms to achieve color vision; birds use droplets of oil to split light into its different wavelengths. Mammalian vision spans the wavelengths from 400 to 700 nm. The range of wavelengths of human vision corresponds to the range of colors from violet to deep red. Birds can also see ultraviolet light, which mammals cannot do. Some insects can discriminate the polarization angle of polarized light, and it is believed that they use that ability for navigation. There are other species differences in the visual system in addition to the ability to discriminate color. For example, the organization of the ascending visual pathways is different in animals with forward-directed eyes compared with animals with eyes that point laterally.

The eye consists of the conductive apparatus and the retina. The conductive apparatus contains the cornea, lens, and the pupil, which is located in front of lens. The lens project an inverted picture on retina. The focal length of the lens can change to focus near objects on the retina, but this ability is lost with age. The pupil can regulate the amount of light that reaches the retina. The retina, which contains the photoreceptors and a neural network that process the output of the photoreceptors, is located at the inside of the back wall of the eye.

In the human eye, the wall behind the photoreceptors is covered with a dark layer. In many animals, the wall behind the photoreceptors reflects light, which causes light to travel through the layer of photoreceptors twice. Such a reflecting layer is present in the eyes of mammals that are mainly nocturnal, such as cat and the cow, causing the eyes to glow in the dark when hit by light. The fact that light passes twice through the photoreceptors increases the sensitivity of the eye, but the slight difference between the direct and reflected image can blue the image and reduce the spatial resolution of such eyes. The dark pigmented layer behind the photoreceptors in humans and other primates prevents light from being reflected after it has passed the photoreceptors from being activated twice.

The sensitivity of sensory system is enormous and it surpasses most of out technical systems. Eyes of insects such as night moths, which are active when light is very weak, can detect one or two light quanta, and even our own eyes are very sensitive and can detect approximately 15 light quanta.

The sensitivity of the eye depends on the stimulus, and the sensitivity of the eye is not uniform over the range of wavelengths to which it responds. The range of vision is similar for most mammals but, for instance, insects can see ultraviolet light, which is outside the visible range for mammals. Rods, part of photoreceptors detecting brightness of light, have their best sensitivity at wavelengths of approximately 500 nm, corresponding to green, bluish light. The color or wavelength of light to which the human eye is most sensitive therefore depends on its state of adaptation. Daylight in the middle of the day has a broad spectrum with considerable energy emitted in the range of wavelength from 420 to 700 nm, which is from violet to red. The light-adapted eye using cones, part of photoreceptors detecting color, is most sensitive to light of wavelength of approximately 555 nm, corresponding to green light. The sensitivity of the eyes also depends on the location on the retina where the light is projected because the density of photoreceptors on the retina is not uniform.

The sensory cells, photoreceptors, are located in the retina, which covers the inside back wall of the eye. The human eye has two kinds of photoreceptors: rods and cones. Rods are more light-sensitive than cones, therefore, rods are used in detection of dim light. Cones provide color discrimination and fine resolution of vision. The outer segment of both types of receptors is the region that is sensitive to light. These cilia consist of stacks of disc membranes formed by folded plasma membranes. The photosensitive substance in the rods, which are the most sensitive photoreceptors, is *rhodopsin*. The eyes of mammals, which can discriminate color, have three different types of cones, each of which contains one of three different but related molecules of photopigment. The different pigments absorb light of different wavelength, which makes the cells sensitive to different parts of the light spectrum – the basis for color discrimination. The inner segment of the photoreceptors contains the nucleus and the energy-producing apparatus of the cells (mitochondria). The photoreceptors end in a small stalk; the synaptic terminal that makes contact with cells in the neural network is located in the retina in front of the photoreceptors. The neural network that is located in front of the sensory cells in the retina processes visual information before it reaches the optical nerve. Because the neural network is located in front of the photoreceptors, light must pass through the neural network in order to reach the photoreceptors, and it must pass through the cell bodies of the photoreceptors to reach the light-sensitive part of the photoreceptors. That means that these structures must be transparent.

