Textbook for literacy program of Global Agricultural Sciences

I .History of the Earth and Agriculture

I -1. Birth of the Earth and human being

I -1-(1) Birth of the Earth

The birth of the space was thought to be 13.7 x 10^9 years ago. The Galaxy was built up by 8.3x 10^9 years ago. The Sun was born from union of interstellar materials produced in explosion of supernova and so on 5.0 x 10^9 years ago. Stars produced from interstellar materials are called stars of second generation. The stars called first generation were born in the Big Bang. However, first generation stars are belonging the group defined as stellar population II and second generation stars are defined as stellar population I. The birth of the Earth was 4.6 x 10^9 years ago. Micro planets in the Solar System repeated collision and union, and the Earth was produced. The energy of collisions and unions produced heat and the earliest Earth was high temperature and discharged gasses. The gasses became source of primordial atmosphere. After abating the collisions, the Earth was cooled down, and vapor in the primordial atmosphere was devolatilized. The water showered down on the surface of the Earth and the Ocean was formed on the Earth with in 1000 years.

I -1-(2) Characteristics of water

The earth is called the planet of water. The description above is the story of the birth of the aquatic planet. The existence of water is essential condition for the birth of the life in the Earth. The Earth could be the aquatic planet because of accidental luckiness. Before the explanation of the luckiness, we have to know why the water is necessary for the existence of the life. Figure 1 is showing pattern diagram of water molecule. Molecular formula of water is H_2O: is composed with 1 oxygen atom and 2 hydrogen atoms. In the outermost electron orbit, 6 electrons exist. Within them, 2 electrons form covalent binding with a electron of hydrogen, respectively. The outermost electron orbit is filled with 8 electrons and became stable. As a result, water molecule has 2 hydrogen atoms and 2 lone pair with the central focus on an oxygen atom. When we consider configuration of these elements, four bars are projected from a center in equally spaced interval in 3 dimension space. This structure forms triangular pyramid like tetrapod in breakwater. When we see this structure in a 2 dimensional plane formed with 2 lines extending to hydrogen atoms, lone pairs are exist in one side. This means that water molecule has electrical polarity. Negative electrode and positive electrode of adjacent water molecules pull each other. Addition to this, hydrogen atoms in water molecule tend to form hydrogen bond with loan pair of adjacent water molecules. For these reason, intermolecular force among water molecules are extremely

stronger comparing to other substances which have similar molar weight. In another expression, larger energy is required to expand the distance between water molecules. Table 1 is showing boiling points, freezing points and sublimation pint of Nitrogen, oxygen, and carbon dioxide comparing to those of water. It is understandable that boiling point and freezing point are extremely high. Specific heat and viscosity of water are also high because of high intermolecular force. Water solves ions because of polarity and organic substances like sugars because of hydrogen bond. Water is excellent solvent. Table 2 is showing difference in physicality between water and air. As mentioned in above sentences, water is high density, high specific heat and high viscosity. Damping rate of light in water and acoustic velocity are higher in water than in air. Saturation amount of oxygen in water depends on temperature and salinity and is 6-8mg/l. Water has three phases, namely ice, water and vapor. In the moment of shift of phase, water discharges or absorbs heat (latent heat). Shift of water phase contribute temperature stability of aquatic environment. Ice floats on water. It is very unique character of water that solid form is lighter than liquid form. This character is also important. Because, if ice were heavier than water, ice formed on the surface of the sea would sink down to the bottom of the sea and the ice could not receive solar energy. This means that the ice would not melt again and thick ice layer would be produced in ocean bottom. y

Ⅰ-1-(3) Distribution of water on the earth.

Existing form of water on the Earth is shown in Table 3. The length of periods in which water remain in the form are also shown as average residence time. Average residence time is calculated by dividing total water by inflow velocity or outflow velocity, presuming total water volume is stable. Almost all water (97%) exists as seawater in the ocean. When water enters the ocean, it will take 3,700 years to evaporate to the air. On the contrary, water vapor in the air will return to the ground only 9 days later. Nearly half of the remainder exists as permanent ice in polar region and glacier. Residence time of permanent ice is extremely long (16,000 years). Most of the remainder exists as ground water, and lake and river water, which we used as drinking water and irrigation water, The ratio of such water is only less than 0.01%. Anyhow, water exists on the Earth. This fact is very lucky for living organisms. Average radius of revolution orbit and mass are compared among Venus, the Earth and Mars in Table 4. Recipient solar energy per unit area inversely relates to square of distance from the Sun. Surface temperature of Venus is very high because of massive solar energy and water cannot exist on the surface of Venus. Mars receive less amount of solar energy and is low temperature. However, water does not exist on Mars. Atmosphere of Mars is rare

because of low gravity relating to the small mass. This is the same reason why no atmosphere exists on moon

In the table albedo is also shown. Albedo is reflection rate of solar energy on the surface of planet. When albedo increase, reflected solar energy increase and recipient solar energy decrease. Albedo of the Earth changes with vegetation and condition of sea. These lucky conditions enabled the existence of sea, the place of the birth of life, on the surface of the Earth.

Ⅰ-1-(4) The birth of the life

Life on the Earth was born 3.8×10^9 years ago. The definition of life is very difficult. In this chapter, it is defined as follows tentatively. 1. System which is separated from external world (individuality). 2. System which procreates offspring (reproduction). 3. System which takes materials from external world and utilize them for energy and other purposes (metabolism). For the production of the living organisms which meet those requirements, several low materials are needed. For the separation from external world, membrane is required and phospholipids are needed as the low material of membrane. For reproduction, DNA is needed as design. Metabolism is cascade of enzyme reaction. Enzyme is protein. Proteins are needed for metabolism. Process of production of first living organisms on the Earth is not clear. Urey and Miller demonstrate that organic substance could be produced from simple chemical substances. It was thought at that time that primordial atmosphere was composed from vapor, methane, ammonia and hydrogen. When they circulated mixture gas of vapor, methane, ammonia and hydrogen and discharge to the mixture gas, amino acids are produced. Today composition of primordial atmosphere is presumed to be different from the composition they thought. We cannot say that they could clarify the process of the birth of life. However, their contribution to the development of science cannot be injured, because they clarified that amino acids, the element of protein can be produced from simple inorganic substances. Actually, amino acids also exist in the space. Most of amino acids on the Earth are L-amino acids. In the space, D-amino acids break down easily. It is not unbelievable to consider that first amino acid on the earth came from the space. Like this, there are various questions concerning the process of the birth of life. A typical question is “protein first or DNA first”. Proteins have catalytic action, though they have no self-replication capacity. On the contrary, DNA has self-replication capacity though no catalytic activity. RNA can be a candidate of origin of life, though it is unstable. Another question is whether the first living organism was autotrophic or heterotrophic. Generally in chemical revolution theories, first living organism is heterotrophic, though surface metabolism theory, in which organic substance was

produced on the surface of pyrite, first living organisms is autotrophic. Because in the theory the comical reaction for the formation of organic substance (formic acid) is as follows. $FeS+H_2S+CO2 \rightarrow FeS_2+H_2O+HCOOH$ -11.7kj/mol This is exergonic reaction (reaction which produce energy). The hypothesis in which first living organism was born in hydrothermal deposit is proposing this reaction. Various theories and hypotheses exist and the process of the birth of first living organism is still enigmatic. However, life was born 3.8 x 10^9 years ago and living organisms have evolved with the changes of the Earth's environment

Ⅰ-2 The evolution of life

Ⅰ-2-(1) Geological timescale

Geological timescale is a system to classify the age of the Earth by the fossil unearthed from soil. There are four levels in geological time scale, namely Eon, Era, Period and Epoch respectively from larger unit. There are 4 Eon. The Hadean Eon: From the Birth of the Earth to 4 x 10^9years ago. The crust of the Earth and ocean were formed. Materials of life was produced by chemical evolution. The Archean Eon: From 4 x10^9 to 2.5 X 10^9 years ago. Ancestor of living organisms appeared. The first living organisms were Procaryote which included Archaebacteria, Eubacteria and Cyanobacteria. The the Proterozoic Eon : From 2.5 X10^9 to 542 x106 years ago. Oxygen accumulated in the air and ozonosphere was formed and amount of ultraviolet light decreased on the surface of the Earth. Eucaryote appeared through uptake of other individuals among prokaryote. Multicellular organisms appeared in the late Proterozoic Eon. The Phanerozoic Eon : From 2.5 x 10^9 years ago to today. Large size multicellular organisms appeared. Beginning of the Phanerozoic Eon is Cambria period. The ages before the beginning of Phamerozoic Eon (the Hadean, the Archean and, the Proterozoic Eon) are named precambrian age. Phamerozoic Eon is divided to 3 eras、namely Paleozoic, Mesozoic, Cenozoic. The Paleozoic Era (542 x10 ^{6} -251 x10 ^{6} years ago) is from appearance of invertebrates to prosperity of dinosaur. The Mesozoic Era (251 x 10^6 -66.55 x10^6 years ago) is the age of prosperity of dinosaur and their Extinction. The Mesozoic Era consist of Triassicm, Jurassic and Cretaceous Period. Magnolyophyta appeard in this era. The Cenozoic Era is from 6.55 x10^6 years ago –today) . This period is characterized by prosperity of Mammalia and Aves. The Cenozoic Era consists of Paleogen, Neogene and Quaternary periods. Human being appeared in the Quaternary period. The Quaternary period consists of Pleistocene and Holocene epoch. The Pleistocene epoch (2.588 x106-11,700 years ago) is period when glacial ages were happen repeatedly. The Holocene Epoch(11,700 years ago –today) is from the end of last glacial age - today

