SEMESTER V

17BTU503B	**EVOLUTIONARY BIOLOGY**	**4H - 4C**
Total hours/week: L:4 T:0 P:0	**Marks: Internal: 40 External: 60**	**Total: 100**

Scope: This will enable for learning the basic concepts of life and gradual evolution of human and other animals.

Objective: This paper aims at introducing students to the fundamentals of Evolutionary Biology.

UNIT- I

Historical Review of Evolutionary Concept: Pre-Darwinian ideas – List of contributors influencing Darwin indicated as a *timeline.* Lamarckism – Merits and demerits. Darwinism – Merits and demerits, Post-Darwinian era –Modern synthetic theory; biomathematics and the theory of population genetics leading to Neo-Darwinism

UNIT- II

Life's Beginnings: Chemogeny – An overview of pre-biotic conditions and events; experimental proofs to abiotic origin of micro- and macro-molecules. Current concept of chemogeny – RNA first hypothesis. Biogeny – Cellular evolution based on proto-cell models (coacervates and proteinoid micro-spheres). Origin of photosynthesis – Evolution of oxygen and ozone buildup. Endosymbiotic theory – Evolution of Eukaryotes from Prokaryotes

UNIT-III

Evidences of Evolution: Paleobiological – Concept of Stratigraphy and geological timescale; fossil study (types,formation and dating methods). Anatomical – Vestigial organs; Homologous and Analogous organs (concept of parallelism and convergence in evolution). Taxonomic – Transitional forms/evolutionary intermediates; living fossils. Phylogenetic – a) Fossil based – Phylogeny of horse as a model. b) Molecule based – Protein model (Cytochrome C); gene model (Globin gene family)

UNIT-IV

Sources of Evolution – Variations as Raw Materials of Change: Types of variations – Continuous and discontinuous; heritable and non-heritable. Causes, classification and contribution to evolution – Gene mutation; chromosomal aberrations; recombination and random assortment (basis of sexual reproduction); gene regulation. Concept of micro- and macro-evolution – A brief comparison

UNIT-V

Forces of Evolution – Qualitative Studies Based on Field Observations: Natural selection as a guiding force – Its attributes and action Basic characteristics of natural selection. Colouration, camouflage and mimicry, Co-adaptation and co-evolution, Man-made causes of change – Industrial melanism; brief mention of drug, pesticide, antibiotic and herbicide resistance in various organisms. Modes of selection, Polymorphism, Heterosis and Balanced lethal systems. Genetic Drift (Sewall Wright effect) as a stochastic/random force – Its attributes and action. Basic characteristics of drift; selection vs. drift, Bottleneck effect. Founder principle.

References

1. Ridley, M. (2004). *Evolution* (3rd ed.). Blackwell.
2. Hall, B. K., & Hallgrimson, B. (2008). *Strickberger's Evolution* (4th ed.). Jones and Barlett
3. Zimmer, C., & Emlen, D. J. (2013). *Evolution: Making Sense of Life.* Roberts & Co.

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Unit I Lecture plan

Sl No	Lecture duration (h)	Topics to be covered	Support material
1	1	Pre-Darwinian ideas	T1, 13
2	1	List of contributors influencing Darwin- indicated in timeline	T1, 17
3	1	Lamarckism- merits and demerits	T1 18
4	1	Darwinism- merits and demerits	T1 19-20
5	1	Post Darwinian era- modern synthetic theory	T1 23
6	1	Biomathematics	T1 39
7	1	Theory of population genetics leading to neo Darwinism	T2 39
8	1	Discussion of important topics	
9	1	Unit Test	
		Total hours for unit 1 9h	

References:

T1: Ridely M (2004) Evolution 3 edition, Blackwell publishers

T2: Hall BR and Hallgrimsom (2008), Strickbergers evolution (4 edition) Jones Barlett

R1: Zimmer C and Emler DJ (2013) Evolution, making sense of life Roberts and co

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Unit II Lecture plan

Sl No	Lecture duration (h)	Topics to be covered	Support material
1	1	An overview of pre-biotic conditions	T1, 51
2	1	Experimental proofs of abiotic origin of micro and macro molecues	T1, 52
3	1	Current concepts of chemogeny	T1 55
4	1	RNA first hypothesis	T1 56
5	1	Cellular evolution proto cell model	T2 64
6	1	Origin of photosynthesis	T2 73
7	1	Evolution of oxygen and ozone build up	T2 80
8	1	Endo symbiotic theory	T1 101
9	1	Evolution of eukaryotes from prokaryotes	T1 104
10	1	Unit test	
		Total hours for unit II 10h	

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Unit III Lecture plan

Sl No	Lecture duration (h)	Topics to be covered	Support material
1	1	Concepts of stratigraphy and geological time scale	T1, 141
2	1	Fossils study- types and formation	T1, 143
3	1	Vestigial organs	T1 149
4	1	Homologous and analogous organs	T2 151
5	1	Taxonomic transitional forms	T2 98
6	1	Evolutionary intermediates	T1 160
7	1	Living fossils	T1163
8	1	Fossil based phylogeny- Horse model	T2 118
9	1	Molecule based protein model	T2 127
10	1	Unit test	
		Total hours for unit III 10h	

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Unit IV Lecture plan

Sl No	Lecture duration (h)	Topics to be covered	Support material
1	1	Types of variation continuous and discontinuous	T1, 181
2	1	Heritable and non heritable variations	T1, 184
3	1	Causes, classification and contribution to evolution	T2114
4	1	Gene mutation	R 2 136
5	1	Chromosomal aberrations	R2 177
6	1	Recombination and random assortment	R2 171
7	1	Gene regulation	R2 209
8	1	Concepts of micro and macroevolution- comparison	T1 203
9	1	Unit test	
		Total hours for unit IV 9h	