It has recently been shown that other light-sensitive cells. Besides rods and cones, are found in the retina. The other light sensors in the retina are involved in resetting the body's clock, which is important for maintaining correct circadian rhythm. This means that individuals whose normal retinal cones and rods are destroyed and are therefore blind can still maintain their circadian rhythm. These photosensitive cells use *melanopsin* as the light-sensitive substance.

The rods and cones are unevenly distributed over the retina, with cones concentrated in the fovea region and rods located in the periphery of the retina. The density of cones is largest in fovea area, and there are no photoreceptors where the optic nerve leaves the retina which is called the blind spot. The neural network in the retina consists of bipolar cells that connect the photoreceptors to ganglion cells (vertical connections). Horizontal cells and amacrine cells make connections between photoreceptors and between ganglion cells (horizontal connections).

B. Hearing

Humans can discriminate between a large number of different sounds, as is evident from our ability to understand speech, recognize the voices of many different people, and discriminate among many kinds of sounds, including music. Several of the basic qualities of sounds that we can discriminate have been identified through psychoacoustic experiments using simple sounds. The ability to discriminate sounds is a result of analyses that occur in the ear (the cochlea) and the auditory nervous system. The cochlea also has an intricate amplifying function that increases the ear's sensitivity by approximately 50 dB.

The ear consists of three main parts, the outer ear (the pinna and ear canal), the middle ear, and the cochlea (inner ear). The outer ear and the middle ear conduct sound to the cochlea, where the sensory epithelium containing the sensory cells (hair cells) are located. The cochlea is fluid filled and enclosed by a bony capsule which has two openings: the round window that is covered by a membrane and the oval window in which the footplate of the stapes rests. Conduction of the stimulus to the receptors in the ear is more complex than in other sensory systems. The two main steps are transformation of sounds in air to vibrations of the cochlear fluid and conduction of the vibrations of the cochlear fluid and conduction of the vibrations of the cochlear fluid to the hair cells.

The sensitivity of our auditory system is also amazing. In the most sensitive frequency range the amplitude of vibration of the eardrum at the threshold of hearing is less than 10^{-9} cm (1/100 of one nanometer [nm]), corresponding to less than 1% of the diameter of a hydrogen molecule. Under the best circumstances, the sensitivity of the auditory system in humans is near its theoretical limits set by Brownian motion of the cochlear fluid. The sensitivity of the human ear is similar to that of other animal species, although the cat has an approximately 10 dB lower threshold than humans between 1 kHz and 7 kHz and 20 dB or more between 10 and 20 kHz. Humans can hear in the frequency range from approximately 20 to 20,000 Hz. The upper limit decreases with age. Some animals have hearing at higher frequencies than do humans. For example, the cat hears up to approximately 50 kHz, approximately the same as the rat. The flying bat, dolphins, and whales can hear sounds above 100 kHz.

The threshold of sensory system depends on the type of stimulation, and the sensitivity of the ear is not uniform over the audible frequency range. The highest sensitivity of the human ear is in the frequency range from 500 to 6000 kHz. The absolute value of the threshold depends on how the sounds are presented: monaural (sound to one ear only), binaural (sound to both ears at the same time) by earphones or in a free field at 0 degrees azimuth (angle in the horizontal angle) or at random incidence.

The dependence of the threshold of sensory systems on prior stimulation is known as *adaptation*. Prior exposure decreases sensitivity of sensory receptors. For vision, the highest sensitivity is achieved when no light has reached the eye for some time (the dark adapted state of the eye). Exposure to light reduces the sensitivity of the eye to an extent and for a period of time that depends on the exposure. In that state the sensitivity of the eyes is determined by the sensitivity of the rods (scotopic vision).

Prior stimulation also affects the sensitivity of the ear, and exposure to loud sounds causes temporary threshold shift (TTS); exposure to even louder sounds cause permanent damage to the ear known as permanent threshold shift (PTS). The decrease in sensitivity that is caused by overexposure is also sometimes referred to as (auditory) *fatigue*. The reduction in the sensitivity of the ear depends on the intensity of the sound and its duration and frequency. The TTS is largest approximately 1/2 octave (1400 Hz) above the frequency of the tone that caused the fatigue (1000 Hz); it accelerates as the intensity of the fatiguing sound is increased.

