General (Comparative) Biology

Course No: BNG2003
Credits: 3.00

Prof. Dr. Klaus Heese

Why Biology ??

Prof. Dr. Klaus Heese

- 1. General Introduction into Biology

- Biology
  - is the scientific study of *Life*

  - *What defines Life ?*
  - *How is Life characterized ?*

Prof. Dr. Klaus Heese

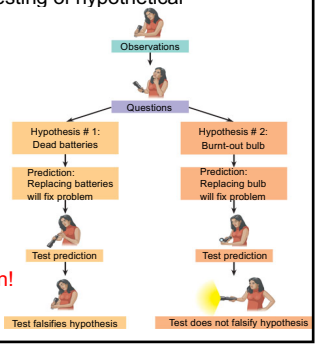
Biologists use various forms of inquiry to explore life

Hypothesis-Based Science

- In science, inquiry that asks specific questions usually involves the proposing and testing of hypothetical explanations, or hypotheses

The Role of Hypotheses in Inquiry

- In science, a hypothesis is a tentative answer to a well-framed question, an explanation on trial; it makes predictions that can be tested



Important: ask the right question!

- We all use hypotheses in solving everyday problems

Designing Controlled Experiments

- Experiments must be designed to test
  - the effect of one variable by testing control groups and experimental groups in a way that cancels the effects of unwanted variables

Limitations of Science

- *Science cannot address supernatural phenomena because hypotheses must be testable and falsifiable and experimental results must be repeatable*

Do *supernatural phenomena* influence biological systems ?

Theories in Science

- A scientific theory
  - is broad in scope
  - generates new hypotheses
  - is supported by a large body of evidence

Induction in Discovery Science

- In inductive reasoning scientists derive generalizations based on a large number of specific observations

Deduction: The "If…then" Logic of Hypothesis-Based Science

- In deductive reasoning, the logic flows from the general to the specific
- If a hypothesis is correct, then we can expect a particular outcome

A Closer Look at Hypotheses in Scientific Inquiry

- A scientific hypothesis must have two important qualities
  - It must be testable
  - It must be falsifiable

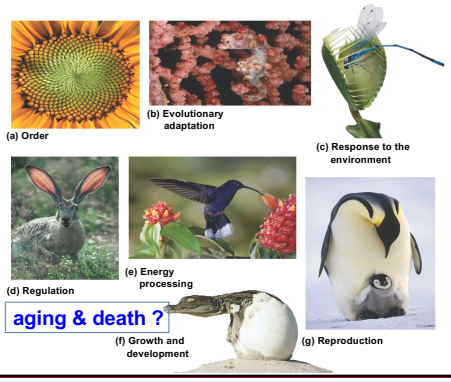
The Myth of the Scientific Method

- The scientific method is an idealized process of inquiry
- Very few scientific inquiries adhere to the "textbook" scientific method

The Phenomenon we call Life

- We recognize life
  - by what living things do (changing)
- Biologists explore life from the microscopic to the global scale
- The study of life extends from the microscope scale of molecules and cells to the global scale of the entire living planet

- Some properties of life



Organization of Life

A Hierarchy of Biological Organization

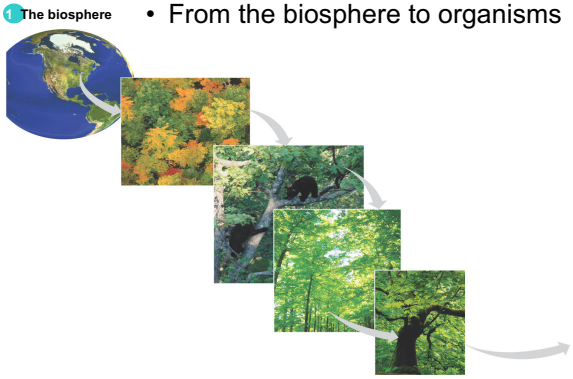
- The hierarchy of life
  - extends through many levels of biological organization