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Unit IV Lecture plan

Sl No	Lecture duration (h)	Topics to be covered	Support material
1	1	Natural selection as guiding force	R1 61
2	1	Basic characteristics of natural selection	R1 63
3	1	Coloration, camouflage and mimicry	R1 69
4	1	Adaptation and co evolution	R1 74
5	1	Manmade causes of changes	R1 72
6	1	Industrial melanism	R2 214
7	1	Drug, antibiotics, pesticide resistance in living organisms	R2 216
8	1	Mode of selection	R2 234
9	1	Polymorphism	R2 237
10	1	Genetic drift (Sewal Wright effect)	R1 174
		Total hours for unit V 10h	

Syllabus:

Historical Review of Evolutionary Concept: Pre-Darwinian ideas – List of contributors, Lamarckism – Merits and demerits. Darwinism – Merits and demerits, Post-Darwinian era –Modern synthetic theory; biomathematics and the theory of population genetics leading to Neo-Darwinism

Pre Darwinism Ideas

Throughout the middle Ages, there was one predominant component of the European world view: stasis.

- All aspects of nature were considered as fixed and change was unconceivable.
- No new species had appeared, and none had disappeared or become extinct.

The social and political context of the Middle Ages helps explain this world view:

- Shaped by feudal society - hierarchical arrangement supporting a rigid class system that had Changed little for centuries
- Shaped by a powerful religious system - life on Earth had been created by God exactly as it existed in the present (known as fixity of species).

This social and political context, and its world view, provided a formidable obstacle to the development of evolutionary theory. In order to formulate new evolutionary principles, scientists needed to:

- Overcome the concept of fixity of species
- Establish a theory of long geological time

From the 16th to the 18th century, along with renewed interest in scientific knowledge, scholars focused on listing and describing all kinds of forms of organic life. As attempts in this direction were made, they became increasingly impressed with the amount of biological diversity that confronted them.

These scholars included:

- John Ray (1627-1705) - put some order into the diversity of animal and plant life, by creating the concepts of species and genus.
- Carolus Linnaeus (1707-1778) - added two more categories (class and order) and created a complex system of classification (taxonomy) still used today; also innovated by including humans in his classification of animals.
- Georges-Louis Leclerc (1707-1788) - innovated by suggesting the changing nature of species, through adaptation to local climatic and environmental conditions.
- Jean-Baptiste Lamarck (1744-1829) - offered a comprehensive system to explain species changes; postulated that physical alterations of organic life would occur in relation to changing environmental circumstances, making species better suited for their new habitat; also postulated that new traits would be passed on to offspring (the theory known as inheritance of acquired characteristics).

Therefore, the principle of "fixity of species" that ruled during the Middle Ages was no longer considered valid.

In the mid-19th century, Charles Darwin offered a new theory which pushed further the debate of evolutionary processes and marks a fundamental step in their explanation by suggesting that evolution works through natural selection.

Lamarckism

- The theory of acquired characteristics put forth by Jean-Baptiste P.A. Lamarck (1744-1829), a French botanist, zoologist and biological philosopher. According to him, evolution occurs because organisms can inherit traits acquired by their ancestors.
- Giraffes can only survive by eating leaves high up on trees so they stretch their necks to reach the leaves and this stretching of the neck is passed on to later generations.
- The basic tenet of Lamarckism has been rejected. Darwinism (the theory of the origin of species and the development of higher organisms from lower forms through natural selection, the survival of the fittest, and the evolution of humans from an ancestor

common to himself and the apes) has prevailed, together with the principles of transmission genetics

De merits of Lamarckism

- Lamarckism could not explain the following areas
- Though the tendency to increase in size has been shown in many forms, there are also instances where there is reduction in size. For example, trees that are primitive, are large in size, while the shrubs, herbs and grasses that evolved later are smaller in size.
- If new organs were to develop in response to a new need, then man should have developed wings by now.
- Changes acquired during the lifetime of an organism cannot be inherited by the offspring. For example, if a man loses his arm in war, he does not produce children without an arm. According to August Weismann, somatic changes acquired during the lifetime of the organisms are non- heritable, whereas, changes in the germplasm or reproductive cells are inheritable by the offspring.

Darwinism

The main aspects of the theory of natural selection – Darwinism are as follows.

1. Rapid multiplication.

2. Limited food and space causing straggle for existence.

3. Natural selection or survival of the fit and elimination of the unfit.

4. Origin of new species.

1. Rapid Multiplication:

Every living organism in this world reproduces itself. The rate of increase of the organisms is always in a geometric proportion. Darwin illustrated this point with the example of the slowest breeder among animals, the elephant. An elephant starts breeding at its 30th year continues to do so until it is 90 years.

It lives up to 100 years. So in its life time it produces 6 offsprings. Darwin calculated that if all these survive, within about 750 years there would be about 19 million elephants. Oysters produce about 80 million eggs in a season. A pair of sparrows would produce 275 billion individuals in about 10 years if there is no death.

2. Struggle for existence:

The rate of multiplication and existence of organisms are more or less common for all living things. But the food supply and space remain unchanged, in other words they are limited. Under these conditions, there starts a competition among the organisms to fulfil their needs of food and space. This is known as struggle for existence. It may be interspecific, that is between the members of different species or intraspecific between members of the same species or between them and the environmental factors.

3. Variations:

Every organism has its own specific characteristics and relationship with its environment, the variability caused by 'variations' may be large or small. Large variations are known as 'macrovariations'. Small variations are termed as 'microvariations'. Variations may be favourable or harmful. Those with useful variations survive while the others perish.

4. Natural selection or Survival of the Fitest:

The organisms with favourable variations are best adapted to the environment in which they live. They have a better chance of survival and perpetuation of their race. This principle is called Natural Selection or survival of the fit. While the organisms without any useful variations or with harmful variations are ill suited to the environment and hence they die and perish. This is known as the 'elimination of the unfit.