The threshold of a test stimulus can be elevated by the concomitant presence of another stimulus of the same type, thereby *masking* the perception of the test stimulus. Masking is pronounced in hearing, where it has been studied extensively. It is well-known how stimulus parameters affect a sound's ability to mask another sound. The efficiency of a sound in masking another sound depends on its intensity and its frequency relative to the test sound. In general, low-frequency sounds are more effective in masking high-frequency sounds rather than vice versa. Different sounds mask each other according to the width of the *critical band*. Two sounds that are separated in frequency by less than one critical band are most efficient in masking each other, while sounds that are separated in frequency by more than one critical band are less effective in masking each other. Stimuli do not have to occur simultaneously to mask each other. A stimulus that occurs just before another (second) stimulus, but does not overlap it in time, may change the threshold of the second stimulus. This temporal effect in masking is referred to as forward masking. Forward masking is less efficient than simultaneous masking. A masker can also affect the threshold of sensory systems to a stimulus that is presented after the masker, and this is known as backward masking. Backward masking is usually less efficient than forward masking, and its effect occurs during a shorter interval of time relative to the test stimulus.

C. Chemical Senses: Olfaction and Gustation

Olfaction and gustation have been called the chemical senses since they are stimulated by chemicals, airborne and fluid, respectively. Both of them have served two vital purposes in vertebrates, namely nutrition and communication for reproduction, identification of food (prey), and for identification of members of their own species. These two senses monitor intake of food and the air breathed. The sense of taste warns about poisonous food and aids in selection of food and regulation of the intake of food in general. Taste pathways have connections with parts of the brain controlling hunger and satiation. We humans mostly associate the smell and taste of food with the pleasures of eating. Enjoyment of the scent of flowers and perfumes is an obvious olfaction in humans.

Olfaction is used by many animals for identification of members of their own species as well as for identification of other species, in a similar way as humans use visual recognition of faces for identification of other humans. Olfaction, especially the *vomernasal* system, has great importance in reproduction in many animals because of the response to *pheromones*. It is not certain if the vomeronasal systems play a role in human sexuality but some observations indicate that it might play a role in reproduction in humans.

While the olfactory receptors respond to a wide range of different odors, taste is limited to four categories, namely, sweet, sour, salty, and bitter (and possibly a fifth, monosodium glutamate). The olfactory system has different sensitivity to different odors, and likewise the taste sense has different sensitivity to the four or five different substances to which taste receptors are sensitive. It is a general impression that the flavor of food is provided by the gustatory sense, but it is in fact the olfactory sense that is the basis for discriminating of many food flavors. The mechano- and temperature-receptors in the mouth also play important roles in providing what is regarded as the flavor of food by providing information about the texture and temperature of the food. This means that the specific flavors of food that we experience are the result of a combination of input from several senses that requires complex coordination in the central nervous system (CNS), including the association cortices, to discriminate among the flavors of foods. The chemical senses, both olfaction and gustaton, have rather high adaptation, which means that prior exposures to stimulation significantly shift the threshold of the sensory system to weak side.

Bitter substances are often toxic and may elicit a warning or even cause vomiting. Other substances, particularly sugar, elicit a sensation of pleasure. In fact, sugar is one of the few sensory stimuli, or perhaps the only one, that elicit a distinct sensation of pleasure without the sensation having been learned by experience. The reaction to most other sensory stimuli that give a sensation of pleasure is the result of a learned experience. Also unpleasant taste or smell is mostly the result of learned experience. One exception may be the smell of bromide, which most people regard as being pleasant. Some animals may be attracted to salty substance that is related to the body's salt balance. Lack of salt seems to elicit a salt hunger in certain animals, that is satisfied by stimulation of salt receptors in the tongue.

D. Somatic Sensation

Somatic senses are those senses we feel with our bodies, and they include sensations of touch and pressure, pain and temperature, and our muscle senses such as vibration. We can feel the size and the form of an object and the texture of its surface. The separation between stimulations at two locations on the skin and the difference in time between two stimulations provide distinct sensation.