Ⅰ - 2 -(2) Evolution of plants

From the viewing point of evolution of plants, this history can be summarized as follows. The birth of life was3.8 x10^9 years ago, the appearance of photosynthetic organisms was 3.2 x10^9 years ago、Appearance of Eucaryote was 2.1 x10^9 years ago, (Eucaryote has organelle, which is micro organ in cell separated from cytoplasm such as mitochondria, chroloplast, centrosome. First Eucaryote was monocellular organisms. These monocellular organisms are classified in Protiocista in 5 kingdom classification system. In early development of Protiocista, green algae (cholorophyceae) appeared. Chlorophyceae forms Viridiplantae (subkingdom) together with, Bryophyte (moss), Fern, Gymnospermae, Magnoliophyta. Viridiplantae have Chlorophyll a, b as photosynthetic pigment, cellulose in cell wall and preserve starch as storage energy. In this connection, we can say prototype of higher plant today is green algae. Bryophyte (moss) was first terrestrial plant. Fern has vascular bundle. Vascular bundle enabled plant to grow up vertically. Gymnospermae was first Spermatophyta, plant which produce seeds. Magnoliophyta is plant of which ovule is covered in ovary (Fig 2). Most of cultivated plants today are Magnoliophyta. From agronomic viewing point, appearance of photosynthetic organisms, appearance of terrestrial plant, appearance of plant which has vascular bundle and can grow vertically, appearance of plant which produce seeds, and appearance of plant of which ovule is covered in ovary are important events. Photosynthesis is production of organic substance from carbon dioxide and water using light energy. Process of photosynthesis was divided into light reaction and dark reaction. Light reaction is process to produce high energy substances by reduction of water using light energy. In this process oxygen is produced as a by-product. Dark reaction is process to produce organic substance from carbon dioxide using the high energy substances. Vascular bundle is an organ running longitudinal direction in stem. The functions of vascular bundle are transportation of materials and mechanical support of plant. Transportation is function of sieve tube and vessel. Generally, vessel is locating inner part of stem and transport water from root to upper parts. Cambium layer exists between phloem and wood portion. Sieve tubes exist in phloem and transport substances produced in aerial parts to lower parts. Strings in the vascular bundle support plant mechanically. Vascular bundle enables plant to stand vertically and to transport materials between remote part such as roots and leaves. Definition of Magnoliophyta is that ovules are located in ovary (Fig 3). More essentially, Magnoliophyta are plants which do double fertilization. In double fertilization, 2 spermatoblasts produced by reduction division, of which number of chromosome are n,

are transported to ovule in pollen tube, and one spermatoblast fusion with egg cell (n) and the other fusion with central cell , of which chromosome number is 2n, and forms albumen, of which chromosome number is 3n (Fig 4). Albumen is used as energy source for growing of embryo. Evolutional meaning of Magnoliophyta is having storage organ. Storage organs in Magnoliophyta today have diversified. Albumen is not always organ for storage in all Magnoliophyta. In rice and wheat, albumen is storage organ. Beans store energy in seed lobe. Edible part of strawberry is lower parts of pistil called blossom end. We are eating ovary of tomato. Sweet potato, potato and onion accumulate their nourishing materials in root and stem (tuber, bulb). Magnoliophyta develop various storage organ and human being utilize those storage organ as harvests.

Ⅰ-2-(3) Evolution of animal

Figure 5 is sowing biological classification in 5 kingdoms theory. Biological classification today is more complicated than 5 kingdom theory and many kingdoms are proposed. However, we use 5 kingdoms theory in this chapter to skip complicated explanation of combination of Procaryote in the process of the birth of Eucaryote （Protista） In 5 kingdoms theory divides living organisms as follows. Procaryote: Organisms which do not have clear nucleus separated from cytoplasm by membrane. Protista: Monocellular organisms which have organelles separated from cytoplasm by membrane including nucleus. Plant: Autotrophic multicellular organisms which cannot move. Fungi : Heterotrophic multicellular organisms which cannot move. Animalia : Heterotrophic multicellular organisms which can move. Except multicellular organisms of which basic body structure is remaining in gastrula and moth and anus do not differentiate such as sponge (Porifera) and jerry fish (Cnidaria), animals are divided to Deuterostomia and Protostomia. In Deutrostomia, blast poor or adjacent part of blast poor became anus and mouth is produced in other part. Echinoderm such as sea urchin, star fish and sea cucumber and vertebrate inculding human being begong to Deutrostomia. Protstomia is animals of wihic mouth is blasto poor. Mollusca such as shellfish and octopus and Arthropoda such as insects and crrb are Protstomia (Fig 5). Multicellular organisms firstly appeared 1.0×10^9 years ago. It was thought that the origine of multicellular organisms is symbiosis of monocellular organisms. After appearance of multicellular organisms, relationship between organisms is complecated and adaptive competition became more serious. Appearance of newspecies and extinction of species have happend repeatedly. Many Procaryote extincted $0.6\text{-}0.5 \times 10^9$ years ago when the Earth cool down and beame snowball Earth. After that multicellular organisms called Ediacara fauna. Organisms in Ediacara fauna are thought to

be earliest multicellular organisms and they had no hard shall on the surface of their body.

All organisms in Ediacara fauna died off 570-510 x 10^6 years ago. Cause of the extinction is thought to be cold climate. In the beginning of Phanerozoic eon (Cambrian period, 540-490 x 10^6 years ago), temperature of the Earth increased, and large multicellular animals appeared. Almost all phyla in animal kingdom appeared in Cambrian period. This is called Cambrian Explosion. Those animals appeared in sea. Appeared animals repeated adaptive competition among species and the winners in the competition could survive. The sea in Cambrian period was a place of evolution experiment. Another mass extinction happened in Ordovician period (488-444 x 10^6). The cause of this extinction is no clear. Fishes appeared in Ordovician period (488-444 x 10^6) and prospered in Devonian period (416-359 x10^6). Devonian period is called age of Prosperity of Fish, Amphibia (First terrestrial animal) appeared 360 x 10^6 years ago. Terrestrial plants (moss and fern) and insects had appeared by this period. Appearance of Reptillian (crawler) was 300 x 10^6 years ago. Mammalia appeared 225 x10^6 years ago. Followings are an example fish to understand evolution of animals. Fish does not exist as monophyletic group in branch classification of organisms. In vertebrate, several classification levels exist. Different groups of fish exist in each branch. In another expression, fish did not exist in one level of the evolutional process to mammalian and human being. In this process, fishes are paraphyletic groups. If we interpreted that fish is monophyletic group, mammalian and human group are species in fish(Fig.6). Vertebrate can divide to Agnatha and Gnathostomata. Definition of Agnatha is vertebrate other than Gnathostomata. In modern species, hagfish and lampern are agnatha. Agnath has no bone in jaw, and their internal skeleton is soft bone and undeveloped. They do not have swimming bladder. Their breast fin and ventral fin are not developed and their swimming capacity is low. When Agnatha appeared in sea as the first fish, Species in nautilus, which have hard shell and high predation capacity, dominate environment of ocean. They had to penetrate to brackish or fresh water environment and obtained capacity of osmotic regulation. It is obvious that Gnathostomata, which has strong jaw and swimming capacity, has higher predation and escaping capacity and higher adaptability than Agnatha. Gnathostomata is divided to Chondrichthyes and Osteichthyes. Chondrichthyes include shark, ray and elephant fish. Chondrichthyes have well developed cartilage bone skeleton and no swimming

bladder. Osteichthyes has well developed hard bone skeleton containing calcium carbonate and calcium phosphate. Osteichthyes have swimming bladder. Swimming bladder is homological organ with lung of mammalian. Earlier species of fish had lung and the prototype of lung and swimming bladder develop to swimming bladder in Actinopterygii and lung in Mammalia. Osteichthyes is divided to Actinopterygii and Sarcopterygii. Actinopterigii means fish which have membranous fin. Teleostei, which include sea bream, carp, sardine, trout, bass, etc is Actinopterigii. Sarcopterigii means fish which have fleshy fin. Sarcopterigii is divided to Tetrapoda and the others. Lungfish and Coelacanth in extant species belong in the others. Tetrapoda include Amphibia, Crawler, Birds and Mammalia.