A Closer Look at Ecosystems

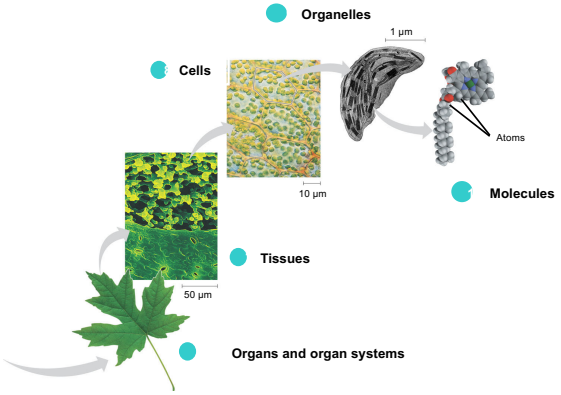
- Each organism interacts with its environment
- Both organism and environment are affected by the interactions between them

Organization of Life

- From the biosphere to organisms



- From cells to molecules



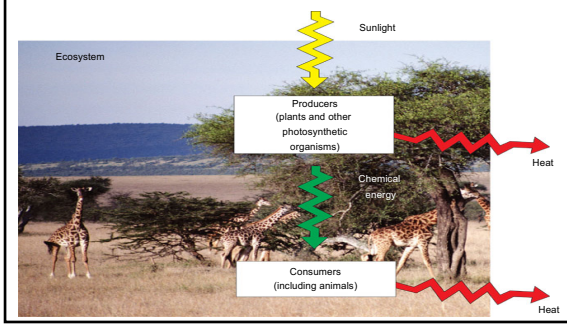
Ecosystem Dynamics

- The dynamics of any ecosystem include two major processes
  - Cycling of nutrients, in which materials acquired by plants eventually return to the soil
  - The flow of energy from sunlight to producers to consumers

Energy Conversion

- Activities of life require organisms to perform work, which depends on an energy source
- The exchange of energy between an organism and its surroundings often involves the transformation of one form of energy to another

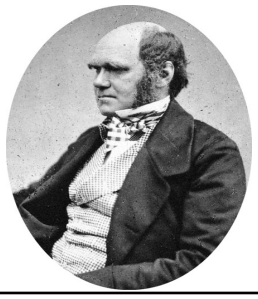
- Energy flows *through* an ecosystem
  - Usually entering as sunlight and exiting as heat



The Origin and Study of Life

- The ***evolutionary view*** of life

came into sharp focus in 1859 *when Charles Darwin* published *On the Origin of Species by Natural Selection*



The Theory of Evolution

1. Cosmic Evolution – Big Bang, origin of time, space, material
2. Chemical Evolution – all elements derive from H_2 (hydrogen)
3. Evolution of the stars – stars die, but never anyone has seen the birth of a star
4. Organic evolution – origin of life (a stone became human being)
5. Macro evolution – change from one species to another (nobody has ever observed it)
6. Micro evolution – variation within a species (no doubt about it)

1.) – 5.) are 'theories' -- we only observe/d 6.)

Science is about observations – but we never really observed evolution yet – it is a theory using 'time' as the most important parameter ! The secret is 'time' !

The 1st Law of Thermodynamics:

It is in no way possible, either by mechanical, thermal, chemical, or other devices, to obtain perpetual motion, i.e. it is impossible to construct an engine which will work in a cycle and produce continuous work, or kinetic energy, from nothing.

The energy of an isolated system is constant. (cannot be destroyed nor be created – but how this world then evolved ?

The Origin of Life - Big bang (BB): all material concentrated in one dot, then it exploded … a very crowded spot ! Then it cooled down by long rain, …

in other words: BB says: nothing exploded and here we are. We all came from a dot and the dot came from nothing.

Uni verse (cosmos) = 1 spoken sentence = we live in a single spoken sentence

Which theory fits best with our scientific observations (not with our assumptions that we may make based on our observations) ?