Mechanoreceptors in the skin are sensitive to deformation of the skin, and different types of mechanoreceptors have different sensitivity to such stimuli. The sensitivity to sinusoidal vibration is greatest around 200 Hz for some receptors. Other receptors are most sensitive to rapid change in deformation of the skin compared with steady deformation of the skin, while in others the opposite is true. For stimulation of the skin, stimuli are most effective in masking each other if they occur within100 msec relative to each other. Stimulation of a small area of the skin has a higher threshold than stimulation of a large area.

The sensory receptors of the skin are distributed over the entire body surface. There is some difference between the receptors located in hairy skin compared with those located in nonhairy skin. Some receptors are located near the surface of the skin while others are located deeper in the skin which causes mechanical stimuli of the skin to be transformed differently before activating receptors. Mechanoreceptors are classified according to their type of adaptation as slow adapting, rapid adapting, and very rapid adapting. There are four kinds of thermoreceptors which are temperature sensitive. Two of these, cool and warmth receptors, are regarded as sensory receptors that respond to innocuous stimulation. The two other kinds of receptors, heat and cold receptors, are nociceptors.

There are many forms of pain, such as somatic pain, neuropathic pain, acute pain,, or chronic pain. Somatic pain, also known as nociceptive pain, is caused by mechanical or chemical stimulation of nociceptors, such as from acute injury or from inflammation and other forms of tissue injuries. Heat and cold can also cause pain. Neuropathic pain refers to pain caused by insult to the nervous system or by changes in the nervous system involving neural placiticity. Such pain may persist after the original cause of pain has resolved, which is called sequela. The clinicians often refer to idiopathic pain whose source and cause are unknown. Itch is a peculiarly unpleasant sensation that causes an urge to scratch the region of the skin to which it is referred. Itch is usually referred to a distinct patch of skin, and scratching the skin relieves the sensation of itch for a time. Allergic reactions often include itch and rarely referred to deeper structure. Itch can be elicited by a wide variety of local and systemic substances. Histamine is powerful elicitor of itch and it has been used in many studies.

2. Trend of Unification in the History of Science

One of the uniform trends in the transition process of human cognition throughout the history of science is unification-oriented. The basic laws or theories become simpler and fewer in number, at each successive level to deeper levels of understanding. This historical observation is called Occam's razor, following the name of the philosopher William of Occam in the 14th century who first formulated. There are many such examples and we consider some representative cases here.

The basic forces governing the natural phenomena are now grouped into four basic types after a period of vigorous search by many people. The first one is gravitation which has been known for a long time since the appearance of mankind on earth. The second is electromagnetic force which is a unified form of electric and magnetic forces and is responsible for the combination of objects in the universe which cannot be explained by gravitation. The properties of atoms and molecules are determined by this electromagnetic force, and many common forces, such as friction, air resistance, drag and tension, are also ultimately due to this force. Both gravitational force and electromagnetic force are of infinite range, and belong to the category of macroscopic force being recognized easily in our daily lives. At the turn of 20th century after realizing the existence of molecule and atom, it turned out that there exist another kind of force of short range, and this microscopic force is called "interaction" because it is more related to the creation and annihilation of elementary particles rather than the acceleration due to the Newton's 2nd law of motion. There are two types of interactions between elementary particles at short distance, strong and weak interactions. The strong interaction is responsible for binding proton and neutron in nuclei and is the dominant one in the reactions and decays of fundamental particles. Some particles, such as electron, do not feel this interaction at all, and such particles are grouped to be called lepton. The weak interaction is responsible for nuclear beta decay and other similar decay process involving fundamental particles. The weak interaction between two neighboring protons is about 10^{-7} of the strong interaction between them, and the range of the weak interaction is smaller that 1 fm (= 10^{-15} m) which is the order of range of strong interaction. The strong interaction is attractive and the weak interaction is repulsive. It is amazing event that we collect all forces in nature and represent them as the four basic forces, and it also suggests the trend of unification in our understanding of nature. We will now review the transition and progress of our understanding of these forces.