I-2-(5) Driving force of evolution

Thinking back the history of evolution, we can understand that relationships among species like competition, predation and coexistence have been driving force of evolution. This type of evolution is the result of very slow process such as adaptation to environment and competition. On the other hand, discontinuous sudden changes happened in evolution history of living organisms. Mass extinction of species groups which prospered in former age necessarily come before the discontinuous sudden changes. Causes of the Great Dying were sudden changes of environment. (Author did not use the word “sudden” in same meaning of “sudden” in daily life such as one day or one year, though the unit of time in this sentence is 1,000 year or 10,000 year) Among environment changes, change in temperature is very important. It is known that the earth was subjected to refrigeration to complete coverage by ice in the adjacent of equator three times. This condition is called snowball earth. Formerly, it was believed that snowball earth was not probable. Because, when the Earth is completely covered by ice, the surface of the Earth become white and albedo (reflection rate of solar energy) of the earth will increase. In this condition the Earth cannot receive enough amount of solar energy to recover the temperature, and the Earth cannot recover from snowball earth condition. However, ocean still remains on the Earth. The existence of the ocean is thought to be the evidence of denial of occurrence of snowball earth. Nowadays, function of ocean for stabilization of global environment is attracting attentions. Sea water is weak alkali and absorbs huge amount of carbon dioxide, a major green house effect gas. When the ocean disappears on the snowball earth, carbon dioxide in the air increase, and the temperature increase because of increase of the content of green house effect gas in the air. This is a proposed mechanism for escape from snowball earth condition. Addition to this, carbon dioxide is discharged by the decomposition of mortal remains of organisms, and volcanic actions change the content of green house effect gas in the air.

Changes of composition of the air, location of continents and axis of the Earth etc. can be triggers of snowball earth and glacial age. The earliest snowball earth happened in 2.4-2.1 x10^9 years ago. This glacial age is called the Huronian glaciations. In this age, cyanobactera appeared and consumed large amount of carbon dioxide and discharged Oxygen by photosynthesis. As a result, content of green house effect gas was shifted and the Earth was subjected to refrigeration. Recovery mechanism from refrigeration is thought to be activity of volcano. After that, heterotrophic organisms which consume oxygen and discharge carbon dioxide increased and balance of green house effect gas was recovered. In the end of the Proterozoic Eon, 2 snowball earth ages happened namely Sturtian glaciations (760～700 x 10^6 years ago) and Marinoan glaciations (620～550 x 106 years ago). The land territory increased and amount of alkali flushed in to ocean from land increased in this age. This made shift of balance of green house effect gas in the air because the absorption of carbon dioxide by ocean increased. These glaciations caused the extinction of Ediacara biota. Ediacara biota is a taxon which prospered in the end of the Proterozoic Eon and was thought to be the earliest muticellular organisms. Their size if large, though they have no hard outer shell. This extinction was a remote cause of Cambrian explosion. There have been various causes of great dying other than temperature change. In the PaleozoicEr, 3 great dyings are known. The end of the Ordovician period（435 x 10^6 Y ago) 85% of species were extinct. There are various hypotheses about the cause of the extinction. Among them, several scientists proposed explosion of supernova as the cause of the extinction. Commonly accepted hypothesis is as follows. A continent was formed in the south pole region by continental drift. Ice was accumulated in the continent and marine regression happened. Most of the species in the age lived in shallow part of the ocean and died by marine regression. After the great dying, the Devonian Period started. The Devonian Period is known as age of prosperity of fish. In the end of the Devonian Period (360 x 10^6 years ago), another great dying happened. Various hypotheses have also been proposed concerning the cause of this mass extinction including refrigeration, marine regression and low oxygen, though clear conclusion is still not obtained. In this great dying, 82% of marine organisms were extinct including most of Agnatha and trilobite. Among mass extinctions, the most serious mass extinction was the great dying in the end of the Permian Period（250 x 10^6 years ago）. In this great dying, 90-95% of species disappeared. Marine regression, activity of volcano, low oxygen, etc. have been proposed as the cause of the extinction. I may right to consider that combination of several factors worked as the cause. The ancestor of dinosaur could survive the age and had period of prosperity in the Mesozoic Era.

Two mass extinctions in the Mesozoic Era happened in the end of the end of the Triassic Period（212 x 10^6 years ago） and the end of the Cretaceous period (65.5 x 10^6 years ago). The cause of the great dying in the end of the Triassic Period is said to be activity of volcano and 76% of species disappeared. Body size of the ancestor of dinosaur was still small and could survive the age of great dying, and they prospered in the Jurassic Period. The great dying in end of the Cretaceous Period is known as the age of extinction of dinosaur. The leading hypothesis for the cause of the mass extinction in Cretaceous Period is striking of huge meteor on the Earth.

Looking back the history of extinction and evolution of living organisms and changes in the global environment, the Earth have changed comprehensively including physical characters such as location of continents, geological formation, albedo and temperature, chemical environment such components of the air and sea water, and fauna and ecosystem. It is said that living organisms are depending on its environment. However, as the example of Huronian glaciations, in which cynobacteria consumed carbon dioxide and the Earth was subjected to refrigeration, living organisms sometimes make impact on global environment. In ecosystem, there are various relations among species and adaptive competitions are implemented. Those relations are driving force of changes of ecosystem and fauna (fig.7). The changes of the Earth and living organisms is holistic changes produced by dynamic relations among the earth, the environment and living organisms, and the changes are still continuing. There are varieties of strategies in adaptive competition among species. Selection of acquisition method of nutrition, autotrophic or heterotrophic, is an important strategy. Autotrophic organisms are usually eaten by heterotrophic organisms in ecosystem. Heterotrophic organisms may look stronger the autotrophic organisms, though heterotrophic organisms can grow depending on existence of autotrophic organisms and autotrophic organisms can grow independently from existence of other species. Predation and prey relation also exist among heterotrophic organisms. Predators are not always more adaptive than preys in adaptive competition, because predators are depending on the existence of prey. It is obvious larger organisms have advantages in the bottle of survival at an individual level. However, larger organisms not always have advantage in survival of population. When conditions are right, strategy of spawning numbers of eggs or babies and early maturation in small size to enable repeat of reproduction in short interval has advantage in population growth. There are 2 major strategies, one is increase of number of next generation. The other is enhancement of individual survival capacity of next generation. These two strategies are in the relation of trade off. There are limitations of energy which can be used for reproduction. In the limitation, when number of offspring

is increased, the body size of the offspring decreases and when the body size of the offspring is increased, number of offspring decreases. These strategies are called r-strategy and K-strategy. The name of strategies are originated from r and K in logistic equation which expresses population growth (Fig.8). In logistic equation r expresses intrinsic rate of growth and K means carrying capacity. Carrying capacity is a limitation of number of individuals in an environment. If there is no limitation, large r has advantage in competition because of rapid growth rate. More realistically, bearing large number of offspring and repeating reproduction in short interval are stronger even though their body size is small and they are weak in bottle of survival. In unstable environmental conditions, fauna in the environment frequently changes and large space always exist in carrying capacity, r-strategy has advantage in such condition. On the contrary in stable condition, there are limited space in carrying capacity and species should defeat other species in battle of survival. In such condition, increasing body size for enhancement of carrying capacity is advantageous. This strategy is named K-strategy. Figure 9 is drawing of photoplankton (diatom) and tree. Most of phytoplankton are less than 1mm and tree can reach several dozen meter. Generation time of phytoplankton is very short. Phytoplankton are r-strategy organisms. Comparing to this, trees are more K-strategic. They have big body size and long life span. When we look tree in details, the organs to produce energy are only leaves, very small portion in whole body of tree. Portion of reproductive organ (flower) is small.

Nearly whole biomass of individual tree is occupied by trunk. It is obvious that trunk is an organ to win in the light acquisition competition. It can be said that tree obtained high carrying capacity at the expenses of rapid reproduction. Above discussion lead us to understand the reason why human being deforested woods to make agricultural land. Cultivated crops can be harvested in short interval, their balance of r-K strategy selections are convenient for human being. However their competition powers in light acquisition are weak when compared with tree. In the stable environment in forest , cultivated crops cannot defeat trees and survive. Human being utilize adaptation strategy of other living organisms, such as accumulation stock energy in seeds and fruits, vertical growth of trees and so on. Apiculture and domestication of dog is utilization of relation between species. These are also utilization of strategy of species in adaptation competition.