An example of adaptation of a species to a changing environment is amply illustrated by the birds known as "Darwin's Finches". Darwin observed 13 species of this bird each with special adaptation for its particular mode of life. Those that fed on insects had long slender beaks by which they could peck small insects from small crevices and eat them.

5. Origin of Species:

As already stated, the organisms with favourable variations transmit the same from generation to generation. With every generation the variations get distinct and refined. Due to the cumulative effect of these distinct variations, organisms emerge as new species in course of time. Thus new species are the evolutionary products of preexisting forms, by developing useful variations. Objections to theory of natural selection.

The role of natural selection has no doubt been regarded as a chief factor in evolution. But it cannot be the sole factor to bring about evolution. Darwin himself accepted the insufficiency of natural selection being the sole arbiter for evolution.

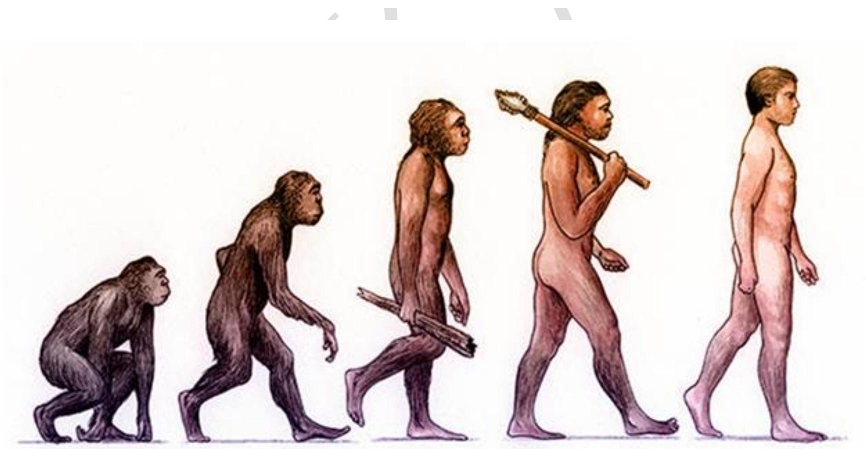
Demerits Darwinism: of theory of natural selection

- Darwin believed evolution by the accumulation of slow and small variations. But in many instances the occurrence of such variations when they are not fully developed are of no use to the individuals in the struggle for existence. For instance, the eye in the case of animals is useful only in a fully formed condition and surely all the features of the eye according to Darwin could not have come into existence at one go. It should have been by accumulation of several mutations. But then each change by itself is of no advantage.
- In many instances the adaptations of individuals seem to be more of a disadvantage rather than any use. For instance the antlers in deer are more obstructive because of their huge size than of any use, when the animal has to run to avoid from predators. In this instance natural selection indeed should have limited the structures not to grow beyond a point of usefulness.
- The main drawback in Darwin's theory is that he assumed that the organisms are having favourable and unfavourable variations. The main aspect in the mechanism of evolution is the origin of variations. Only then one can explain the role of natural selection. Natural selection according to Darwin is only an arbiter to decide which variation is favourable or

unfavourable. But the crux of evolutionary theory is to explain how a variation can arise. Further, Darwin also did not distinguish between heritable and non heritable variations.

- Natural selection theory does not satisfactorily attribute the reasons for the presence of vestigial organs. For example appendix in human beings. These organs should have been eliminated by natural selection during the course of evolution.
- If all the species were to be evolved by the accumulation of small variations, there should have been transitional forms in almost all the species. But this is not the case. Darwin however explained this away by attributing it to the faulty preservation of fossils. In areas where no interlinking forms were found, Darwin used the term "missing links". For instance between man and monkey.
- Natural selection as believed by Darwin was only a selective force and not a creative force. Many of the current observations have indeed shown that the environment not only chooses favourable variations but also is a causative agent for variations.

THE MODERN SYNTHETIC THEORY OF EVOLUTION: NEO-DARWINIAN THEORY



The Modern Synthetic theory of Evolution explains the evolution of life in terms of genetic changes occurring in the populations that leads to the formation of new species. It also explains about the genetic population or mendelian population, gene pool and the gene frequency. The concepts coming under this synthetic theory of evolution includes the genetic variations, reproductive and geographical isolation and the natural selection.

The Modern Synthetic populations, of Evolution, describes the merging of the Darwinian evolution with the Mendelian genetics, resulting into a unified theory of the evolution. This theory is also referred as the Neo-Darwinian theory. Synthetic theory of Evolution was introduced to us by few legendary evolutionary biologists naming T. Dobzhansky, J.B.S. Haldane, R.A. Fisher, Swall Wright, G.L. Stebbins, Ernst Mayr in the years 1930 and 1940.

The Modern Synthetic theory of Evolution showed a number of changes as to how the evolution and the process of evolution are conceived. The theory gave a new definition about the evolution as "the changes occurring in the allele frequencies within the populations, " which emphasizes on the genetics of evolution.

The modern synthetic theory includes the scientific evidence from the genetics. It explains the concepts which occur when the allele frequency of the population changes. According to this theory, when the changes are great enough, there is a formation of new species. A species is a group of individuals which are capable of interbreeding and producing a fertile offspring.

Factors of Modern Synthetic Theory of Evolution

There are some factors describing the modern theory of synthetic evolution which are as explained below-

In addition to these reactions, the other factors affecting the working of the process are Migration of the individuals from one form of the population to other, hybridization between the races of species increase the genetic variability of the population.

1. **Recombination or Variation**

Recombination of the new genotypes from the existing genes. The gene combinations having same individuals with two kinds of alleles, mixing of the chromosomes during sexual reproduction of two parents produce new individuals, an exchange of the chromosomal pairs of alleles during the meiosis which is called as crossing over produce the new form of gene combinations. Chromosomal mutations like deletion, inversion, duplication, translocation, polyploidy result in the recombination.