A. Transition of human understanding of gravitation

The nature of the motion of a falling body has been of subject of interest since the time of ancient Greeks. Aristotle had asserted that "the downward movement of any body endowed with weight is quicker in proportion to its size." That is heavier objects fall more quickly. This assertion, however, has self-contradiction as follows. Suppose we have two objects with weights 1 kg and 2 kg each. According to Aristotle when we drop two objects simultaneously, 2 kg will fall more quickly than 1 kg. When we combine two objects with weight 3 kg, it should fall more quickly than 1 kg or 2 kg. But there is a loophole here. If we look at 3 kg object in detail we know that it is composed of two objects 2 kg and 1 kg. Then 2 kg tends to fall more quickly and 1 kg fall less quickly, thus overall 3 kg should fall less quickly than 2 kg because it has some resistance from 1 kg. This is evidently self-contradictory. Galileo (1564-1642) noted this inconsistency and suspected all objects fall with the same acceleration. In 1638 latter years in his life Galileo wrote the treatise entitled "Dialogues Concerning Two New Sciences" where he detailed his studies of motion. Galileo introduced the concept of acceleration and showed that gravitational force exerts constant acceleration to falling body and the free-fall acceleration is independent of the mass of the objects in modern terminology. Galileo showed the importance of experiment to prove a proposition deductively and is regarded as progenitor of classical physics in this sense. What he studied and clarified is now known as terrestrial gravitation.

In the early days it was thought that the motion of the planets has nothing to do with the terrestrial gravitation. The motion of earthbound bodies and heavenly bodies were thought to be different in kind and governed by different laws. Scientists like to examine seemingly unrelated phenomena to show that a relationship can be found if they are examined closely enough. This search for unification has been going on for centuries. In 1665, the 23-year-old Isaac Newton made a basic contribution to physics when he showed that the force that holds the moon in its orbit is the same force that makes an apple fall. Newton concluded that not only does the earth attract an apple and the moon but every body in the universe attracts every other body. This is called universal gravitation and Newton later showed that he could derive Kepler's law from his gravitational law with the calculus he invented. The historical development of gravitational can be viewed as a model example of the way the method of scientific inquiry leads to insight. Copernicus provided the appropriate reference frame for viewing the problem, and Tycho Brahe supplied systematic and precise experimental data. Kepler used the data to propose some empirical laws, and Newton proposed a universal law from which Kepler's law could be derived. Although Newton's gravitational law later was slightly modified by Einstein's general relativity, it is still good enough to be applied in launching satellites.

B. Electromagnetism – Unification of electricity and magnetism

Electromagnetic forces are responsible for the structure of atoms and for the binding of atoms in molecules and solids. The early Greek philosophers knew that if one rubbed a piece of amber, it could be used to pick up bits of straw. There is a direct line of development from this ancient observation to the electronic world in which we live. The connection is indicated by the word "electron", which is derived from the Greek word for amber. The Greeks also knew that some naturally occurring stones, which we know today as the mineral magnetite, would attract iron. These were the modest origins of the sciences of electricity and magnetism. These two sciences developed quite separately for centuries, until 1829, when Hans Oersted found a connection between them: an electric current in a wire can deflect a magnetic compass needle. In fact Oersted made this discovery while preparing a lecture demonstration for his physics students.

The new science of electromagnetism (the combination of electrical and magnetic phenomena) was developed further by workers in many countries. One remarkable figure was Michael Faraday, a truly gifted experimenter with a talent for physical intuition and visualization. That talent is attested to by the fact that his collected laboratory notebooks do not contain a single equation. Faraday's discovery, law of induction, is the basis of alternate current electricity generator invented by Tesla. Tesla sold his patent to Westinghouse, but his name remained in the SI unit of magnetic field. In the mid-19th century James Clerk Maxwell put Faraday's ideas into mathematical form, introduced many new ideas of his own, and put electromagnetism on a sound theoretical basis. Maxwell's four equations play the same role in electromagnetism that Newton's laws of motion play in classical mechanics and the laws of thermodynamics play in the study of heat.