The 2nd Law of Thermodynamics:

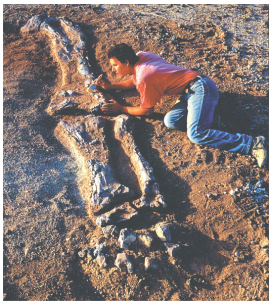
Everything tends toward **disorder** – that is in clear agreement with our observations.

via aging to dust …, however ---> in contrast:

Evolution: higher order/systems appeared: We developed from RNA to cell, bacteria, fish, monkey and then into human being!?
Evolution: the earth is an open system – it works if you add energy and overcome the 2nd law of thermodynamic – *however*:
1) the universe is a closed system
2) adding energy is destructive without a force mechanism that controls it (Pearl Harbor, Hiroshima, sun on your house roof , car, etc
3) Only chlorophyll can use the energy of the sun - a plant cell (the biological system that makes photosynthesis) is extremely complex – thus, adding energy is not bringing order – you need to use the energy properly (solar cells)

'**Evolution**' accounts for life's **unity** & **diversity**

- the history of life
  - is a saga of a changing earth 'billions' of years old (?)

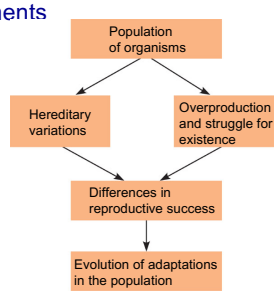


- ***Diversity is a hallmark of life***
- Biologists explore life across its great diversity of species

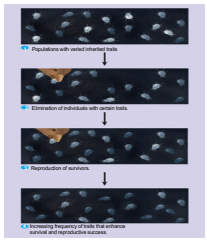
- *The Origin of Species* articulated two main points
  - Descent with modification
  - Natural selection

Natural Selection

- Darwin proposed natural selection
  - as the mechanism for evolutionary adaptation (epigenetic changes) of populations to their environments



- **Natural selection** is the evolutionary process that occurs
  - when a population's heritable variations are exposed to environmental factors that favor the reproductive success of some individuals over others

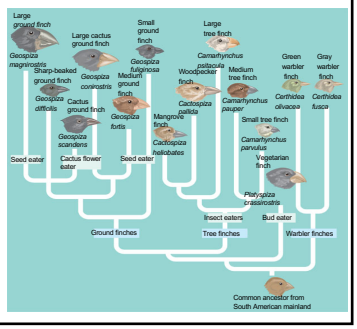


The Tree of Life

- Many related organisms have very similar anatomical features, adapted for their specific ways of life
- Such examples of kinship connect life's "unity in diversity" to Darwin's concept of "descent with modification"

- **Darwin** proposed a hypothesis that natural selection
  - could enable an ancestral species to "split" into two or more descendant species, resulting in a "tree of life"

- Each species is on twig of a branching tree of life extending back in time through ancestral species more and more remote
- All of life is connected through its long evolutionary history



Grouping Species: The Basic Idea

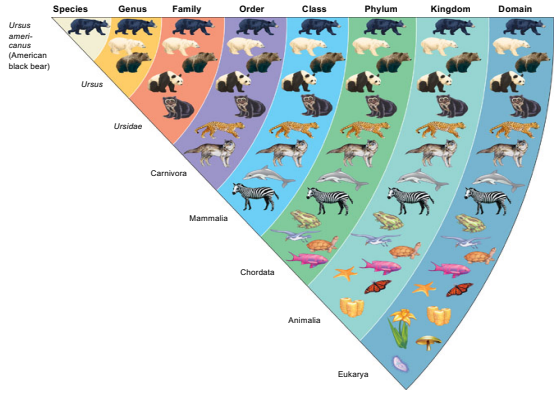
- Taxonomy
  - Is the branch of biology that names and classifies species according to a system of broader groups
  - the conception, naming, and classification of organism groups.