2. **Mutation**

The changes that occur in the gene due to phenotypic effect differential as the mutation. This produces a various number of changes that may be harmful. Many of the mutant forms of genes are recessive to the normal genes in a homozygous condition. These mutations cause variations in offsprings.

3. **Heredity**

The transmission occurring in the variations from the parents to their offsprings is a primary mechanism in the evolution. The organisms which possess hereditary properties are favored in the struggle for the existence. By this, the offsprings benefit from the characteristics of parents.

4. **Natural selection**

Natural selection produces a change in the frequency of the genes from one generation to the other favoring the differential form of the reproduction. The natural selection process creates an adaptation.

Biomathematics and Population genetics and neo Darwinism

Evolutionary biology has been the subject of extensive mathematical theorizing. The traditional approach in this area, which includes complications from genetics, is population genetics. Most population geneticists consider the appearance of new alleles by mutation, the appearance of new genotypes by recombination, and changes in the frequencies of existing alleles and genotypes at a small number of gene loci. When infinitesimal effects at a large number of gene loci are considered, together with the assumption of linkage equilibrium or quasi-linkage equilibrium, one derives quantitative genetics.

Ronald Fisher made fundamental advances in statistics, such as analysis of variance, via his work on quantitative genetics. Another important branch of population genetics that led to the extensive development of coalescent theory is phylogenetics. Phylogenetics is an area that deals with the reconstruction and analysis of phylogenetic (evolutionary) trees and networks based on inherited characteristics. Traditional population genetic models deal with alleles and genotypes, and are frequently stochastic.

Many population genetics models assume that population sizes are constant. Variable population sizes, often in the absence of genetic variation, are treated by the field of population dynamics. Work in this area dates back to the 19th century, and even as far as 1798 when Thomas Malthus formulated the first principle of population dynamics, which later became known as the Malthusian growth model.

The Lotka–Volterra predator-prey equations are another famous example. Population dynamics overlap with another active area of research in mathematical biology: mathematical epidemiology, the study of infectious disease affecting populations. Various models of the spread of infections have been proposed and analyzed, and provide important results that may be applied to health policy decisions.

As in the synthetic theory of evolution, natural selection can be understood in terms of changing allelic frequencies in a population. Thus, the ability to study allelic frequencies in a population is vital to the study of evolution. The Hardy-Weinberg Law is essential to the study of population genetics. It states that in a sexually reproducing population, allelic frequencies, and therefore phenotype, should remain constant under the following 5 conditions:

1. large population size
2. no mutation
3. no immigration or emigration
4. random mating
5. random reproductive success

A population that meets all of these conditions is said to be in Hardy-Weinberg equilibrium.

Natural populations rarely experience Hardy-Weinberg equilibrium. Natural selection ensures that mating and reproductive success is not random, large populations are rarely found in isolation, and all populations experience some level of mutation. However, the Hardy-Weinberg

Law is still very useful. The fact that populations that meet those 5 conditions will have unchanging phenotypes (will not evolve) is proof that variability and inheritance alone are not enough to cause evolution; natural selection must drive evolution. The law also allows us to estimate the effect of selection pressures by measuring the difference between actual and expected allelic frequencies or phenotypes**.**

Possible questions

1. Explain Darwin's theory of evolution with suitable examples
2. Explain Pre-Darwinism and write in detail about the merits and demerits of Darwinism
3. Explain: Lamarckism, its merits, demerits and advantages over Darwinism
4. Explain modern synthetic theory and compare it with Neo-Darwinism
5. Write an essay on origin of life on Earth..
6. Explain the pre-biotic conditions and events on Earth and evolution of macromolecules
7. Define Lamarckism
8. What are the demerits of Darwinism?
9. Describe coacervates
10. Write short notes on heterosis
11. Explain Modern synthetic theory of evolution
12. Discuss Miler's experiment and its significance
13. Discuss the role of biomathematics in evolution

Syllabus
Life's Beginnings: Chemogeny – An overview of pre-biotic conditions and events; experimental proofs to abiotic origin of micro- and macro-molecules. RNA first hypothesis. Biogeny – Cellular evolution based on proto-cell models Origin of photosynthesis – Evolution of oxygen and ozone buildup. Endosymbiotic theory – Evolution of Eukaryotes from Prokaryotes

LIFE'S BEGINNING: CHEMOGENY

In 1864, Louis Pasteur described his experiments showing that microbial life could not originate spontaneously in the absence of preexisting life. This work is considered a landmark in modern science because it settled a longstanding controversy over spontaneous generation

Spontaneous generation is the idea that organisms could form miraculously from non-living material.

But Pasteur's results posed a new riddle for evolutionary biologists: If life could only arise from life, how did living organisms initially appear on the planet?

The answer came in the 1920's when A.I. **Oparin** of Russia and J.B.S. **Haldane** of England independently presented compelling arguments that the origin of life could be explained, not as the result of rapid spontaneous generation of whole organisms in a few weeks, but from a long and gradual process of chemical evolution.

Much progress has been made since the 1920's, but, as with most complex scientific questions, many uncertainties remain and many new avenues of inquiry have been uncovered.

Today, research into the origin of life is interdisciplinary with workers trying to answer four main questions:

1. *What was the Earth's physical environment like when life first evolved?*
2. *What sorts of chemical reactions could produce the building blocks of life and could these occur naturally in the early Earth's environment?*

3. *How could the complex organic molecules be compartmentalized into a contained unit?*
4. *How did the genetic code evolve?*

What Was The Earth's Early Environment?

Life has dramatically changed the Earth. Organisms have altered the composition of the atmosphere, affected the types and concentration of minerals and ions in the seas, and even worked and churned the soil. So, if we want to understand the conditions in which life first appeared, we cannot rely on just an examination of present day Earth. We use two pieces of information:

1. Rocks buried deep in earth.
2. The four inner, or terrestrial, planets (Mercury, Venus, Earth and Mars) and our moon were formed from similar materials in the same way. Because they have a similar history, anything we learn about the formation of Mars, Venus, Mercury, or the moon will inform us about early Earth.

