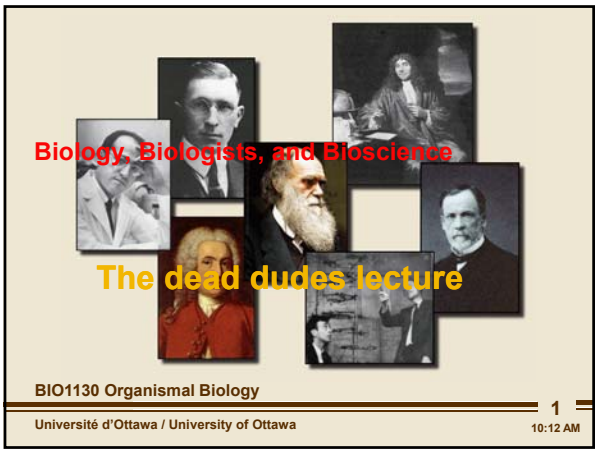

In this lecture:

- History of biology, a natural science, compared to that of the physical sciences.
- Misconceptions about "facts" of biology
- How biology is done – scientific method in natural sciences.

Defining biology (Treviranus 1802)

The subject matter of our investigations will be the various forms and manifestations of life, the conditions and laws controlling their existence, and the causes by which this is effected. The science, which occupies itself with these subjects, we shall designate by the name biology, or science of life.

- Junk DNA = regulatory DNA
- Biology – the beginning of the 19th century
- 1500 years – medieval times

Important stages in the history of Biology

- 400 BCE – 450CE: Greek and Roman ages
- 450 – 16th century: Medieval ages
- 16th-18th century: Renaissance and the scientific revolution
- 19th century
- 20th century
- 21st century

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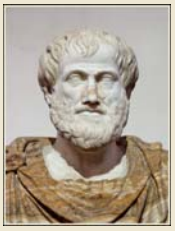
4
10:12 AM

- Greek and roman ages were very advanced, huge industrious civilizations, nomadic, brought back minerals, gold, tin, built ships throughout the Mediterranean

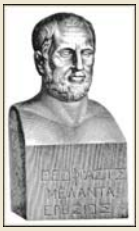
Important stages in the history of Biology

400 BCE – 450: Greek and Roman ages

Hippocrates
(460-370 BCE)



Aristotle
(384-322 BCE)



Theophrastus
(371-287 BCE)

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- Hippocrates – first philosopher to study human biology, first recordings regarding human systems HUMAN BIOLOGY
- Aristotle – big philosopher, as Greek culture travelled he kept a record for the Greek areas of all of the animals that were seen (giant list of all the organisms that were encountered – birds, fish, vertebrates etc.), prioritizes as being inferior and superior to one another with man being at the top, creating the Scala Naturae (scale of the living world – inventory of living animals) ANIMAL BIOLOGY
- Theophrastus – PLANT BIOLOGY – Father of classification of taxonomy - did the same thing as Aristotle, inventory of plants, why would you want to have an inventory? – Medicinal benefits (drugs), plants have no way to escape predators thus they create poisons and chemicals to protect themselves from predators (whereas animals have physical armor), he put together an inventory of ten books where he gave their benefits in the medical field, put together a compendium of plants with groups of names and such, 9 of his books still exist today of the ten

***Each of these works are lists or catalogues of the living world that really didn't address the biology of the organisms themselves. This is because the Greek philosophers all believed Plato's ideal that all organisms were unchanged unique types and their differences could be attributed to a special internal "essence", a philosophy called essentialism.

Important stages in the history of Biology

400 BCE – 450: Greek and Roman ages

- *Scala naturae* the great chain of being
- Essentialism

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•Scala Naturae – the most superior being are the gods, tier one angels underneath gods (according to picture), second angels, man, birds (flying animals – closer to heaven?!), aquatic animals, land animals, organisms with roots in soil, animals that lived in the soil

- Each level has a purpose and is equally important in the Scala naturae, there is no change in the chain, arranged in order of importance, large diversity – known as the essentialist thought – fixed role in the scale and there is no change In addition to his other works Aristotle tried to organize the living world in his scala naturae where the gods, were at the top of the great chain of being with humans underneath them. At the bottom was the inert world and the elements; and in between all the other types of living things.

Aristotle believed that both inanimate and animate objects had fixed characteristics

14th cenutry - europeans believed that all organisms were created by god and they would never become extint. No species would ever arise - this was the idea of natural theology which sought to name and catalogue all of god's creation.