Ⅰ-3. History of human being and agriculture

Ⅰ-3-(1) Birth of earliest human being

A mole like small animal adopted to forest environment about 65 x10^6 years ago and first primate appeared. Haplorhini, monkeys, which lack vitamin C synthesis

capacity, appeared in primates 63 x 10 ^{6} years ago. Appearance of ape was 25 x 10^{6} years ago. First human being was differentiated from jocko (chimpanzee) 5-6 x 10^{6} years ago. The earliest human being was *Australopithecine*. *Australopithecus* classified in ape-man. They might use chipped stone tools called Oldowan stone affairs. Oldwan stone affairs were discovered in Olduvai valley in Tanzania. Appearance of genus *Homo* was probably 2.5 x 10^{6} years ago. There have been various species in genus *Homo*, though the relation among those species is not known. Appearance of *Homo sapiens* was around 250 x 10^{3} years ago and *Homo sapiens* departed Africa 100 x10^{3} years ago and spread to other continents. On the way of expansion, many events might happen. As an example Toba event, gigantic explosion of Toba volcano in Sumatra island, happened 75 x 103 years ago. It that time surface temperature of the Earth decreased and human population decreased to less than 10,000. Mongoloids reached the New World 30-20 x10^{3} years ago through the Bering Sea. In the ages, American continent was connected to Eurasian continent because of marine regression in glacial age. By the end of the last glacial age, human being reached adjacent of southern end of South American Continent. Dogs were domesticated before the end of the last glacial age. From the end of last glacial age, the Holocene Epoch started. Human beings have developed agricultural technology and expand agricultural production using various methods.

Ⅰ-3-(2) Origination of agriculture

Origination of agriculture is an interesting topic and is often discussed in various sectors. However, it is obvious that the origin of agriculture is pluralistic, when we see variety of agriculture performed today in the world. Paddy fields are spread in the region of Southeast Asia to East Asia. Farmers in West Asia and Europe cultivate barley, wheat, pea and beet. They keep goat and sheep. In the region from Southeast Asia to Papua New Guinea, people cultivate sugar cane, yam, taro and banana and eat pig, chicken and dog. Native Americans have cultured potato, tomato, corn and pumpkin and have reared lama. Agriculture in savanna in West Arica is characterized by cultivation of black-eyed pea, gourd and sesame. It cannot be believed these various agricultural cultures have simple origin. However, it is possible that there are common necessary conditions for development of agriculture. Except agriculture which is implemented in originally suit for agriculture, preparation of infrastructure, such as arable land and irrigation channel, is required. For the preparation of infrastructure, tools, technologies and driving force are necessary. For long term stable production in same place, fertilizers are needed. Cultivated crops themselves should have adaptive

characteristics to the environment of the locality. It can be thought that various plants in natural environment had been checked their appropriateness as cultivated crops rather than breeding efforts to improvement of the characteristics in earliest history of agriculture. Procuration of labor power is an interesting issue and have been discussed. It was formerly thought that development of agriculture made request for labor power for maintenance of infrastructure, and communal living started. Actually, earlier collective farming originated in the place not adequate for agriculture as Tigris Rver and Euphrates River. It may reasonable to think that group living started at first for religious activities or commerce and agriculture started to secure enough food using redundant labor force for infrastructure maintenance. Anyhow, developments of agriculture have strongly linked with civilization in the meaning of institutionalization and organization of society in the process of establishment of centralized government. Mesopotamia is thought to be the earliest agricultural civilization. Mesopotamia means place between rivers in Greek. The rivers are Tigris River and Euphrates River. By 6500 BC people who did cultivation had settled in the area and several communities had been formed. In a prevailing hypothesis, the origin of cultivation of barley and wheat was Anatoria high land in Turk, origin of Euphrates River called fertile crescent, at around 9000 BC. Sumerians immigrated to Mesopotamia around 3000 BC and formed city-states. Ethnic of Sumerian is not clear. Political system of the city-states was theocracy by king and large scale flood control and irrigation were implemented. The origin of rice cultivation was middle stream of Yantze River the age is considered to go back to earlier than12000 BC. There remains possibility to find older trace of rice cultivation in future. Development of rice cultivation probably contributed changes of societies along Yantze river, though the details have not been clarified.

I-3-(3) Development of agricultural society.

The most important development in farm tools was invention of iron tool and use of farm tools made with iron. Before using of iron tools, farmer use wooden stick or stick with stone tool on the edge of stick. Workability of wooden stick and stone tool was very low. Using iron spade and iron harrow and plowing by cattle with iron plow efficiency of cultivation was improved and expansion of arable land and large scale irrigation were enabled. The earliest civilization which had iron is thought to be Hittite. However, the oldest trace of iron making was discovered in KamanKalehoyuk ruins with iron knife. The age of production of the knife was estimated to be 1800 BC. Hittite was an ancient empire established in Anatolia high land, where Kaman Kalehoyuk ruins exist. About

1595 BC, Hittite came down to Mesopotamia and abolished Babylonia Kingdom. Hittite implemented agriculture using iron tools there. Hittite perished around 1190 BC. Hittite had trade connection with Egypt. Iron tools were distributed to West Asia and Egypt by Hittite. Several researchers are saying that there were iron tools in Ancient China in Yin Dynasty by 1050 BC. In accepted notion, iron tools came from western area to China between 6 century BC and 5 century BC in Spring and Autumn Period. Iron tools were popularized in China in Warring States Period. Popularization of iron tools changed society of China drastically. Plowing technique by cattle with iron plow was evolved and agricultural productivity increased dramatically. Qin dynasty, the final winner of Warring States Period, implemented large scale public project including construction of long wall and large scale irrigation using iron tools. Domestication of animals also deep relation to development of agriculture. It is necessary to keep animals from young age for domestication. For this reason, keeping animal as pet is important for domestication. Animals domesticated in early age came close to human society by themselves. Dogs scavenged leftover food around human society and went hunting with human beings. For this reason, dog was the earliest domesticated animal. There are several opinions, though dog was domesticated form wolf in East Asia in 12,000 BC Domestication of dog was before the start of agriculture. Domestication of cat was later than the domestication of dog. It was commonly explained that coexistence with human being established because of habit of hunting mouse. This habit was convenient for human being to stamp out distractive animals which entered in storage of harvested crops. In this explanation, domestication of cat was after development of agriculture. However, the oldest (9,000 BC) fossil of domesticated cat was discovered in Cyprus Island. The cat was supposed to be reared as pet of a person of noble ranking. Goat and sheep were domesticated in Southwest Asia at about 10,000 BC. Domestication of goat and sheep can be explained by the development of agriculture. These animals were domesticated for food. Agricultural works take up time for hunting from farmers, in order to secure animal proteins farmer needed to enclose animals in their adjacent place. Pig is thought to have plural origins. Boars were domesticated in China, West Asia and Europe around 8,000 BC. Boars are prolific and can be gentled when they are reared from baby. Cattles are domesticated in West Asia around 8,000 BC. Probably the purpose of the domestication was for food. Dairy cattle and working cattle were improved from beef cattle. Domestication of horse was done

in Ukraine around 4,000 BC. Food conversion efficiency of horse is low. Horse is coward and has less advantage as animals for food comparing to cow, goat and sheep because of low food conversion efficiency. Domestication of horse might be difficult, though horse fits cold environment. Probably, the purpose of the domestication was also for food. However, fossil of horse which has trait of application of a bit was discovered from Ukraine. The age of the fossil is near the beginning of domestication of horse. The use of horse as work animal started in early history of domestication of horse. Horse was used for transportation or plowing at first. The history as working animal is long in cattle than in horse, because control of horse need higher technique than control of cattle. However, function as working animal for transportation is higher in horse. Technique and instrument to control working horse as manege improved. People use horses to drive combat vehicle and shot arrow from horseback. Those war-horses were powerful weapon and several nomadic people who has higher horse control skill established horseback races states. It is thought that chicken were domesticated in Northeast Thailand or Lao. Probably, some jangle fowl made their habitat in human community to escape from their predator in wild forest and people started use their eggs and flesh. Nomadic herding started after initiation of agriculture, because nomadic herding needs domesticated animal and needs for domestication of cattle and sheep was born to implement agriculture.

Many animals were domesticated for food, though the utilization of their excretory substances was important for the development of agriculture. Land degradation by repeated cultivation is serious issue in agriculture, especially in cultivation of barley and wheat. It is effective to fallow the field and graze farm animal periodically for recovery from land degradation. Excretory substances from farm animal make the field fertile. A simplest land utilization is fallow the field every two years. This is called two fields system. Two fields system was mainly used in Mediterranean area. In feudalism in Europe established in 8-9 century, farmers were tied with seigneur by contract. Three fields system popularized in West Europe under feudalism. In three fields system agricultural land in community was divided into three parts. One was used as spring plowing field and peas, oat or barley was cultivated in the field (summer field). One was used as autumn plowing field and wheat or rye was cultivated in the field (winter field). The other part was fallowed. The utilization of the land was rotated in 3 years cycle. Fallow soil was used as common grazing land. In this system, fields and fallow soil were managed cooperatively under the control of

seigneur. Fields were allocated to each farmer depending on the productivity of the field. This system was depending on the feudalistic contractual relationship and feudalism enabled three fields system. Three fields system increased utilization ratio of the land from 1/2 to 2/3. Three fields system together with improvement of other agricultural technology such as popularization of plowing increased agricultural productivity in Europe. As results, population in Europe increased and Europe expanded globally.