Solar system formed about 4.6 billion years ago (abbreviated b.y.a.) when a swirling cloud of gas and dust began to contract.

In the early years after the formation of the solar system, the terrestrial planets continued to be bombarded by smaller bodies of various sizes as the last of the particulate material from the formation of the planets was swept-up by their gravitational pull.

This **bombardment**, measured from radioactive dating of the moon's craters, and by comparing lunar, martian, and mercurian cratering records, gradually declined in intensity until it reached present-day levels about 3.5 billion years ago.

The effect of the bombardment on the origin of life was significant. Bombardment affected:

1. the temperature of the early Earth
2. the composition of the atmosphere
3. delivered biogenic elements to Earth (biogenic elements are those chemicals common to all living organisms - like phosphates)
4. Finally, the high energy released could also have delayed the origin of life.

Let's look at each of these effects in more detail:

About 3.9 b yeas, the earth had solidified but the violent bombardment would have prevented the continuous existence of life on the planet before **3.8** billion years ago. Large impacts would have produced globally lethal conditions by boiling large volumes of ocean water effectively sterilizing the surface of the planet with steam. This has been called **the impact frustration of the origin of life**.

The interesting thing is that the oldest fossils from rocks in Greenland are about 3.8 billion years old. This means that life was existed on the planet almost as soon as it was physically possible for it to do so.

What was the atmosphere like 3.8 billion years ago?
What chemical elements were present and in what quantities?
It turns out that the answers to these questions are also tied up with the bombardment.

As the planet cooled, an atmosphere formed. When scientists initially tried to work out what was in the first atmosphere they reasoned that, because most of the matter in the solar system is hydrogen the early atmosphere of Earth must have been rich in hydrogen. Therefore, they concluded other elements (such as carbon, oxygen, nitrogen, and sulfur) would be bound to hydrogen in their reduced forms as

CH_4 (methane),
NH_3 (ammonia),
H_2S (hydrogen sulfide), and
H_2O (water)

BUT if such an atmosphere did exist it would have been blasted away by meteor impacts during the bombardment phase.

The more probable source of the atmosphere present 3.8bya would have been gases released from the cooling rocks such as we now get from volcanoes and other vents through the crust. Based on an analysis of gases vented by modern volcanoes, it seems likely that this early atmosphere consisted mostly of water vapor (H_2O) and carbon dioxide (CO_2) and nitrogen gas (N_2).

Note that this atmosphere is very different from the one we have today.

- Today, the atmosphere contains only about 0.03% CO_2.
- The reduction of CO_2 in the atmosphere is the result of the action of living organisms. Much carbon exists today in the form of minerals rather than as CO_2 in the atmosphere. Most carbonate minerals are remains of skeletons of once-living organisms.

2. Where did the oxygen come from? -Photosynthesis
3. Nitrogen on early Earth would have been at approximately its same percentage as Earth's present atmosphere.

4. Trace amounts of **hydrogen (H)**, **methane (CH_4)**, **hydrogen sulfide(H_2S)**, **hydrogen cyanide(HCN)**, and **formaldehyde(CH_2O)** would have been present.
As the Earth cooled, water vapor condensed as rain and formed oceans and seas.

In addition to an atmosphere very different from the one we know, lightning, volcanic activity (crust thiner), and ultraviolet radiation (no ozone) were much more intense when the Earth was young.

What Was the Origin Of Complex Organic Molecules?

We are going to make an assumption: the chemical components found in all living prokaryotic and eukaryotic cells was present in the ancestral organism from which all life derived. In other words: the spontaneous interaction of the molecules present in the early earth's atmosphere formed more complex organic molecules, such as amino acids, sugars, fatty acids, and nitrogen bases - the building blocks of life as we know it today. As these organic compounds accumulated they formed an "organic soup" in which additional reactions could take place. The energy needed to drive the formation of these organic molecules was derived from the sun's radiation, electrical discharges in the form of lightening, and heat from the cooling earth.

Synthesizing the Chemical Components of Living Organisms

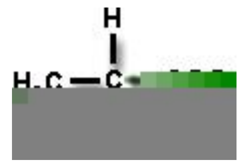
Important point - Laboratory simulations cannot establish that the kind of chemical evolution that has been described here actually created life on primordial earth, but only that some of the key steps **could** have happened.

Proteins

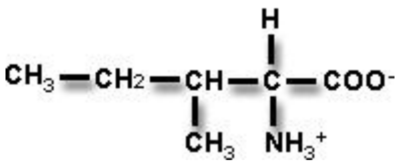
Proteins are made up of subunits, called **amino acids** so we must first talk about how to make amino acids.

There are 20 different types of amino acids used in living organisms, but all have the same central structure consisting of a carboxyl group (COO-), an amino group (NH3), and a carbon with a hydrogen and a variable side chain. For example:

Alanine:



Isoleucine:

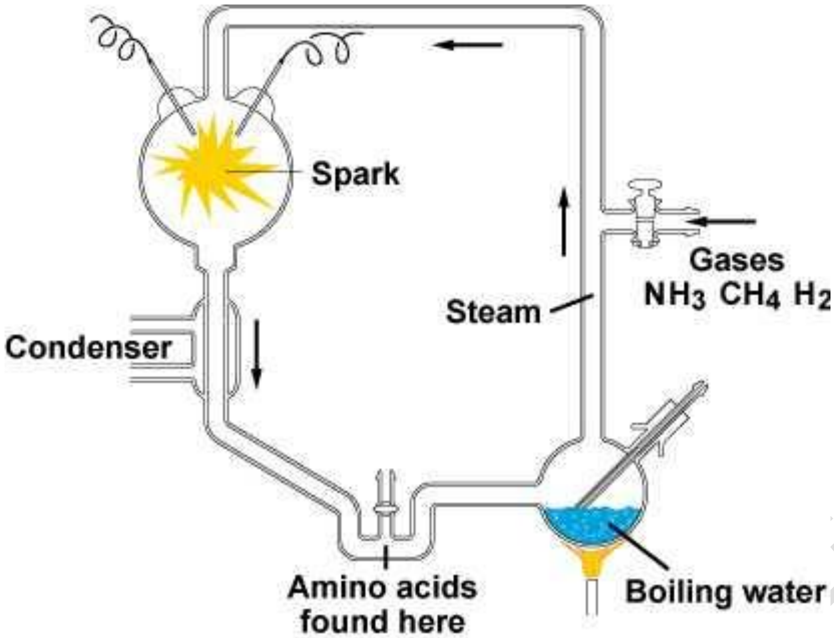


1953 experiment by Stanley Miller. While a graduate student at the University of Chicago, Miller began work to test the Oparin-Haldane hypothesis by creating laboratory conditions comparable to those of the early Earth.

First he created a "comic strip version" of primitive Earth.

In a flask he put:

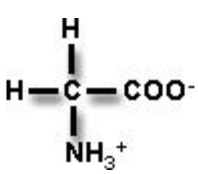
1. water (for the primeval sea),
2. methane (CH3), ammonia (NH3), and hydrogen for the atmosphere (note there is no O2 no CO2).
3. He sealed it off and exposed it to sparks for lightning and other forms of high energy such as UV radiation and heat (from Earth's interior)
4. A condenser cooled the atmosphere, raining water and any dissolved compound back into the flask (= the sea).



After one week, Miller analyzed the contents of the solution and found a variety of organic compounds, including molecules such as formaldehyde (O-CH2)

This molecule continues to react to form formic and then acetic acid (CH3-COOH)
Eventually the experiment yielded amino acids:

For example, Adding an amino group (in other words an ammonia) to acetic acid and you have an amino acid **glycine**:



But getting from amino acids to proteins is difficult:

1. Amino acids are asymmetrical molecules that exist in right and left-handed forms that are mirror images of each other: the L-isomer and the D-isomer. When amino acids are made in the

laboratory a mixture of L- and D-amino acids is found. However, the amino acids present in living organisms are all L-isomers.

2. To make a protein, the amino acids attach COOH end of one to the NH3 end of another. To do so, they must lose a molecule of water. Amino acids aren't likely to link up with one another and form such chains on their own and the reaction rarely happens spontaneously. Furthermore, it is unlikely that a water-producing reaction would occur if the amino acids are in water. (Remember: In the living cell, specific enzymes catalyze these dehydration reactions. But we don't have enzymes yet!)

Perhaps organic polymers were synthesized and accumulated on rock or clay surfaces. If the conditions are hot and dry enough, the water molecule can be lost and amino acids can join.

Using this process, Sidney Fox and his research group at the University of Miami have formed substances like proteins, called **protenoids**, by drying warm mixtures of amino acids. They suggest that volcanic activity could have generated high temperature to form proteins on the early Earth, even if only temporarily and locally. It is possible to imagine waves or rain splashing dilute solutions of chemicals onto fresh lava or other hot rocks on the early earth and then rinsing proteinoids back into the water.

Problem with this idea: High temperatures pose a problem, because organic molecules tend to break down as they are heated.

An alternative idea suggests that clay, even cool clay, may have been used. Clay has some interesting properties:

1. It has a slight charge that can attract and hold other molecules.
2. Clays may contained small amounts of metal atoms, such as copper, iron, or zinc. These metal atoms function as catalysts facilitating the dehydration reactions that link amino acids together.
3. Clay also seems to be able to store energy absorbed from radioactive decay and then discharged this energy at times when the clay changes temperature or degree of dehydration.

One more problem: Proteins are twisted or folded to form a macromolecule with a specific comformation, or three-dimensional shape. This comformation determines the function of the protein. For example, the unique shape of an enzyme permits it to "recognize" and act on the substance it regulates. The shape of the molecule is determined by the order of amino acids in the chain -- how do we get the very precise order of amino acids in early earth's environment?

2. **Nucleotides and Nucleic Acids**

Each nucleotide is composed of 5-carbon sugar, a nitrogen containing **base** (and by that I mean either a single ring called a pyrimidine or a double ring called a purine) and a phosphate group

There are three kinds of nucleotide-based molecules:

a. **Adenosine phosphates** - such as ATP (Adenosine triphosphate) - the energy carrier used by the cell.

b. **Nucleoside coenzymes** - such as NAD+ and others that transport hydrogen atoms and electrons during metabolism.

c. **Nucleic Acids** - responsible for the storage transmission and translation of genetic information. Such as **Deoxyribonucleic acid** (DNA) and **ribonucleic acid** (RNA).

Considering the atmosphere of the primitive earth to have contained water vapor, carbon dioxide, carbon monoxide, methane, and ammonia and/or nitrogen, then in the presence of an energy source, such as sunlight or lightning, a number of small molecules like hydrogen cyanide, HCN, are formed. These then undergo spontaneous reaction with other HCN molecules, again in the presence of some energy source and produce adenine and guanine bases (often abbreviated A and G) easily. The other two common bases, cytosine (C) and uracil (U), can also be formed in such experiments, although with more difficulty.

The next step is to combine the nucleotides with other chemicals to make more complex structures like RNA and DNA. For RNA, for example, the adenine or guanine has to be attached to the sugar molecule called ribose and a phosphate group. Ribose and other sugars can be synthesized in the lab from the molecules present in the early earth's atmosphere.