Important stages in the history of Biology

450-16th century: Medieval ages

- **Europe**
  - **400-700 Early middle ages (Dark Ages)**
  - **1000 - 1300 High middle Ages**
  - **1300-1500 Late middle ages**

Black plague (1347-1351)

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7

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- 450 – 16th century – Rome begins to deteriorate, Germans attack Rome causing it to disappear in Europe, economy collapses even though they had a tremendous infrastructure, having to grow your own food – sub system families, hand-to-mouth living, Rome shrinks back to a Mediterranean country, took almost 300 years for the population to increase and the natives, British etc to commence the industry yet again, cathedrals being built in the 1200's because Europe is again rich – science is booming again.
- 1347 – plague – destroys Europe, rats transmitted by flea, dense population = wild spread, 1 in 3 ppl died/ 1 in 2 (high guess), industry of commerce collapses yet again, no systems to communicate, stalls the system, Ring around the rosy**, 300 years yet again for Europe to get back on it's feet
- 1492 – Christopher Columbus – beginning of the massive explorations of Europe, thought he was going to India
- Islamic nation was not affected by the plague, continued inventory, books converted to Arabic, Golden Age of Islam,

Important stages in the history of Biology

450-16th century: Medieval ages

- **Byzantium**
  - **Al-Jahiz (781-869)**
  - **Al-Dinawari (826-896)**
  - **Avicenna (980-1037**
  - **Al-Baitar (d. 1248)**
  - **Abu al-Abbas al Nabati (13th century)**

Avicenna

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8

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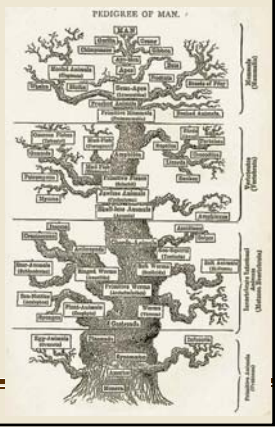
- Al Jahiz – published papers on what he thought was a food chain/ web, notice that you could take certain domestic animals and breed them with others in order to improve agricultural stock (selection), doing it at the time of the Scala Naturae which
- Al Dinawari – more plants to the inventory, takes it further and watches and studies the seed, germination, similarities of the embryos, they must share something in common as they start out the same and develop differently, there is not necessarily fixed Strata
- Avicenna – 3 cultures – wrote medical catalogue - takes everything the Greeks and romans knew about medicine and creates a compendium that spans 3 cultures, so accurate used until 1600's and many of the medical professionals come from Islam where this is booming
- Al Baitar – creating dosages of medicine – pharmacology, 18th century ppl used his book for medicine, pharmaceutical catalogue
- Abu – method where you take something, split into two things, manipulate them, and watch the differences occur, up until this time everyone just observed, sad thing as Europe grows out of medieval ages they destroy the Islamic world – crusades – and stole everything from them in terms of medicine and put it into their system

Special creation

- **Pattern**
  - **Species don't change**
  - **Each species created on Oct 23, 4004 BCE**
  - **Species are not old**
- **Process**
  - **A designer of some sort**



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- Special creation – scientific revolution – still fixed hierarchy,
- 4004 BC – religious views

Important stages in the history of Biology

16th-18th century: The scientific revolution and the start of modern sciences

- Copernicus (1473-1543) earth not the center of the universe.
- Kepler (1571-1630) – planetary motion
- Newton (1643-1727) – laws of motion, gravity and thermal conduction
- Galileo (1561-1626) – further proof of earth revolving around the sub
- Boyle (1627-1691) – behaviour of gases
- Pascal (1623-1662) – origins of calculus
- Descartes (1596-1650) – geometry

- Van Leeuwenhoek (1673) – first microscope,
- Harvey (1650's) – Anatomy and physiology
- Linnaeus (1735) – Systema naturae.

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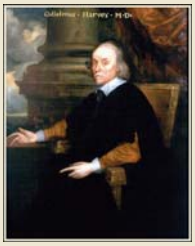
- Copernicus – the earth revolves around the sun, was not politically correct at that point in time, thus, they keep it hush hush while still keeping it written in a book, while on his death bed he decided to release his book and than died,
- Gailleo – furthered Copernicus' findings, shared his findings with everyone, ex communicated and sent to spend his life in purgatory
- In 1992 pope John Paul said the earth revolves around the Sun
- Van Leeuwenhoek – created the microscope, cells of cork (known for), placed in the Scala naturae, if we look into details we discover more,
- Harvey – studying the human body, cutting them open, starting to learn more
- Linnaeus – gave us a way to organize the world – nested hierarchy (eg. Courses on computer – folders) with a system of hierarchy (slide 13)
- Taxonomy – the level of family was inserted later on after Linnaeus
- King Philip Came over from Germany for sex
- Noun modified by an adjective – Linnaeus gave this to us (genus and species – written in italics, standard topography, different language thus in italics), he still didn't do much in regards to biology
- 1800's

Important stages in the history of Biology

16th-18th century: The scientific revolution

Van Leeuwenhoek
(1632-1723)



Harvey
(1578-1657)

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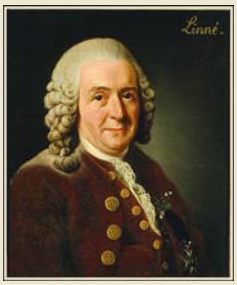
The "scientific revolution" 16th – 18th century

Linnaeus – Systema naturae, 1735



- Taxonomic hierarchy
- Binomen and binomial nomenclature

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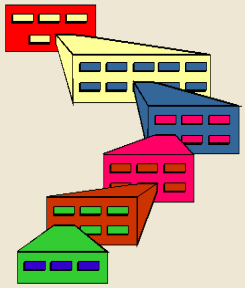
The practice of naming and classifying organisms originated with naturalist Carl Linnaeus. Linnaeus described and named thousands of species on the basis of their similarities and differences. A taxonomic heirarchy which arranged organisms into ever more exclusive categories. A family is a group of genera that closely resemble one another. Similar families are grouped in orders, similar orders into classes, into phyla, and into kingdoms. World is classified into three domains.