I-3-(4) From agricultural revolution to today

Agricultural revolution happened in Europe in the 18th century. In a restricted sense, The Agricultural Revolution means shift of agricultural form happened in Great Britain such as introduction of rotation system like Norfolk husbandry. Similar shifts happened all over West Europe in same ages. Agricultural revolution means shift of agriculture to system which require no fallow soil. For example, crops cultivated in same field were changed in Norfolk husbandry as follows. Barley (first year) →clover (second year)→wheat (Third year)→turnip (fourth year) →Barley. Among them clover was cultivated as feed crop. Turnip as well as potato was used as feed in winter season. In this system, farmers do not need to fallow their land and can keep domestic anima even in winter, though they need intensive work force and large independent land. With the progress of agricultural revolution, agricultural production increased, population increased, and capitalistic tenant farmers appeared. The formation of capitalist class was a cause of the Industrial Revolution in latter day. Agriculture in those days still depend input of fertilizer to increase production on excretes of human being and domesticated animal. Possible amount of fertilizer for input was the limiting factor of production. Studies of chemical fertilizer were one of the top issues in science in late 19th century and early 20th century. Among them, invention of Haber-Bosh process (1908) was revolutionary. Using this process nitrogen fertilizer can be produced from nitrogen in the air and hydrogen in high temperature and high pressure condition. Haber-Bosh process facilitated supply of nitrogen fertilizer in cheap price. Expansion of arable land requested increase of agricultural work, though working force by humans and working animal had limit. Especially after the discovery of the New World by Columbus, farmers had to manage huge area in comparable to Europe and Asia by limited manpower in North America, South America and Australia. Mechanization of agriculture was inevitable in those areas. Steam tractor and inter-combustion tractor were firstly sold in 1859 and 1892, respectively, though they were unsellable because of high price. Ford could succeed in price reduction by mass production by assembly line operation of car and sold Fordson tractor model F in 1917.

This model was sold in huge numbers. Cultivated species themselves are important in agriculture as well as system and technology. In early phase of the development of agriculture, plants compatible to the environment and have high productivity were selected as cultivated plants. Introduction of productive and high value plants have been important in all ages for development of agriculture. Discoveries of new land have been triggers of introduction of new cultivated species. Cultivated species in new land were introduced to other areas. After discovery of the New World by Columbus in 1949, tomato, potato, corn, chili, tobacco, etc. introduced from the New World to Europe, then they were distributed to all over the world. Breeding, the method to improve character rustics of cultivated species is another effective method to get cultivar with high value and easiness of production. People have implemented breeding intentionally of unintentionally before popularization of knowledge that characteristics (phenotype) were controlled by gene. Charles Darwin published "On the origin of species" in 1859. After that the idea that characters of species gradually change with time have been popularized. This is extremely recent when compared with long history of development of agriculture. Discovery of Mendel's law of heredity, which is explaining that combinations of genes conduces genetic phenomena, was 1865 and rediscovery of his law was 1900. Mendel's law opened modern thremmatology and selective breeding and cross breeding have aggressively been tried for improvement of cultivated species after that. Watson and Crick proposed double helix structure of DNA in 1953 pioneering later molecular biological breeding technique such as direct introduction of gene to organisms. Big production increase was progressed as the result of continuous efforts such as introduction of high productivity cultivar and mass input of fertilizer between 1940-1960. This is called green revolution. Improvements of cultivar and techniques were still carried out after that. International Rice Research Institute (IRRI) was established in Los Banos, Philippines in 1960, and IR8, a high productivity cultivar of rice, was produced in 1966. Consultative group on International Agricultural Research (CGIQR) was formed in 1971.

Main products of agriculture are foods and foods are traded by money today and sometimes foods are trade goods. International food trades have often caused serious social discussions. In1798, Malthus published "Theory of population". He made a prediction of future food deficiency in his book. In his theory, food deficiency cannot be evitable, because agricultural production increases in liner function, though population grows exponentially. In those days, increase of food production was urgent. Ricardo published "Principles of political economy and taxatation" in 1817 and he advocated "gain from trade" and principle of comparative advantage. The meaning of gain from

trade is as follows. Production efficiency of products are different among countries because of difference of condition. By trading of products which is produced in higher productivity country public welfare will increase. For example, in the case, England and Portugal both produce wine and woolen cloth (laxa), and productivity of wine is higher in Portugal than in England and productivity of woolen cloth is higher in England than in Portugal, producing wine only in Portugal and producing woolen cloth only in England and trade them between the countries enables production of two goods in low cost by smaller labor force. Definitely, it is correct. However, wine producers in England and woolen cloth producers in Portugal will lose their job. In the case of agriculture, environmental condition for production and per capita cultivated acreage differ among countries, and there exists extreme difference in production efficiency and cost in production for same good among countries. For international specialization to improve global productivity, we have to make effort to realize global free trade principle by abolition of tariff. However, many objections to abolition of tariff exist in countries which have large farmer population comparing to their cultivation acreage, because abolition of tariff weakens agriculture and make many jobless people in such countries. General Agreement on Tariffs and Trade(GATT) was established in 1948 for promotion of free trade principle. GATT Uruguay Round (1986-1995) was a place of international deliberation about service trade, intellectual ownership and liberalization of trade of agricultural products. The negotiations about agricultural products could make little headway. Future unexceptional tariffication of agricultural products and minimum access were determined, though complete liberalization was not agreed. Foundation of World Trade Organization was agreed in GATT Uruguay Round and organized in1995. WTO has made little progress in promotion of liberalization, and trend of block economy in which free trade was implemented in region have appeared. Singapore, Brunei, Chile and New Zealand signed on for Trans-Pacific Partnership (TPP) in 2005. And TPP was effected in 2006. USA, Australia, Malaysia, Vietnam and Peru joined in the negotiation of expansion of the partner countries and outline was agreed between 9 countries at November 12th 2011and final agreement was scheduled in 2013.

After agricultural revolution and industrial revolution, various industries including agriculture have developed rapidly. Those developments involved negative impacts to environment and human society, and various criticisms to have arisen for such too rapid and poorly balanced developments. Keeling began

measurement of carbon dioxide in the air at Mt. Mauna Loa, Hawaii from 1958 concernedly increase of carbon dioxide by consumption of large amount of fossil fuel. Latterly, he succeeded to show the fact of increase of carbon dioxide known as Keeling curve. Rachel L. Carson published "Silent spring" in 1962 raising an alert over dangerousness of chemical substances including agricultural chemicals. In 1972, Club of Rome published "The limit to growth" and predicted limit of growth because of degradation of environment, if human being would "growth" without change. The shift from rapid expansion and development of industries to well balanced sustainable growth have been widely supported globally after 1980s. In those trends, bio-energy and bio-materials attracted people's attention as relatively safe materials which do not act upon balance of green house gas in the air, and importance of agriculture was acknowledged. Corn price as well as price of other crops rapidly escalated in 2008. The trigger of the escalation was expectation for demand rise of corn for production of bio-ethanol. After that, balance of utilization crops for energy and food have often be discussed. Similarly, it is doubtless fact that agricultural infrastructure development such as water utilization and flood control by construction of dam will increase food production, though criticisms to such public works exist. Construction of Aswan High Dam was completed in 1970, and the dam created huge arable land spreading from Egypt to Sudan. However, it was the other side of the fact that the dam made negative environmental effects on environment of downstream basin and river mouth area. It has been proven that the theory of population by Malthus is not absolute truth. Agriculture today is not requested only to increase food supply, though requested to develop sustainably for construction of happy and comfortable human life and society.