Maxwell's great discovery in electromagnetism was that light is an electromagnetic wave and that one can measure its speed by making purely electrical and magnetic measurements. With this discovery Maxwell linked the ancient science of optics to those of electricity and magnetism. The previously separated sciences of electricity and magnetism became linked under the common designation of electromagnetism. This linking was later shown to be a fundamental part of the special theory of relativity, according to which electric fields and magnetic fields can be transformed into one another due entirely to the relative motion of the observer. Heinrich Hertz took another giant step forward when he produced the electromagnetic phenomenon that he called "Maxwellian waves" but which we now call shortwave radio waves. It remained for Marconi and others to push forward with the practical applications of the phenomenon, wireless communication using electromagnetic wave. The scope of Maxwell's equations is remarkable, including the fundamental principles of all large-scale electromagnetic and optical devices such as motors, radio, television, microwave radar, microscopes and telescopes.

C. Unification of electromagnetic and weak interactions

Two electrons exert electromagnetic forces on each other according to Coulomb's law. At a deeper level, this interaction is described by a highly successful theory called "quantum electrodynamics (QED). From this point of view we say that each electron detects the presence of the other by exchanging photons with it, the photon being the quantum of the electromagnetic field.

We cannot detect these photons because they are emitted by one electron and absorbed by the other a very short time later. Because of their transitory existence they are called virtual photons. Because of their role in communicating between the two interacting charges, they are sometimes called messenger particles. This kind of theory of exchanging virtual particle is an example of gauge theory, and electromagnetic theory is the simplest of them since there is only one type of virtual particle involved, photon. The gauge theory of electromagnetic interaction is called U(1) theory and it belongs to a category "abelian" gauge theory. The extension of gauge theory to non-abelian case was done by Yang and Mills, but its usefulness was not appreciated until 1967 when Weinberg and independently Salam proposed a unified scheme of electromagnetic and weak interactions between leptons that do not feel strong interaction.

A field theory of the weak interaction was developed by analogy with the field theory of the electromagnetic interaction. The messenger particles that transmit the weak interaction between leptons are not massless photon but massive particles, identified by the symbols W and Z. It was an ingenious application of Yang-Mills theory endowing mass to massless gauge particles. The theory was so successful that it revealed the electromagnetic interaction and the weak interaction as different aspects of a single electroweak interaction.

The qualification for relevant unified theory is that it should show not only unification but also a new feature of the unification. Maxwell's electromagnetic theory predicted electromagnetic waves. There were two remarkable features in Weinberg-Salam theory. The first is the renormalizability, that is somewhat professional term which was proven to be relevant and useful in electromagnetic interactions. Renormalizability is the feature of field theory that can produce meaningful computational results. The renormalizability of Weinberg-Salam theory was proven later in 1971 by 't Hooft. The second feature is its prediction of neutral weak current. Before that only charged weak current exists, that is the process of weak interaction under which the particle changes of electric charge as can be seen in the following example, neutron decay, which is thought to be the essential process happening during the beta decay.

$$n \rightarrow p + e + \overline{\nu_e}$$

In the above process, neutron decays to proton, electron, and neutrino. The existence of neutral weak current, i.e. the weak interaction mediated by the neutral particle, was later confirmed by experiment. This is another example of the triumph of unification-oriented approach in science. The Nobel Prizes in physics were awarded to Weinberg and Salam, with Glashow who extended the theory to hadrons, in 1979, and 't Hooft with Veltman, his thesis supervisor, in 1999 for their works in this field.

3. Consciousness, Soul and Unification Thought

As we go to deeper level of understanding of nature, our physical perception of human being has advanced in various ways. The chemists think human body is a prominent chemical plant and thermal engineers regard it as a kind of heat engine. With the tremendous achievements of computer technology, it will be a natural progress to consider human body as a sort of computer. While the input devices of computer are rather simple ones, such as keyboard, mouse, and scanner, the input to human computer takes various and complicated forms through the five primary sensory organs, such as visual information, auditory information, olfactory information, gustatory information, and somatic tactile information, and we do not yet have the full understanding of their entity and operation process. Nevertheless, the knowledge of information of various sorts has contributed greatly to the human existence and industrial advancement either consciously or unconsciously. The study of visual information which humans trust mostly has developed to aesthetics which plays primarily important role in architecture, design, and wardrobe. The information of food restaurant and perfume, the success of which depends on gustation and olfaction, is transmitted via vision on first hand, and thus the importance of vision is emphasized.