The "scientific revolution" 16th – 18th century
Linnaeus – Taxanomic hierarchy



Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Rodentia
Family: Castoridae
Genus: *Castor*
Species: *canadensis*

13
10:12 AM

Apis pubescens, thorace subgriseo, abdominae fusco, pedibus utrinque margine ciliatis

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Binomial nomenclature

Apis mellifera
(Honey bee)

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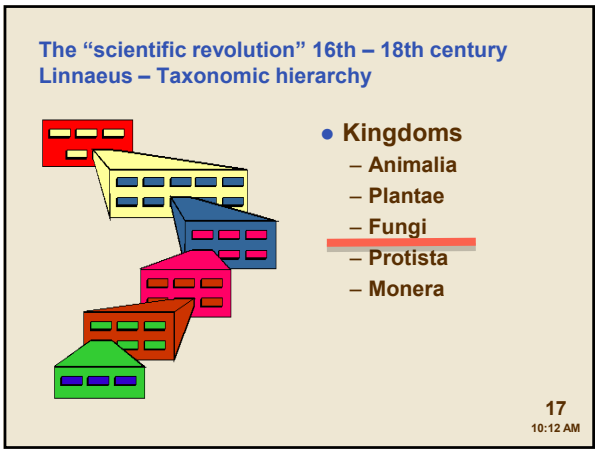
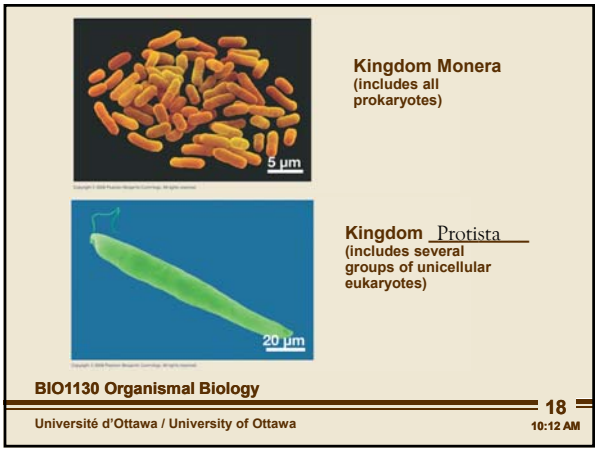


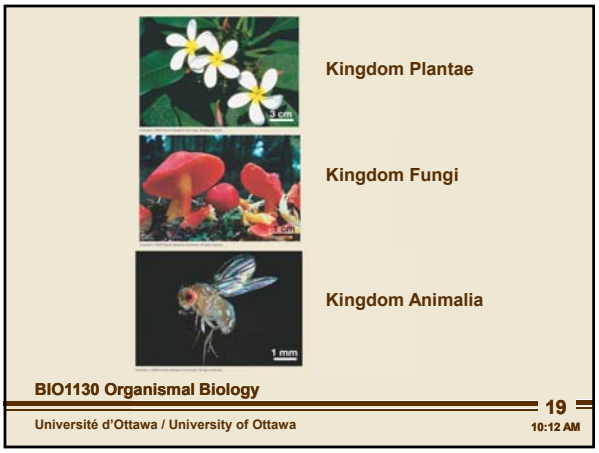
•• Protista and monera are below the line because they are single-celled protists, there are aggregations of cells, no specialization. Above the line are multicellular organisms that have cell-to-cell communication. Monera are prokaryotes and everything above is an eukaryote (have a double membrane around the nucleus – thus DNA replication is a complexity in the machinery of the cell)

In prokaryotes the cytoplasm does everything.

• Mitochondria came before the chloroplast

• Food digested externally for fungi, and absorb the breakdown product





Domains of life

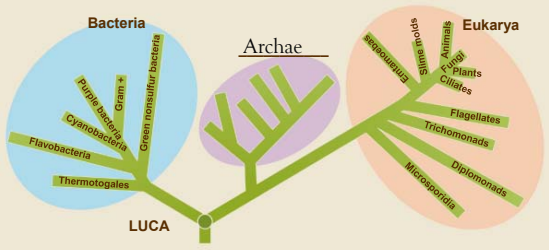


Figure 3.20 and 18.16

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- Archea found within the last 15-20 years, live without O2, live in high temps, high cold, extremophiles, these might be the remnants of life forms of the planet. Archea found in meteorite
- LUCA - universal common ancestor