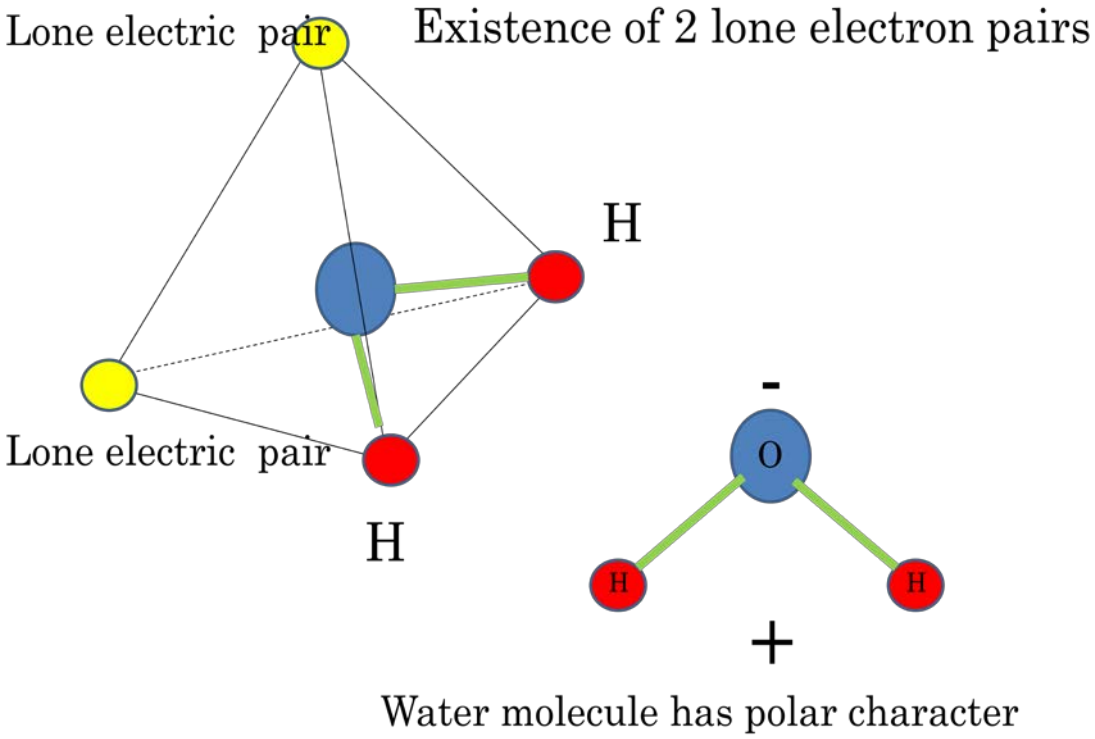

Lone electric pair
Existence of 2 lone electron pairs
H
Lone electric pair
H
-
O
H
H
+
Water molecule has polar character

Fig. 1

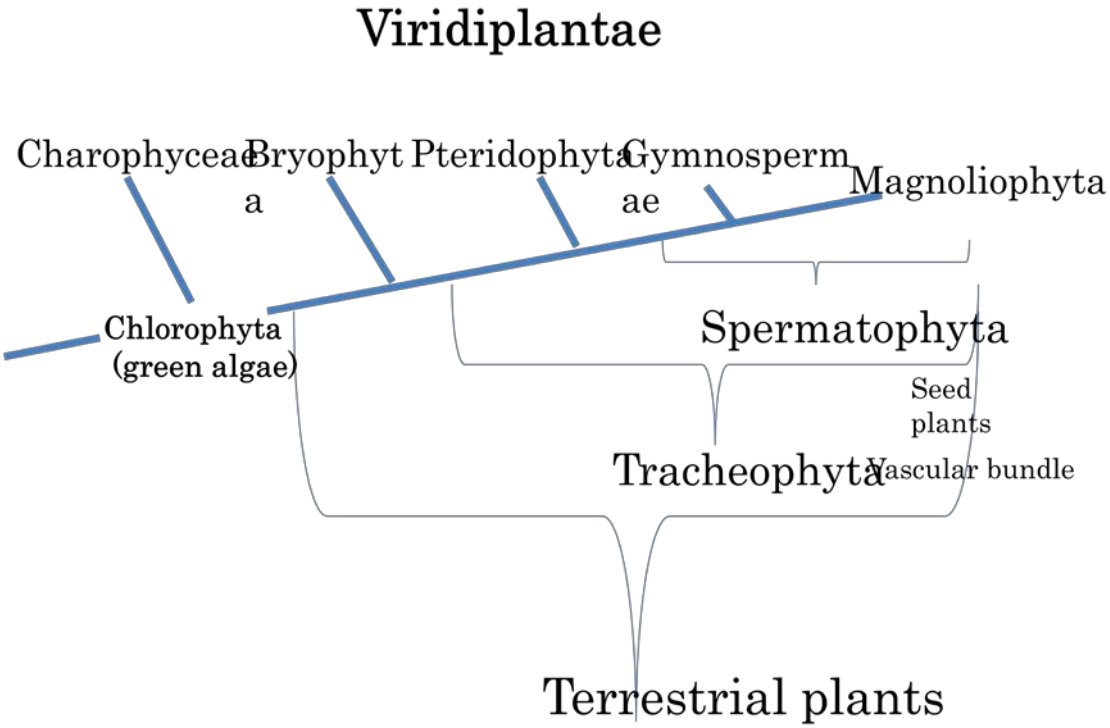
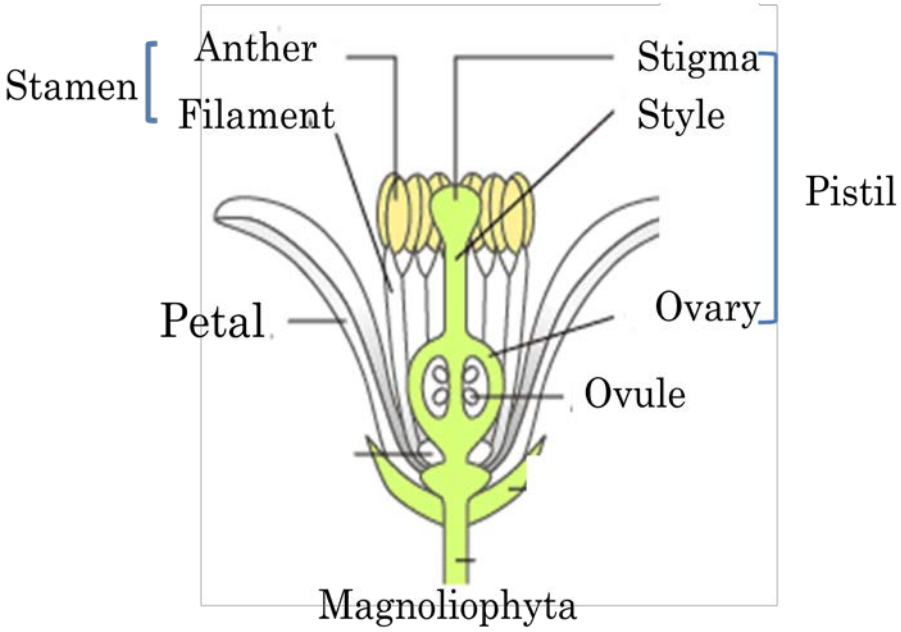
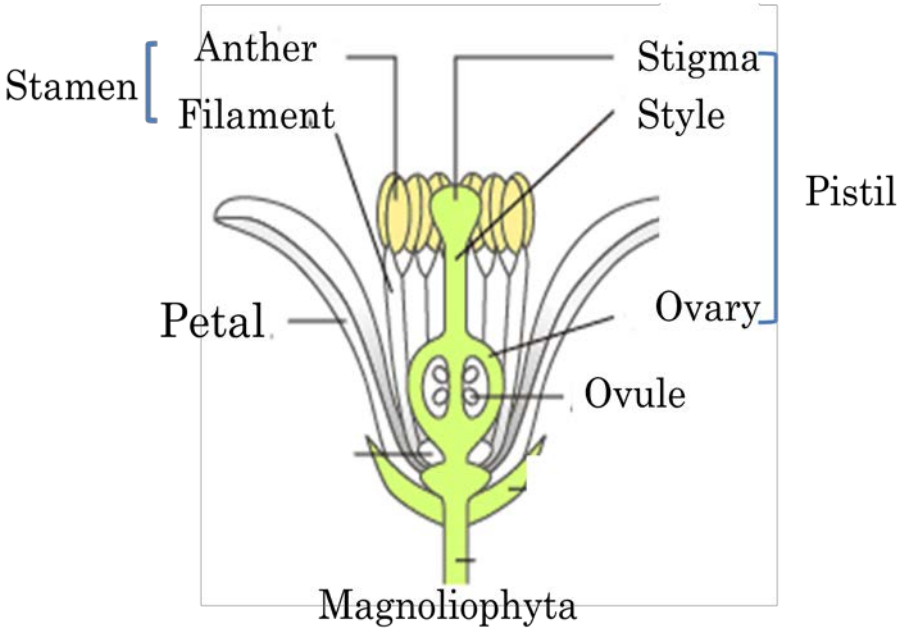

Viridiplantae
Charophyceae
Bryophyta
Pteridophyta
Gymnosperm
ae
Magnoliophyta
Chlorophyta
(green algae)
Spermatophyta
Seed
plants
Tracheophyta
Vascular bundle
Terrestrial plants

Fig. 2



Ovule is covered by carpel and exists in ovary.