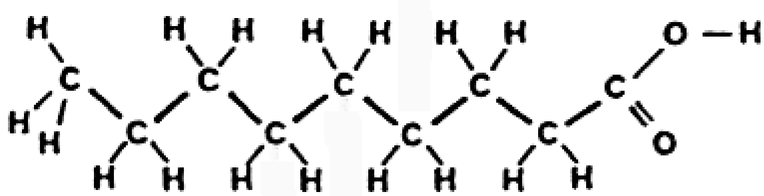
Phosphate is, however, a problem - phosphates appear to have been rare on early Earth.
3. **Simple Sugars and Carbohydrates**

Most cells use **carbohydrates** directly or indirectly for energy and as major structural materials. Carbohydrates are monomers or polymers of a sugar. A **sugar** is composed of carbon, hydrogen, oxygen in a 1:2:1 ratio.

4. **Fatty Acids and Lipids**

Lipids, which function in the storage of energy and are key components of cell structures such as membranes, are mostly composed of fatty acids.

Fatty acids can be formed simply by adding several carbons to acetic acid. A fatty acid is a long unbranched hydrocarbon with a carboxyl group (-COOH) at the end:



Extraterrestrial Organic Synthesis

It is possible that some organic compounds reached the early earth from space - this is called **panspermia**.

In 1969, a meteor struck near Murchinson, Australia. Analysis of the meteorite fragments revealed the presence of a variety of organic molecules including amino acids, pyrimidines, and molecules resembling fatty acids. Initially, there were even serious proposals that the organic material was biogenic in origin, but consensus was soon reached that abiotic chemical synthesis was the most plausible explanation.

This is significant for two reasons:

1. Heavy bombardment of meteors could have delivered a significant amount of essential compounds to the surface of the Earth.

2. The fact that these compounds could appear under abiotic, extraterrestrial conditions makes it seem more likely that similar compounds had been able to form on the primitive Earth.

We don't know yet how much organic matter was supplied to the oceans by natural synthesis on Earth and how much by meteor infall. That ratio is not as important as the fact that the right materials were present on the earth for further reactions to act on.

The Evolution Of Cell Membranes

All life on this planet is cellular life. All cells are bounded by membranes that encapsulate the macromolecular machinery of the life process. How did the first membrane structures on Earth appear?

Cell membranes of all living organisms contain hydrocarbon chains, which constitute an oil-like layer that forms a barrier between the internal and external compartments of cells. Proteins, which provide the enzymatic and transport activities that are primarily functions of membranes, are embedded in this fluid barrier. Therefore, to understand the origin of membrane structure we need to know how lipids and their hydrocarbon moieties provide the essential barrier properties of membranes.

Membrane lipids are typically phospholipid molecules. One of the most common, a constituent of most membranes, is phosphatidylcholine. That just means phosphate is chemically bound to glycerol and choline. The glycerol, in turn, is linked to two fatty acids, each consisting of an acidic carboxyl group (-COOH) attached to a long hydrocarbon chain. other common membrane phospholipids include phosphatidylethanolamine and phosphatidylserine.

Because they are relatively complex, phospholipids probably did not form the earliest membranes. Do molecules simpler than phospholipids assemble into membranes?

Certain molecular structures are polar, with relatively strong electrical charges expressed by their component atoms; others are nonpolar. Polar structures tend to be soluble in water and are usually referred to as **hydrophilic**. Nonpolar structures are **hydrophobic**; that is they tend to be soluble in oil and not in water. Some compounds (particularly lipids) that have both hydrophilic and hydrophobic residues on the same molecules are referred to as **amohiphilic**.

Hydrocarbons, by themselves, are nonpolar molecules. However, if oxygen is added to a long hydrocarbon chain, the molecules become amphiphilic, since oxygen is typically polar. All lipids have oxygen in their molecular structure, usually as carboxyl and phosphate - oxygen containing groups, chemically linked to nonpolar hydrocarbon chains.

Self-assembly of Lipids into Bilayers - Amphiphilic molecules have a remarkable property: they self-assemble into stable bilayer structures. When lipid such as phosphatidylcholine is dried, for example, the lipid molecules form lamellar structures. (*Lamellar* means that the structure has layers of molecules.) If water is then added, water molecules penetrate between the lipid layers along hydrophilic planes, causing the lipid to swell. The swelling produces a variety of fairly stable structures such as lipid cylinders, each of which contains thousands of concentric lipid bilayers.

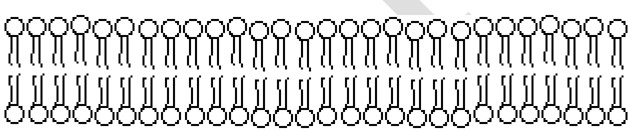
Why do lipid components form a stable bilayer structure in an aqueous environment? For thermodynamic reasons. Hydrocarbon chains can't dissolve in water, and oil do not mix. When lipid molecules are placed in water their hydrocarbon chains tend to stay in contact with one another away from the water. This tendency, which is called the hydrophobic effect, stabilizes the bilayer structure.

If lipid remains in contact with water, stable spherical structures called **liposomes** form. Liposomes represent a good model for the first types of membranes to appear in the origin-of life saga.