Georges-Louis Leclerc, Comte de Buffon

(1707-1788)

- **Common ancestor**
- **Biogeography**

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21

10:12 AM

- Leclerc: period of time with global travel, as he travels (depending on environment he's travelling) he notices that animals seem to have a morphology that seem to adapt them to their environments and shape the appearance of the cat (ie cat – started from one series and changed as they moved to other areas with different environmental conditions).
- This is a problem because he believes species change but this is completely contradictory to the scala naturae who says animals are fixed species.
- Called the father of biogeography. He had a huge affect on Charles Darwin.

suggested the idea of vestigial structures

Erasmus Darwin

1731-1802

- **Translated Linnaeus into English**
- **The temple of nature**

BY firm immutable immortal laws Impress'd on Nature by the GREAT FIRST CAUSE, Say, MUSE! how rose from elemental strife Organic forms, and kindled into life

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22

10:12 AM

- Erasmus Darwin: grandfather to Charles. He begins to believe that warm-blooded vertebrates have a common origin while translating. He didn't write about it, but wrote a poem called the temple of nature about it, outlining most of the concepts of change in a artistic way in order to avoid confrontation with the church.

Georges Cuvier
(1769-1832)

- Catastrophic theory
- Extinction

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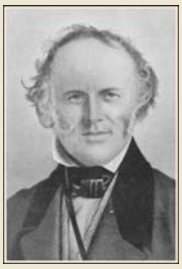
23
10:12 AM

- Cuvier - when you collect bones you can form an organism, two theories: lost world (only available at certain parts of the world) however they were never found and the new theory of extinction arose. This is contrary to the scala because these were perfect organisms who were living in perfect environments. Thus he provides the catastrophic theory: ie. Noah's Arc. He believed that change happens quickly.
each layer of fossils was due to catastrophes and then new organisms colonized on top

Charles Lyell
(1797- 1875)



- Uniformitarian theory of geological change
- Stratigraphy and the geological time scale

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24
10:12 AM

- Lyell: noticed layers were in a certain sequence, put rock profile together from data collected around the world (noticing that fossils change), Strata represents a history of sediments and creation over time – slow process. Impossible to create the layers of rock on Oct 23. World is older than people believe challenging the idea of the day the world was created – everything could not arrive all at once. Uniformitarian theory – world happened gradually.

- Slow change of the Earth, Scala naturae is not consistent – ideas in the 1800's. But how is this mechanism being created?

The mid-19th century starts to bring some changes in the new field of Biology. Essentialism is challenged; maybe all things are not fixed and unchanging. Spontaneous generation, how organisms arise is discredited by Pasteur. In sedimentary rock Cuvier finds fossilized animals that have gone extinct. Geologists such as Lyell show that successive layers of the sediments have increasing age as they appear deeper and deeper. The fossils near the top resemble many of today's organisms; the deeper ones don't. Increasing evidence is suggesting that species aren't fixed and placed on the earth at the same time

Jean-Baptiste Lamarck
(1744-1829)

- Transmutation of species

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25
10:12 AM

- Lamark – famous for his mistakes; he tried to explain where the change would come from. Inheritable traits were acquired (transmutation**). What was he missing? In complex multicellular organisms one of the first things that happens is that cells are put aside in order to produce gametes for reproduction – which are not affected by environmental implications. Therefore there is a perfect copy of the organism of the first zygote that was created.
he proposed the first comprehensive theory of biological evolution based on specific mechanisms. He proposed that a metaphysical Perfecting Principle caused organisms to become better suited to their environments. Simple organisms evolved into more complex ones, moving up the ladder of life. Microscopic organisms were replaced at the bottom by spontaneous generation.
He theororized that two mechanisms fostered evolutionary change. Principe of use and disuse said that body parts grow in proportion to how much they are used. The inheritance of acquired characteristics said that changes that an animal acquires during its lifetime are inherited by offspring. However this is not true.
Lamark made four important contributions to the development of an evolutionary worldview:
1) all species change through time 2)recognized that organisms change in response to their environments 3) changes are passed from one generation to the next 4) he hypothesized the existence of specific mechanisms that caused evolutionary change (first three were cornerstones for darwins theory)

- Lab information: section B is Monday September 24*. Meet at Lamoureux - visit website for the bus schedule. Time 2:20 Mon. Make observations of 5 plants, combine findings with other ppl, produce a graph of one plant, formulate a hypothesis and predict the effect of a change in the water level in Mer Bleue on your plant. Identify plant species in 10m2 and record the plant species available.