Fig. 3



Ovule is covered by carpel and exists in ovary.

Fig. 4

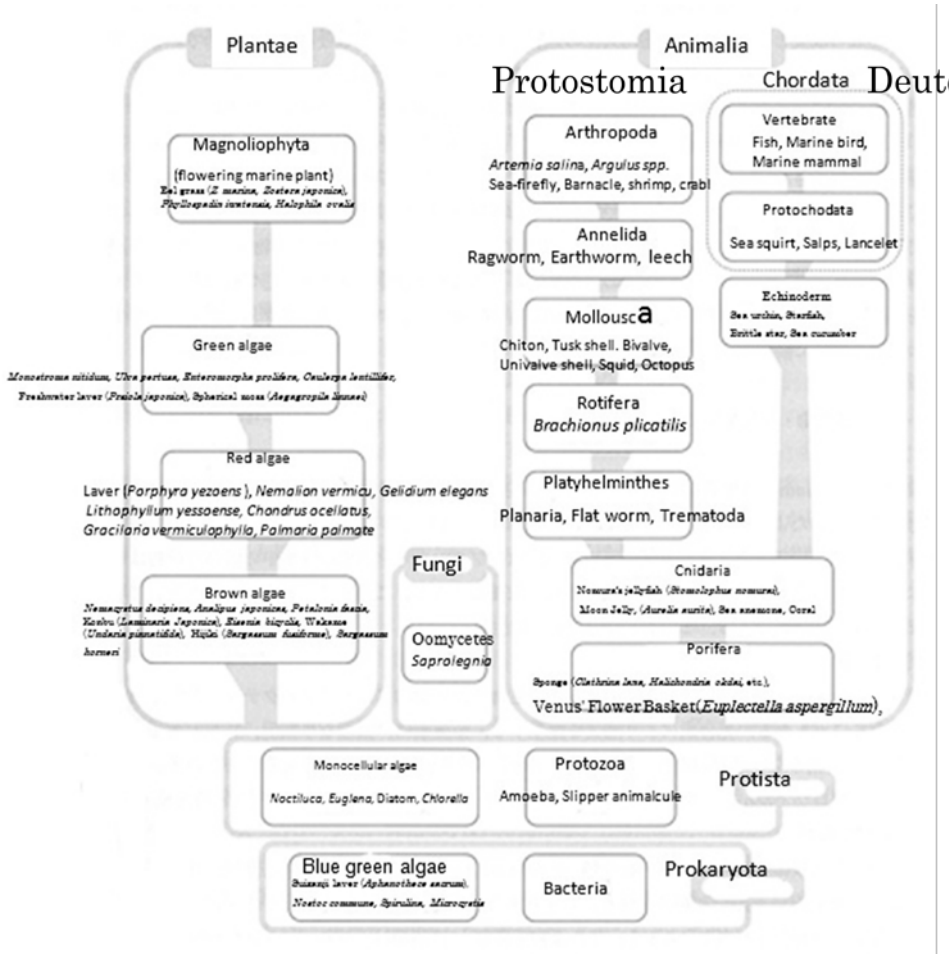

Plantae
Animalia
Protostomia
Chordata
Deuterostomia
Magnoliophyta
(flowering marine plant)
Eel grass (Z. marina, Zostera japonica), Phyllospadix iwatensis, Halophila ovalis
Arthropoda
Artemia salina, Argulus spp.
Sea-firefly, Barnacle, shrimp, crabl
Vertebrate
Fish, Marine bird, Marine mammal
Protochodata
Sea squirt, Salps, Lancelet
Annelida
Ragworm, Earthworm, leech
Echinoderm
Sea urchin, Starfish, Brittle star, Sea cucumber
Mollusca
Chiton, Tusk shell. Bivalve, Univalve shell, Squid, Octopus
Green algae
Monostroma nitidum, Ulva pertusa, Enteromorpha prolifera, Codium lentillifer, Freshwater laver (Prasiola japonica), Spherical moss (Aegagropila linnaei)
Rotifera
Brachionus plicatilis
Red algae
Laver (Porphyra yezoens), Nemalion vermicu, Gelidium elegans
Lithophyllum yessoense, Chondrus ocellatus, Gracilaria vermiculophylla, Palmaria palmate
Platyhelminthes
Planaria, Flat worm, Trematoda
Fungi
Cnidaria
Nomura's jellyfish (Stomolophus nomurai), Moon Jelly, (Aurelia aurita), Sea anemone, Coral
Brown algae
Nemacystus decipiens, Analipus japonicus, Petalonia fascia, Kombu (Laminaria japonica), Eisenia bicyclis, Wakame (Undaria pinnatifida), Hijiki (Sargassum fusiforme), Sargassum horneri
Oomycetes
Saprolegnia
Porifera
Sponge (Clathrina lana, Halichondria okadai, etc.),
Venus' Flower Basket(Euplectella aspergillum),
Monocellular algae
Noctiluca, Euglena, Diatom, Chlorella
Protozoa
Amoeba, Slipper animalcule
Protista
Blue green algae
Suizenji laver (Aphanothece sacrum), Nostoc commune, Spirulina, Microcystis
Bacteria
Prokaryota

Fig. 5

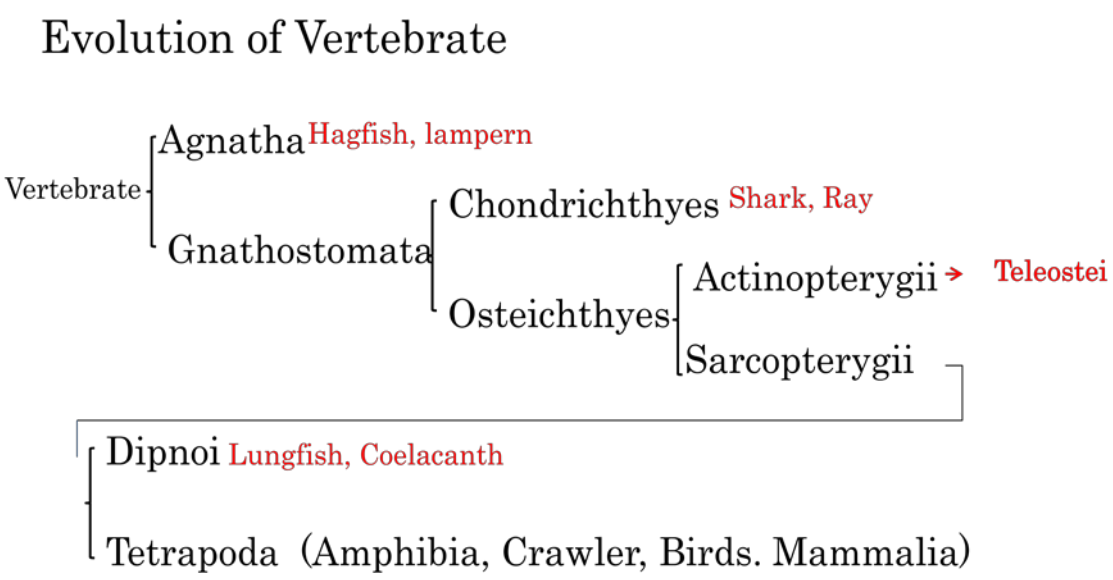

Evolution of Vertebrate
Vertebrate
Agnatha
Hagfish, lampern
Gnathostomata
Chondrichthyes
Shark, Ray
Osteichthyes
Actinopterygii
Teleostei
Sarcopterygii
Dipnoi
Lungfish, Coelacanth
Tetrapoda (Amphibia, Crawler, Birds. Mammalia)