Seeing is believing! Vision is truly the first gateway to human perception, and the roles of the other senses are just to confirm what vision obtained. Some proverbs stressing vision are the following.

What we learn only through the ears makes less impression upon our minds than what is presented to the trustworthy eye. ~ Horace ~

What the eye does not admire the heart does not desire. ~ Proverb ~

The eyes have one language everywhere. ~ George Herbert ~

For centuries, scientists dreamed of being able to peer into a human brain as it performs various activities—for example, while a person is seeing, hearing, smelling, tasting, or touching something. Now several imaging techniques such as PET (positron emission tomography) and the newer fMRI (functional magnetic resonance imaging) make it possible to observe human brains at work. There are two areas of the brain that become particularly active when volunteers read words: the primary visual cortex and an additional part of the visual system, both in the back of the left hemisphere. Other brain regions become especially active when subjects hear words through earphones.

To create these images, researchers gave volunteers injections of radioactive water and then placed them, head first, into a doughnut-shaped PET scanner. Since brain activity involves an increase in blood flow, more blood—and radioactive water—streamed into the areas of the volunteers' brains that were most active while they saw or heard words. The radiation counts on the PET scanner went up accordingly. This enabled the scientists to build electronic images of brain activity along any desired "slice" of the subjects' brains.

Much excitement surrounds a newer technique, fMRI, that needs no radioactive materials and produces images at a higher resolution than PET. In this system, a giant magnet surrounds the subject's head. Changes in the direction of the magnetic field induce hydrogen atoms in the brain to emit radio signals. These signals increase when the level of blood oxygen goes up, indicating which parts of the brain are most active. Since the method is non-invasive, researchers can do hundreds of scans on the same person and obtain very detailed information about a particular brain's activity, as well as its structure. They no longer need to average the results from tests on different subjects, whose brains are as individual as fingerprints. The technical jargons are explained in what follows.

PET (Positron Emission Tomography)
a type of scan that measures changes in blood flow associated with brain function by detecting positrons, positively charged particles emitted by radioactively labeled substances that have been injected into the body.

fMRI (Functional Magnetic Resonance Imaging)
a new method of scanning the brain's activity that needs no radioactive materials and produces images at a higher resolution than PET. It is based on differences in the magnetic resonance of certain atomic nuclei in areas of neuronal activity.

cortex, The cerebral
the outermost layer of the cerebral hemispheres of the brain, responsible for all forms of conscious experience.

In spite of the tremendous achievements of modern science and technology soul is not yet a scientific term. It is only known to be the activity of the highest level among the human consciousness, and may be a sort of wave if it really exists physically. There is, however, the word "soul" in all civilized languages on earth. Although a man is mortal, he may have a considerable influence over by what he has done during his lifetime, even after death. Recent studies assert that all living things, including plants and microbes, have consciousness. Why does the sunflower turn its face toward the sun? Although it became clear now that that action is caused by physical reason not by any consciousness of sunflower, we can suspect whether the instinct and consciousness of all living things are results of physical effect. The roots of some plants grow down in search of water vein. That is because the increment activity of the part of the root in the direction of water vein is brisk. There is no religion in the living of animals as well as in plants. The awareness of soul and religion is the attribute only humans have. As sunflower turns its face toward sun and roots of plants reach out to water vein, man is religion-oriented. That is because religion has some healing effects to the traumata of human body and soul. Most of the religions, however, stand upon the local culture and custom. Islam is the prop and stay of Arabic world, and Christianity has served the living center in western society since the Roman empire. The unification of the three kingdoms in ancient Korea had its ground in Buddhism. The unification thought, exclusively originated in Korea, has made an overseas expansion to the whole world, surmounting the difference of language and culture, and this is mainly due to the excellent leadership of Rev. Sun Myung Moon, the founder who takes up the running in everything, but also due to the common tendency and taste of humans to seek religion, thus some comfort during the hard course of their lives.

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