Essentialist explanation of change

- **Transmutation** (not Lamarck)
- **Transformation**
  - ~~Finalism~~
  - **Environmental** (this is Lamarck)

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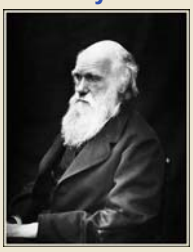
26
10:12 AM

- look back at podcast) ***Transmutation – essentialist is different: the essence itself mutates, massive changes. At this point in time they are trying to manipulate the scala natura to become more flexible with the ideas being thrown around

Important stages in the history of Biology

19th century: Modern biology



Darwin
(1809-1882)

Wallace
(1823-1913)

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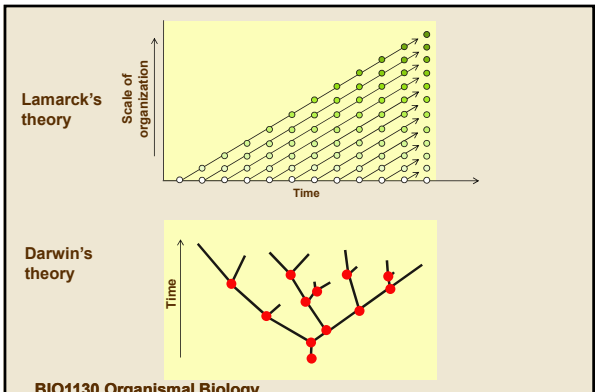
27
10:12 AM

Darwin and Wallace change our entire idea of where change comes from. They both recognize that in a population of organisms they are ~~not all the same. There are inherent variations in a population. Some~~ animals may be better adapted to environments than others ie. A population of birds with different sized beaks, larger beaks can survive as they can crack the nuts. Darwin travels around the world on the beagle for about 7 years as a young boy, and spends his years studying the data ~~collected. He comes up with the ideas of natural selection.~~

- Wallace asks Darwin to read his book, which is exactly the same theory as Darwin's – thus leading to a simultaneous publishing of their books. The largest amount of data collected was from Darwin.
- We need to look at the population for variation; there are inherent variations in the population.
- ~~Darwin travelled for 5 years (visiting the Galapagos) collecting~~ various things around south America, while he was in constant communication with lyle, he sent his stuff back home to Britain as he collected it and landed at shore - leading to the theory of natural selection. Evolution and natural selection were two theories he struggled with for twenty years. He was trying to explain the diversity occurring.



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28
10:12 AM

- Slide 28 – not Lamark's theory but simply modified essentialism. The range shows the gradual change
- ~~There is a belief still of spontaneous generation~~
- Darwin believes that a population has individuals with various traits that make them unique to one another, therefore leading to variation in the population based on disadvantages and advantages (natural selection). He first calls it artificial selection until he finds out ~~that nature has an impact on this.~~
- Darwin's Five theories; he never proposed a theory for evolution. Darwin was the right person, in the right place at the right time. His significance was related to large amount of species collected. 2 of the five theories were accepted immediately: common ancestry, no constancy of species (everyone was happy because people like couvier, lyle, buffon were working away at the scala naturae.

The 20th century sees many advances in biology and whole new disciplines and fields of study arise. But it won't be until the middle of the century that the true nature of heritability is unraveled with the identification of DNA, not protein, as the heritable substance. Watson and Crick described the DNA double helix in 1953, but it won't be until the early 1960's that the genetic code is finally cracked.

Darwin's five theories

- No constancy of species
- Common ancestry
- Gradual changes
- Multiplication of species
- Natural selection

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29
10:12 AM

- Multiplication theory: loss and gain, number of species is always changing

Darwin's five theories
No constancy of species

- Fossils
- Extinction
- Transitional forms
- (Vestigial structures)

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30
10:12 AM

- Transitional Forms: the horse, vestigial structures (no use anymore and closely linked to transitional forms)
- Few dead organisms fossilize; fungi – recycling system, it was though that soft body organisms cannot fossilize only those with bones and shells/ mineralized parts, but they do
- Plants fossilize as coal (carboniferous)
- Burja Schales: Wallock found them and thought they were arthropods, 50 years later it was realized that they were soft body organisms
- By this point there was five global mass extinction
- Transition form: how did we get from A to B?
- Why are plants not a good thing to eat? Nutrients are in the cytoplasm, surrounded by a rigid wall of cellulose, which is why horses teeth are massive grinding incisors/ molars
- Fungi and bacteria are the only things that can break down cellulose

Darwin's five theories – No constancy of species
Fossils


Petrified wood


Invertebrate


Insects in amber

Figure 17.5

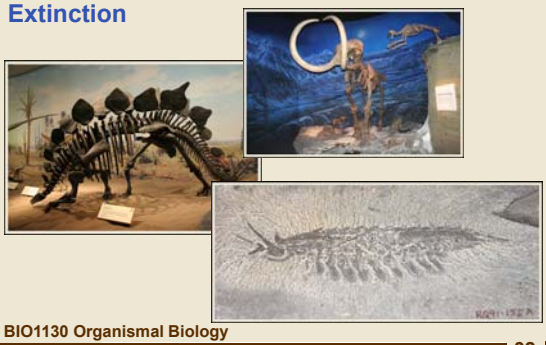

Mammoth in permafrost

31
10:12 AM

scientists can assign relative and absolute ages (radiometric dating) to geologic strata and the fossils they contain. isotopes with half lives are used to determine how old the fossils or bones are.
Many species have a continuous distribution: living in suitable habitats throughout large areas. They require no special historical explanations. Other groups exhibit DIsjunct Distributions. Here closely related species live in widely separated locations. Dispersal and vicariance create disjunct distributions. Dispersal is the movement of organisms away from where they originate. Vacariance is the fragmentation of a continuous geographic distribution by external factors.