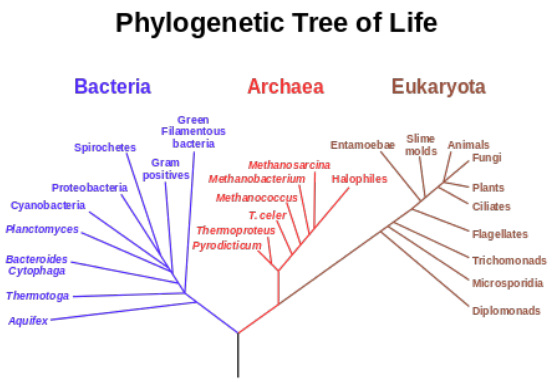
Taxonomy (from Ancient Greek: τάξις taxis, "arrangement," and -νομία -nomia, "method") is the science of defining groups of biological organisms on the basis of shared characteristics and giving names to those groups. Organisms are grouped together into taxa (singular: taxon) and given a taxonomic rank; groups of a given rank can be aggregated to form a super group of higher rank and thus create a taxonomic hierarchy. The Swedish botanist Carolus Linnaeus is regarded as the father of taxonomy, as he developed a system known as Linnaean classification for categorization of organisms and binomial nomenclature for naming organisms.
With the advent of such fields of study as phylogenetics, cladistics, and systematics, the Linnaean system has progressed to a system of modern biological classification based on the evolutionary relationships between organisms. Check: http://en.wikipedia.org/wiki/Taxonomy_(biology)

Phylogeny
plural phy·log·e·nies: the evolutionary history of a kind of organism: the evolution of a genetically related group of organisms as distinguished from the development of the individual organism

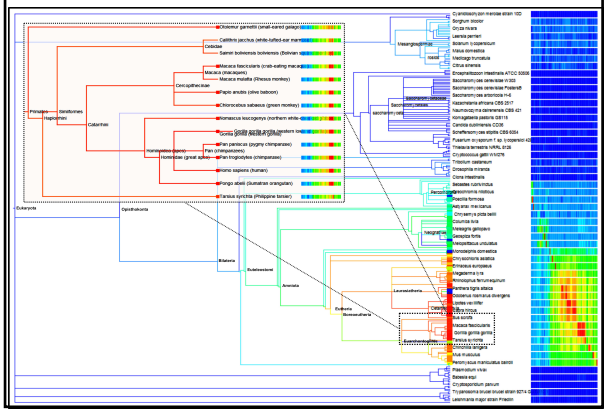
Phylogenetics /ˌfaɪloʊdʒəˈnɛtɪks, -lə-/ (Greek: φυλή, φῦλον - phylé, phylon = tribe, clan, race + γενετικός - genetikós = origin, source, birth) – in biology – is the study of the evolutionary history and relationships among individuals or groups of organisms (e.g. species, or populations). These relationships are discovered through phylogenetic inference methods that evaluate observed heritable traits, such as DNA sequences or morphology under a model of evolution of these traits. The result of these analyses is a phylogeny (also known as a phylogenetic tree) – a hypothesis about the history of evolutionary relationships. The tips of a phylogenetic tree can be living organisms or fossils. Phylogenetic analyses have become central to understanding biodiversity, evolution, ecology, and genomes. Taxonomy is the classification, identification and naming of organisms. It is usually richly informed by phylogenetics, but remains a methodologically and logically distinct discipline. The degree to which taxonomies depend on phylogenies (or classification depends on evolutionary development) differs depending on the school of taxonomy: phenetics ignores phylogeny altogether, trying to represent the similarity between organisms instead; cladistics (phylogenetic systematics) tries to reproduce phylogeny in its classification without loss of information; evolutionary taxonomy tries to find a compromise between them.
https://en.wikipedia.org/wiki/Phylogenetics