Fig. 6

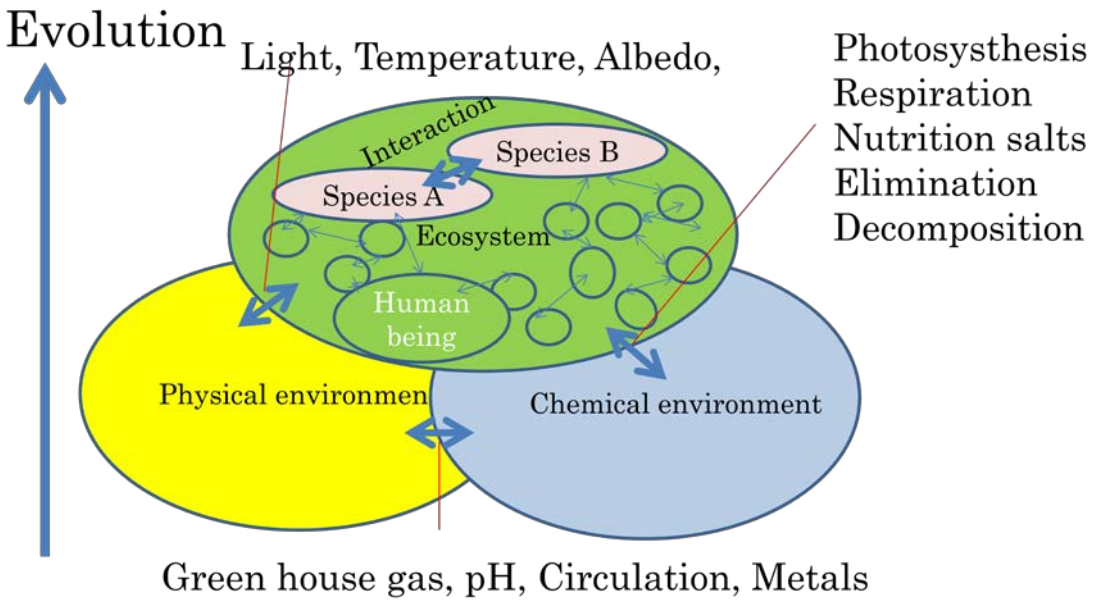
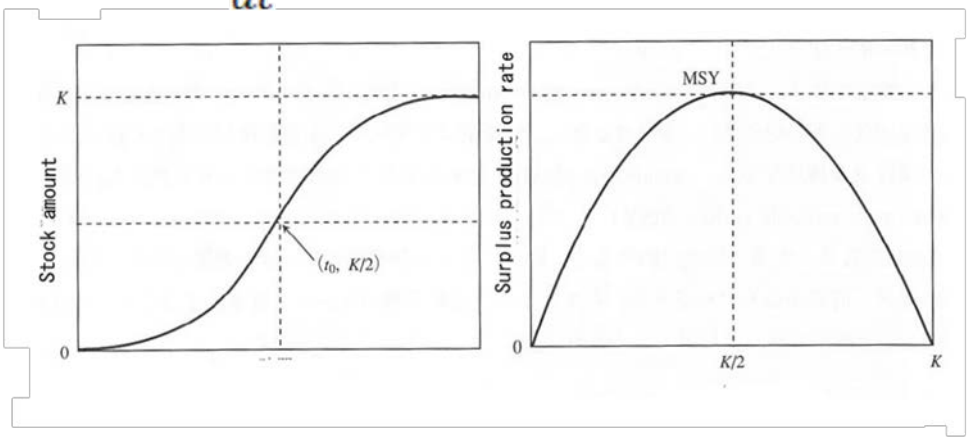

Evolution
Light, Temperature, Albedo,
Photosysthesis
Respiration
Nutrition salts
Elimination
Decomposition
Interaction
Species B
Species A
Ecosystem
Human being
Physical environmen
Chemical environment
Green house gas, pH, Circulation, Metals

Fig. 7

Adaptive strategy : r-K strategy theory

$$\frac{dN}{dt} = r(K - N)N$$



Population growth by logistic model (left) and relation between biomass and population growth rate in Scherfer's surplus production model (right).

Fig. 8

Phytoplankton are r-strategy
Large trees are K-starategy

生物生産の特徴

Fig. 9

Table 1

Inter molecular force between water molecule is strong because of hydrogen bonding and polar character

	MW	BP	FP	Sublimation P.
Water (H_2O	18	100°C	0°C	
Nitrogen (N_2)	28	-196°C		
Oxygen O_2)	32	-183°C	-219°C	
Carbon dioxide (CO_2)	44			-79°C

Table 2 Comparison between air and water (20°C)

	water	air	impact to aquatic organisms
Density	ca 1g/cm^3	1 /800	easy to float
Specific heat (constant pressure)	4.18J/K/g	1/4	stability of water temperature
Viscosity	1.002X 10^{3}Pa s	2 order smaller	
Light absorption	large	small	vertical distribution of light
Oxygen	6-8 mg/l	1/5 of air	Oxygen deficiency happens
Acoustic velocity	1,500m/s	340m/s	
Number of phases	3 Vapor, Water, Ice	1	

Table 3 Distribution of water and mean residence time

Place	volume(10^3km ^{3})	ratio (%)	MRT
Ocean	1,338,000	97	3,700 years
Permanent ice/ glacier	24,100	1.7	16,000 years
Ground water	23,400	1.7	300 years
Freshwater lake	91	0.007	10-100 years
Brackish lake	85	0.006	10-10,000 years
Soil moisture	16.5	0.001	280days
Atmosphere	12.9	0.001	9days
River	2.12	0.0002	12-20 days

Table 4　Comparison among the planet

	Venus	Earth	Mars
Distance[1]	108,208,930,km	149,597,871km	227,936,640km
Irradiation[2]	2,660W/m^2	1,370W/m^2	590W/m^2
Albedo	0.65	0.37	0.15
Surface temp.	400℃	15℃	-53℃
Mass	4.869X10^{24}kg	5.9736X10^{24}kg	0.64196X10^{24}kg
	Air	Air	Thin air

[1] Average radius of revolution orbit

[2] strength of irradiation of sunlight at revolution orbit

[3] reflection rate at the surface of planet

Appendix chronological table

x10^9 years ago	
13.7	Birth of Space
8.3	Birth of the Galaxy
5.0	Birth of the Sun (Second generation Star)
4.6	Birth of the Earth (collision and in
3.8	Birth of Life
3.2	Beginning of photosynthesis (appearance of cyanobacteria)
2.4～2,2	The earliest glacial age (presently known)
2.1	Appearance of Eucaryote
	Appearance of green algae
1.0-0.6	Appearance of multicellular organisms
x10^6 years ago	
600-500	Snow ball earth.
	Mass extinction of Protists
570-510	Extinction of **Ediacara fauna**
540-490	Cambrian explosion
490-440	Appearance of fish (Ordovician period)
420-360	Prosperity of fish (Devonian period)
	Appearance of terrestrial plants
	Appearance of Spermatophyta (seed plant)
360	Appearance of Amphibia (Terrestrial animal)
300	Appearance of Reptillian (crawler)
250	Appearance of Magnoliophyta
225	Appearance of Mammalia
65	Appearance of Primates
63	Appearance of **Haplorhini (**lacks vitamin C synthesis capacity)
25	Appearance of **Ape**
6-5	Differentiation of human being from chimpanzee
	Australopithecine
2.5-1.8	Use of stone tools (Oldowan stone affairs)
X 10^3 years ago	
500	Appearance of *Homo erectus pekinensis*
250	Appearance of *Homo sapiens*
10	*Homo sapiens* departed Africa
7.5	Toba event (gigantic explosion of Toba volcano)

Human population decreased to less than 10 thousands

30-20 Human being reached American continental.

12,000 BC Cultivation of upland rice in Hoxi and Hunan province in China

11,500 BC Construction of ruins of Göbekli Tepe (Southeast Turk)

7,000 BC Ruins of Jericho Evidence of keeping animal and agriculture

7,000-6,500 BC Large scale paddy rice cultivation (Zhejiang province)

6000 BC Construction of irrigation facilities

4500～4000 BC Construction of shrine in Mesopotamia

Formation of agricultural community (Neolithic age)

3,500 BC Sumerian moved too south Mesopotamia

3,150 BC Integration of upper and lower Egypt dynasty

1,800 BC Oldest iron tool (Kaman Kalehoyuk ruins, Turk)

1,700 BC Yin dynasty (China)

1,680 BC Hittite Kingdom was established

1,190 BC Downfall of Hittite Kingdom

expansion of iron culture to Egypt and Mesopotamia

770～221 BC (Spring and Autumn period)

Popularization of iron too in China

8-9 century Feudal system was established in Europe

Agricultural community popularized in west Europe

10-11 C Beginning of three field system in Europe

1492 Columbus discovered the New World

18 C Agricultural revolution

1798 "Theory of population"(Malthus)

1817 "Principles of political economy and taxatation"(Ricardo)

1859 "On the origin of species" (Darwin)

Sale of steam tractor

1865 Discovery of Mendel's Law

1892 Sale of internal combustion tractor

1900 Rediscovery of Mendel's Law

1908 Invention of Haber-Bosh process

1917 Sale of Fordson Tractor model F

Green revolution

1945 Institution of FAO

1953　Propose of Double helix structure of DNA (Watson and Crick)

1958　Keeling star the measurement of CO2 in atmosphere in Hawaii

1960　Founding of IRRI　(International Rice Research Institute)

1962　Rachel Carson published “Silent Spring”

1966　IR-8 was made

1979　Completion of Aswan High Dam

1971　Institution of CGIAR (Consultation Group for International Agricultural Research)

1972　Club of Rome published “The limit to growth”

1986　Start of GATT “Uruguay Round”

1995　Founding of WTO (World Trade Organization)

2008　Escalation of oil and crop prices

2011　Accident in Fukushima Atomic Power Plant