Darwin's five theories – No constancy of species

Extinction



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32

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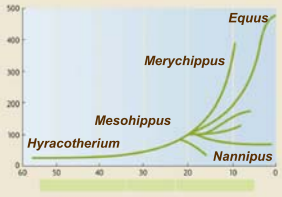
Darwin's five theories – No constancy of species

Transitional forms

Evolution of the horse



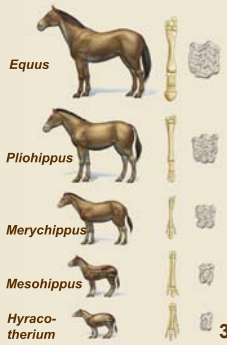


Figure 17.13

33

10:12 AM

Darwin's five theories – No constancy of species

Transitional forms

Archaeopteryx lithographica

Figure 17-21a

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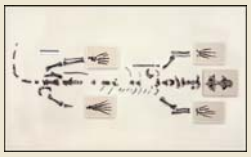
34

10:12 AM

- Archaeopteryx – halfway between reptiles and birds
- Feathers were common among reptiles/ dinosaurs

Darwin's five theories – No constancy of species
Transitional forms
Puijila darwini

Meet the discoverer



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35
10:12 AM

Darwin's five theories
Common ancestry - evidence

- **Comparative anatomy**
- **Comparative embryology**
- Vestigial Structures
- **Biogeography**
- **Molecules**

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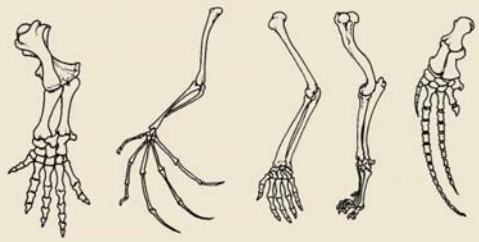
36
10:12 AM

- First four were the things Darwin used for evidence

Darwin's five theories - Common ancestry
Comparative anatomy
Homology – Divergent evolution



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37
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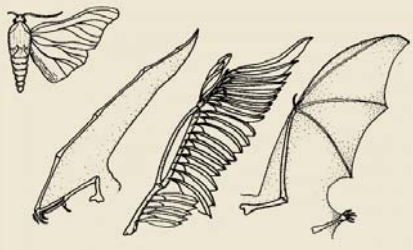
- ~~Homologous structures – same underlying embryology,~~ bone pattern used for different purposes

Darwin's five theories - Common ancestry
Comparative anatomy
Homoplasy (analogous) – Convergent evolution



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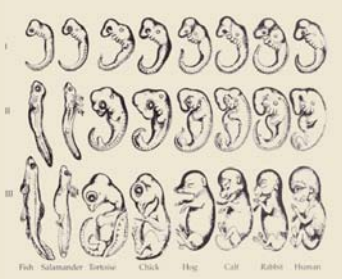
- Homoplasy is the opposite of homology: insects, birds, bats and teredactels fly – they have different ancestors, belong to different phylum

Darwin's five theories - Common ancestry
Comparative embryology



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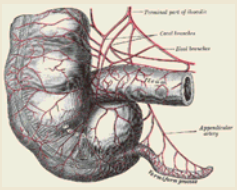
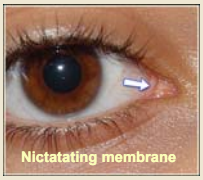
- Insect is an arthropod – shell on the outside, all others are vertebrates with structure on the inside (slide 38)
- Once the zygote has divided into 8, division occurs (4 on top 4 on bottom—different cell rearrangement ie. In the grooves – spiral cleavage is what allows embryos to develop and differentiate)

Darwin's five theories - Common ancestry
Vestigial structures



Appendix



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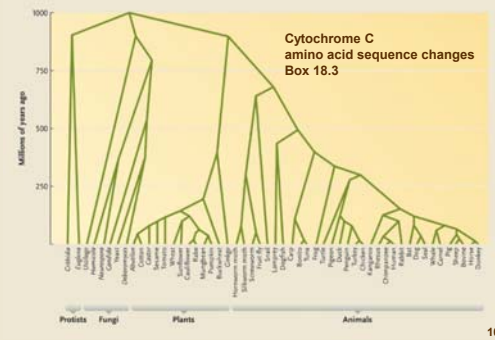
Darwin's five theories - Common ancestry

Molecules



41
10:12 AM

- Appendix – contains the micro flora that digested cellulose/ major role for digestive tract's bacteria
- Graph – everyone is related due to the doubled nature of every genome in every species

Darwin's five theories

- No constancy of species
- Common ancestry
- Gradual changes
- Multiplication of species
- Natural selection

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42
10:12 AM

Pasteur (1822-1895)