- Classifying life





Taxonomy based on Genomics



The Three Domains of Life

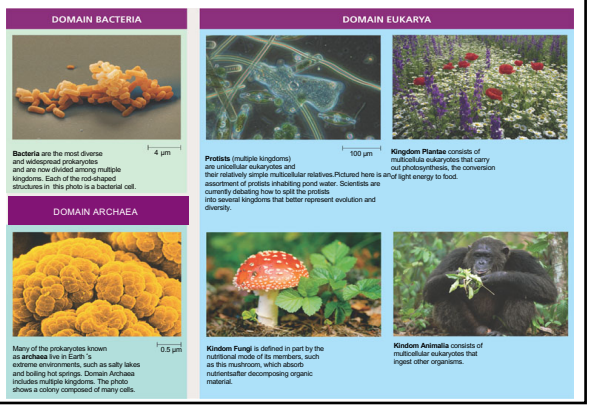
- At the highest level, life is classified into three domains
  - Bacteria
  - Archaea
  - Eukarya

  } Prokaryotes

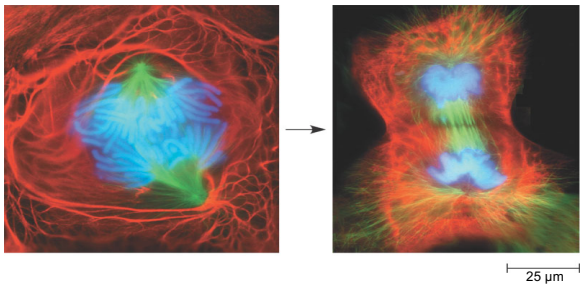
  Eukaryotes

- Domain Bacteria and domain Archaea
  - Consist of **prokaryotes**
- Domain Eukarya, the **eukaryotes**
  - Includes the various protist kingdoms and the kingdoms Plantae, Fungi, and Animalia

The Three Domains of Life



- The ***Cell*** is the lowest level of organization that can perform *all* activities required for ***Life***

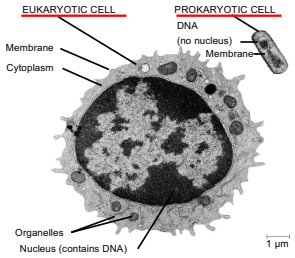


Two Main Forms of Cells

- All cells share certain characteristics
  - they are all enclosed by a membrane
  - they all use DNA as genetic information
- There are two main forms of cells
  - Eukaryotic
  - Prokaryotic

- *Eukaryotic* cells are subdivided by **internal membranes** into various **membrane-enclosed organelles**

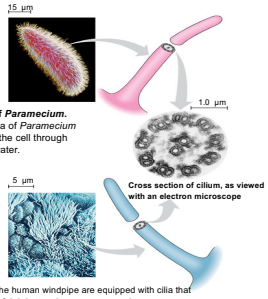
- *Prokaryotic* cells **lack** the kinds of membrane-enclosed organelles found in *Eukaryotic* cells



Unity in the Diversity of Life

- as diverse as life is
  - there is also evidence of remarkable unity

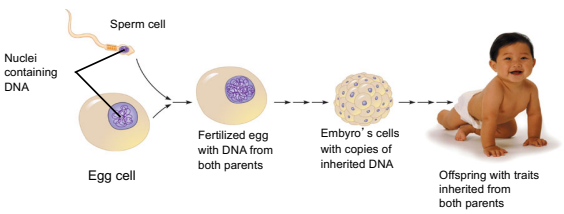
The fact that one system has something in common with another does not prove that one thing evolved from the other.



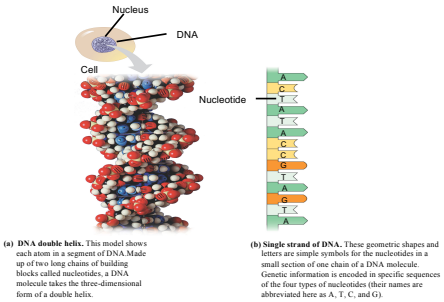
Cilia of windpipe cells. The cells that line the human windpipe are equipped with cilia that help keep the lungs clean by moving a film of debris-trapping mucus upward.