- Life from life not spontaneous generation
- Germ theory

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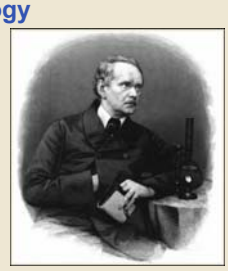
43
10:12 AM

-
- Pasteur gives the idea that life comes from life – there is no spontaneous generation
- 1800's it is now clear that the main element of life is a cell

Important stages in the history of Biology

19th century: Modern biology

- **Cell theory**
  (Schleiden and Schwann – 1860)
  - **The basic unit of all organisms is the cell**
  - **Individual cells have all the characteristics of life and**
  - **All cell come from the division of other cells**



Schleiden (1804-1881)

- schwann cells – zoology
- schleiden – plantology

Mendel (1822-1884)

- **Rediscovered 1900.**
- **Law of segregation of characters**
- **Law of independent assortment**

- mendel - pea plants cross
- Mendel discovered crosses of traits and mixtures of different characteristics, recessive and dominant etc. Mendellan inheritance says you get half the characteristics from each parent. 2 traits in each organism (haploid and diploid cell)

Important stages in the history of Biology

20th century

- Synthetic **theory of evolution**
  - **Population genetics and natural selection based on Mendelian genetics**

Huxley (1887-1975)

- Huxley gives us the synthetic theory of evolution, and said heritable traits are genetic and that you could look at a room full of people and be able to predict the number of x and y chromosomes amongst the population

Darwin's five theories – Gradual change

Biogeography – gradual population changes

Thalassoma lucasanum
(Cortez rainbow wrasse)

Thalassoma bifasciatum
(Blue headed wrasse)

Continental drift 1
Continental drift 2

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47
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Important stages in the history of Biology

20th century: Modern biology

- Cellular respiration, ATP and mitochondia (1930-1950)
- Ecology (1940's)
- DNA is the genetic materials (1943)
- DNA structure (1953)
- Gene regulation (1961)
- Genetic code (1960's)
- Recombinant DNA experiments (1970's)
- Cloning of a mammal (1997)
- Human genome sequence (2000)

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Types of Biology

- Molecular biology and biochemistry
- Genetics
- Cell biology
- Physiology
- Developmental biology
- Morphology
- Evolution and systemic biology
- Ecology
- Behavioural biology
- Nutrition
- Disease mechanisms
- Pharmacology
- Genomics
- Proteomics

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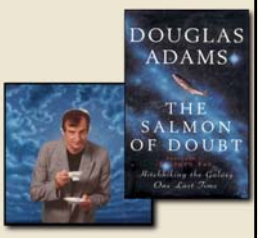
Important stages in the history of Biology

16th-18th century: The scientific revolution and the start of modern sciences

Douglas Adams 1952-2001

Four ages of sand

- –First - Telescope 1608
- –Second - Microscope 1678
- –Third - _____1961
- –Fourth - Fiber optics 1980s



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Some terms used in doing science

- **Theory and Fact**
- **Hypothesis**
- **Law**
- **Prediction (logical vs chronological)**

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- Theory – the best explanation for what phenomenon observed, hypotheses that have been massed together to find one outcome
- Fact is solid evidence – little theories turn into fact in the realm of science
- Theory is seen as wishy washy
- Law is a theory that can be applied universally ie. Darwins theory of Natural selection cannot be a law because we cant apply it across the universe but gravity, molecules etc can be
- No two living objects behave identically to each other

Physical science	Natural science
• Inanimate objects	• Animate objects
• Physical and chemical laws	• More than physical and chemical laws (Genetics)
• Universal	• Not Universal

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Changing thoughts on what living things are

- Physicalists – with the exception of humans all living things are machines (Descartes, 17th century)
- Vitalists – physical and chemical laws apply but living things have a vital force (essence)

- Organicists (1930) – vital force replaced by genetic program and the importance of emergence (swarm behaviour)

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53
10:12 AM

- Vitalists: theres something special/ essence that makes life behave a certain way. There is no real evidence to prove the natural world – cant describe it by math, geometry. However they see that the whole is worth more than all of the parts separately: hemoglobin – complex structure facilitates things – if heme is attached not myoglobin there is a greater availability for oxygen to bind which makes it easier for the others to bind as well eg. The birds swarming, gathering data about the population
- Genetic code programs how the physics and chemistry are related.
- Natural science – narratives: theories, stories
- Darwins theory does not have any formulae in it

he difference between the two can be seen in how each group viewed the living world. Physicalists felt that all living things, with the exception of human, were machines and that it should be possible to reduce the machines into the various parts that made the whole machine work. The natural scientists, vitalists, didn't agree and they felt that there was something special about living things compared to the inanimate world –they had a vital essence of life but beyond that they couldn't explain what it was in a way that would satisfy the reductionist views of the physicalists. This divide between the two sciences would continue for literally hundreds of years until the underlying genetics of what that vital life force was discovered. Around 1930 the best of the two views of life were combined in the organacists (holistic) view that life was ruled by the laws of physics and chemistry but that through the genetic program the whole was more than the sum of its parts – a concept referred to as emergence, or emergent properties.