The Cell's Heritable Information

- Cells contain chromosomes made partly of DNA, the substance of genes
  - Which program the cells' production of proteins and transmit information from parents to offspring



- The molecular structure of **DNA**
  - accounts for it information-rich nature

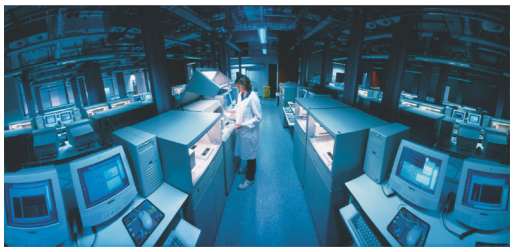


(a) DNA double helix. This model shows each atom in a segment of DNA Made up of two long chains of building blocks called nucleotides, a DNA molecule takes the three-dimensional form of a double helix.

(b) Single-strand of DNA. These geometric shapes and letters are simple symbols for the nucleotides in a small section of one chain of a DNA molecule. Genetic information is encoded in specific sequences of the four types of nucleotides (their names are abbreviated here as A, T, C, and G).

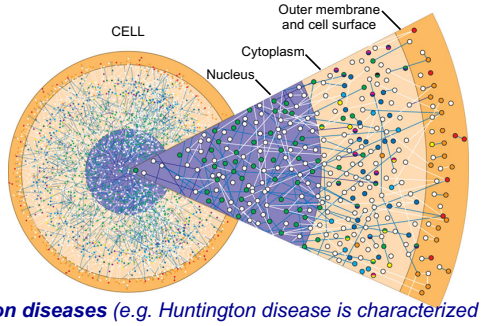
Genomics

- The study of DNA structure, an example of reductionism has led to further study of heredity, such as the Human Genome Project



Diseases: Alzheimer's disease; Parkinson's disease: gene mutations

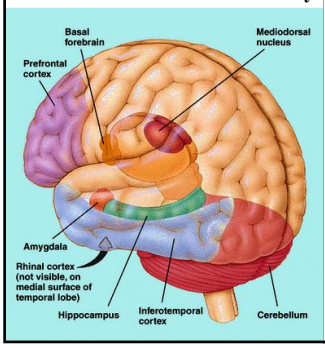
Proteomics

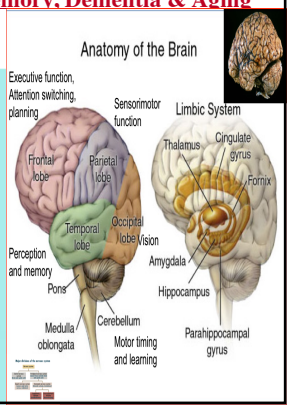


Prion diseases *(e.g. Huntington disease is characterized by a change of the 3D structure of a protein without a change in a gene (neither mutation nor epigenetic change)*
Similar diseases: Alzheimer's and Parkinson's diseases.

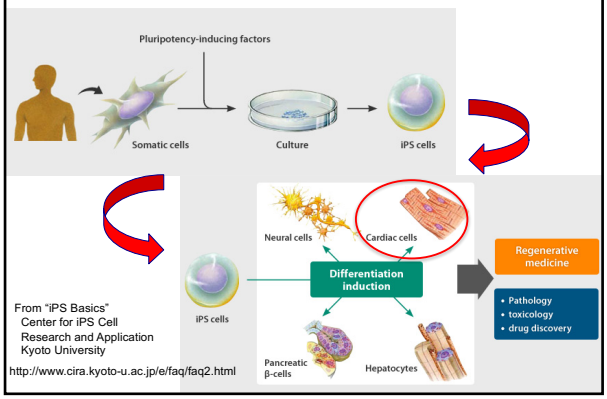
The human brain – the most complex biological sub-system of the human body: Memory, Dementia & Aging

Structures of the Brain that play a role in memory





iPSCs – induced pluripotent stem cells



From "iPS Basics"
Center for iPS Cell Research and Application
Kyoto University
http://www.cira.kyoto-u.ac.jp/e/faq/faq2.html

Systems Biology

- Systems biology seeks to create models of the dynamic behavior of whole biological systems
- With such models scientists will be able to predict how a change in one part of a system will affect the rest of the system

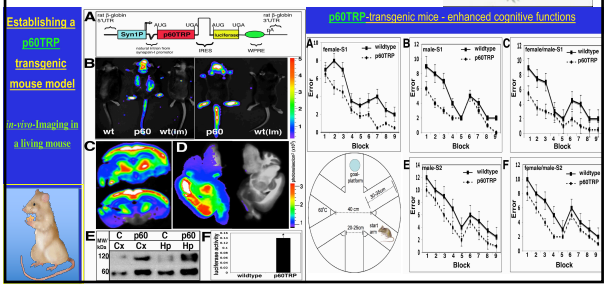
- Systems biology
  - Is now taking hold in the study of life at the cellular and molecular levels
  - Includes three key research developments: high-throughput technology, bioinformatics, and interdisciplinary research teams

A single change (e.g. mutation) in a gene (or protein) may induce a change in a protein function and thus affect the entire biological system (organism) !

Systems Biology

Systems biology seeks to create (e.g. animal) models of the dynamic behavior of whole biological systems

Transgenic p60TRP mouse



- **Biological systems** are much more than the sum of their parts
- A system is a combination of components that form a more complex organization

The Emergent Properties of Systems

- Due to increasing complexity new properties emerge with each step upward in the hierarchy of biological order

The Power and Limitations of Reductionism

- Reductionism involves reducing complex systems to simpler components that are more manageable to study

Systems Biology

What is the difference between the 3 biological systems of life:

Human – animal – plant ?

Each system is more than the sum of its sub-systems – still,

is the sum of the same sub-parts always the same biological system?

Or, in other words:

What is the difference between the 3 biological systems of life:
or, between/among:

Human – animal (monkey, fish) – plant – … – table – stone, ... ?

	Have /	don't have
Human		
Animal		
Plant		
Table		
Stone		

A few challenging questions?

- Why did we not observe yet a tree that is older than about 4000 years ?
- Why is oil still under pressure beneath the earth surface after so many years ?
- Why there are so many trees going vertically through many layers that are supposed to be 100 000y or more different in age ?
- If the spin of the earth around itself is slowing down (about 33s added since 1970), how could the dinosaurs stay on earth so many years ago ?
- The earth is losing the moon – many years ago the tides would have taken away Korea
- In the beginning was material that concentrated to a dot and after high spinning exploded to become the universe – but - where this material/dot came from ?
- Where did the laws or principle of nature come from ? Why are they not evolving ?
- Where did the energy come from ?
- **Conservation of spinning moment:** if big bang started as a spinning dot – all pieces should have the same spin – however, the Venus, Uranus and probably Pluto rotate backwards compared to other 6 planets including the earth.
- 8 out of 91 rotate backwards. Jupiter, Saturn and Neptun have moons orbiting in both directions! Even some entire galaxies spin backwards.

----> why it is so ---> to show us the Big Bang theory doesn't work out?

Has 'modern science' really provided convincing evidence that evolution exists?

Evolution and its consequences:

Statistic changes after 1963 in the USA:

Tremendous change in:

- Sex crimes increase
- Underage persons' pregnancy increase
- Suicides increase
- Killing / shooting increase

Fairy tale (story):

The princess kisses the frog and the frog became a prince

In Evolution:

After billions of years the frog became the prince

The secret is not the kiss – in Evolution it is billions of years.