Physical science

- Inanimate objects
- Physical and chemical laws
- Universal
- Based on empirical observations
- Experimentation preferred method

Natural science

- Animate objects
- More than physical and chemical laws (Genetics)
- Not Universal
- Based on historical narratives
- Induction most used method

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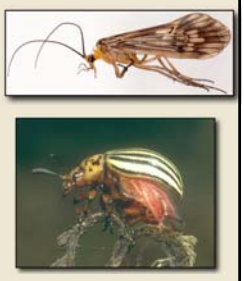
54
10:12 AM

But for the natural scientists stories were the only way to describe their observations of the natural world and once again they were looked down on by the physical scientists of the time. They felt that scientific investigation through experimentation and deductive reasoning was a far superior approach to the inductive reasoning of their natural science colleagues. How could you simply observe a bunch of events and hope to show a major pattern of the living world, which is how induction works; from the specific to general. It's the opposite of the experimental deductive approach that goes in the opposite direction from general to the specific – you know what will happen and test to see that it does.

Induction vs. Deduction



- Deduction (from the general to the specific): All insects have wings and this animal is an insect. This animal has wings.
- Induction: (from the specific to the general) This animal is an insect and it has wings therefore all insects have wings. (many multiple observations!)

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- Induction – observe as much as possible than make idea
- Deduction: here is the way it is, and than you see if it applies to everyone else

- Induction – looking for pattern
- Deduction – find a pattern and keep testing it

Physical science	Natural science
• Inanimate objects	• Animate objects
• Physical and chemical laws	• More than physical and chemical laws (Genetics)
• Universal	• Not Universal
• Based on empirical observations	• Based on historical narratives
• Experimentation preferred method	• Induction most used method
• Single theory	• Multiple theories
• Single falsification enough to abandon a theory	• Single falsification not necessary to abandon a theory

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56
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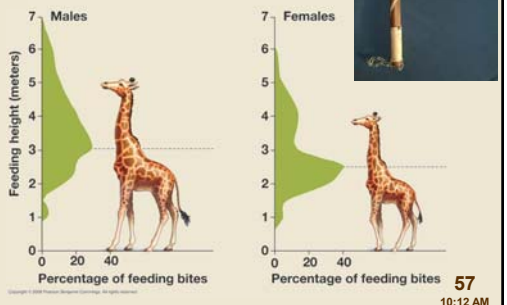
Multiple theories

- Food competition
- Sexual competition

Video 1, 2



57
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- Giraffe: sexual competition, neck used as weapon (physical scientists would tell us to get off the bandwagon)

Anatomy of a scientific explanation (theory)

- Two parts
  - Pattern
  - Mechanism or process
- Questions to be asked
  - What?
  - How (proximate cause)? or Why (ultimate causes)?

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Proximate causes
(Physical science-like biology)

- Phenotype – morphology and behaviour
- Mechanical (predictable)
- Here and now
- Genes in action
- Experiments

Ultimate causes
(Natural science-like biology)

- Genotype - Genes and history
- Variable (probabilistic)
- Evolutionary past
- Changes in genetic programs
- Historical narratives

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59
10:12 AM

- Induction, deduction, proximate, ultimate – know the differences
- Proximate – cause and affect is immediate
- Ultimate – cause and affect over a long period of time

Additional experimental components

- Controls
- Control of variables
- Sampling error
- Repeat the test

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60
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Stages in an investigation.

- Observations
- Questions of how and why
- Hypothesis
- Test (experiment)
- Conclusion

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61
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Darwin's five theories – Natural selection

Natural selection – Industrial melanism

Peppered moth

- **Observation 1:** Original museum collections had all white peppered moths and by 1900 traps collected 90% black.
- **Question 1:** Why did the moths shift from light to dark morphs?

Peppered moth

- **Hypothesis 1:** Fitness decreased when the moths that were more visible against the background colour of the trees.
- **Null hypothesis1:** Fitness remains the same and is not affected by the background.
- **Hypothesis 2:** The bark colour of the trees has changed.
- **Null hypothesis 2:** The bark colour of the trees has not changed.

Peppered moth

- **Experiment 1:** Artificially rear light and dark morphs and place on tree and observe survival (fitness)
- **Experiment 2:** Locate light and dark coloured trees.

Peppered moth

- **Result 1:** Birds selected most visible moths
- **Result 2:** Dark trees showed same distribution as coal based industry

Peppered moth

- **Question:** Do moths "rest" on backgrounds that match their colouration?
- **Question:** What impact would the clean air act, that reduced pollutant immisions have on the moth population morphs?
- **Question:** What happens to other moths with light and dark colour morphs

Distribution of scientific facts

- Journal selection
- Manuscript preparation
- _____
- Revision
- Publication

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68
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Types of literature – what's the diffence

- Primary
- Secondary
- Tertiary

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69
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