Evolution Theory: today, this theory is taken for granted, however:

1) What defines me as biological system? ACGT ?

2) Who am I ?

3) Where I come from ?

4) Why am I here ?

5) Why am I aging?

6) Where do I go after death ?

Only in 1959 (100 years after Charles Darwin's theory was published in 1853) US president Eisenhower approved US$ 1 billion to promote the theory of evolution! Before that, only about 3,000 words in the text books – in 1963: >33,000 words in text books

-----> in fact , the big bang will happen some day and has been described already !

50% of the US scientists believe in Evolution
But only about 5% of the US population believe in evolution

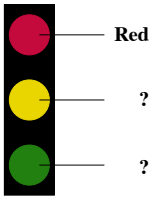
There was a time all scientists believed
- that all planets turn around the earth! (but all rather turn around the sun, with our moon turning around the earth)
- that big rocks fall faster than small rocks (but in vacuum all fall with the same speed)
- if you are sick, take out the blood (go to the barber; in the USA, Japan (Korea?) you have the blue/red sign outside)

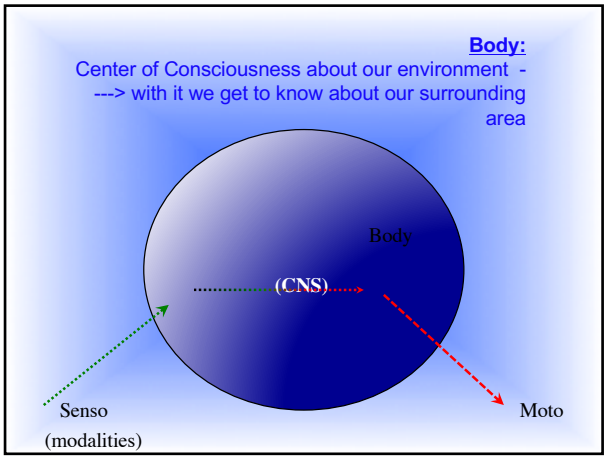
- However, even if many people believe in something, that does not make it true !
Has 'modern science' really provided convincing evidence that evolution exists?

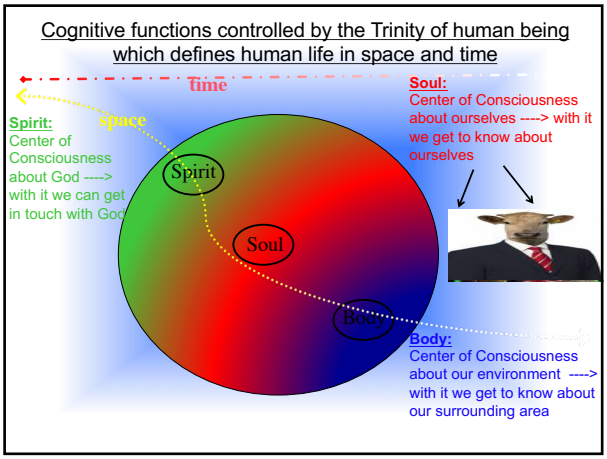
Memory & Learning

Genes, environment & education ----> behavior
***epigenetic* changes (inheritable)**

environment and education: mechanisms: learning and memory

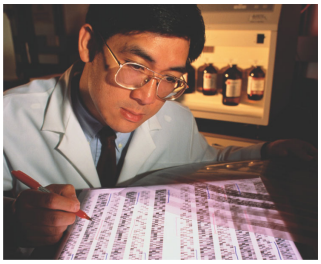






The Culture of Science

- Science is a social activity, characterized by both cooperation and competition



Science, Technology, and Society

- Technology applies scientific knowledge for some specific purpose

Types of Data

- Data are recorded observations; they can be quantitative or qualitative

Discovery-based Science

- Discovery science describes natural structures and processes as accurately as possible through careful observation and analysis of data