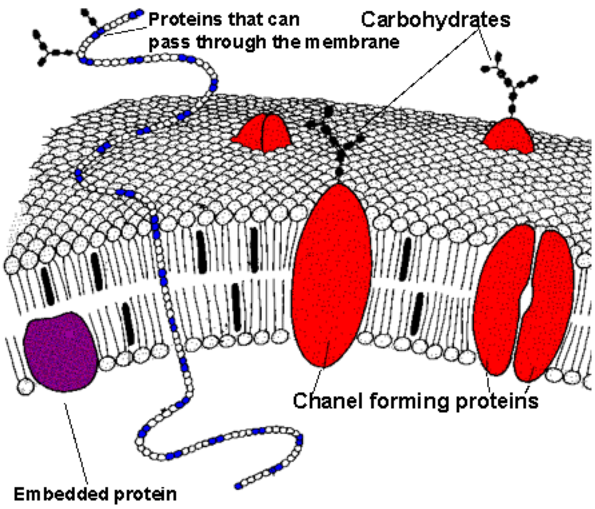
The first cells required some mechanism by which a membrane could encapsulate a system of replicating macromolecules. Although this seems difficult, the drying-wetting procedure offers an easy solution. If membrane-forming lipids are dried in the presence of large molecules, the molecules are sandwiched between alternating lipid bilayers. Upon rehydration, a substantial fraction of the the molecule are encapsulated within vesicular membrane structures. This has the additional advantage of concentrating molecules from dilute solutions. A primary function of amphiphilic compounds is to provide closed microenvironments. If macro molecular catalytic-information system were encapsulated within a vesicular membrane, the components of the system would share the same microenvironment. This would be a step towards true cellular function. Encapsulation would also produce individuals; each cell would be different from its neighbors.

A second role of early membranes was probably related to energy production, because energy-yielding processes are necessary to provide for growth of the catalytic-information system. In contemporary cells, membranes are central to energy production. Chloroplast membranes capture light energy by means of embedded pigment systems. The chemiosmotic synthesis of ATP that takes place on membranes.

That is there are **cell membranes** - selectively permeable membranes separating metabolic pathways from the outside environment.
The basic structure of a cell membrane is phospholipid bilayer with proteins dispersed and embedded in it:



There are various simple ways to get lipid bilayers -- the problem is ingetting the proteins embedded into them:

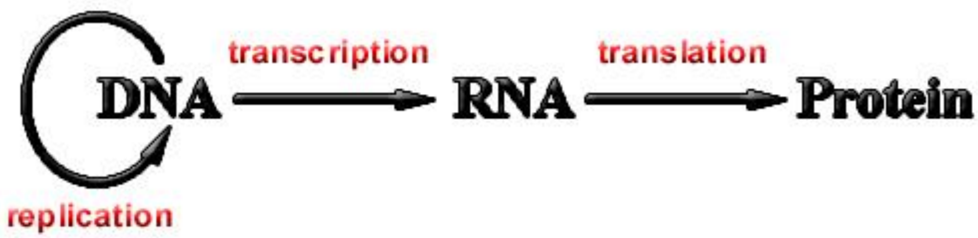


The Origin Of Heredity

Laboratory simulations and the presence of organic molecules in stony meteorites indicate normal chemical processes could give rise to aggregates of organic molecules that are reminiscent of the molecular components of organisms. But a key problem remains - these aggregates pf organic molecules have a limited time of existence. They will eventually deteriorate and break down. Once they are gone, chemical processes are the only mechanism we have described to produce more. Making that enormous jump from chemical evolution to real organisms requires a mechanism for these systems to reproduce themselves - some mechanism of heredity that would pass along not just key molecules but also instructions for making more of these molecules. If we can solve this problem we will have solved one of the great mysteries of the origin of life.

Clues to the origin of life are not easy to find when looking at contemporary organisms. In all contemporary cells, the information about how to build proteins (which, in turn, either catalyze the production of or makeup key structures) is encoded in the double helix of deoxyribonucleic acid (DNA). That information is copied when it is transcribed into a molecule of ribonucleic acid (RNA). Then translated into a particular sequence of amino acids that make up a polypeptide chain. When the chain is folded it becomes a protein. The function of that protein (becoming part of a structure or performing some metabolic catalysis) is determined by the specific type and order of the amino acids in the polypeptide chain. The order in which the amino acids are strung together is crucial because it determines how the chains will fold and twist into the three-dimensional shapes of individual proteins. On the molecular level in contemporary cells, reproduction, then, is the replication of the DNA (since this molecule encodes all of the information of life) when the cell divides.

But here is the problem - when we look at modern organisms, we see that DNA cannot replicate itself, but must be copied by specific enzymes. These replication proteins, in turn, are controlled by the transcription and translation of the DNA. If proteins are necessary to reproduce DNA but to produce proteins we need DNA, which came first in evolution? DNA or proteins?



This chicken and egg problem has puzzled scientists for some time. At first it seemed as if proteins came first. After all, proteins are so fundamental to life, they seemed to some the necessary first step in the evolution of life. As we have seen, this hypothesis is supported by the fact that the building blocks of proteins, amino acids, are relatively easy to produce in laboratory simulations of prebiotic evolution. Sidney Fox has demonstrated that it is possible to assemble these amino acids into polypeptide chains and protenoids. But to be effective as biological structures or enzymes, proteins must have a very specific sequence of amino acids. If by some enormous stroke, a single copy of an effective protein spontaneously arose, it would be a dead end. Even if successfully assembled, proteins have no way of copying themselves. they cannot replicate themselves and pass on information about how to make more of their specific structure.

A. G. Cairns proposed a possible solution in the early 1980s. he suggested that naturally occurring microscopic mineral crystals in clays might have served as the basis for replication until the time when nucleic acids evolved and took over the function of replication. Clay microcrystals consist of flat plates of silicate lattices with regular arrays of ionic sites occupied by various metals. When such a crystal is contained in a droplet of water, the metal ions form irregular patterns of electrostatic potential that can attract particular molecules to the surfaces of the lattice and catalyze chemical reactions. Which reactions are catalyzed depends upon the precise arrangement of the metal ions. Molecules synthesized in this manner could be released back to the water. Because a crystal grows by incorporating silicate and metal ions from the surrounding water, the new materials are similar in composition to the original parts of the crystal that generated them. Thus crystals could, in principle, both replicate information and transfer it to other molecules. What is uncertain is whether they could have done so with sufficient precision to serve as a basis for the evolution of life. According to this theory, the clay lattice first directed the synthesis of primitive enzymes. For a long time, the clay crystals functioned as primitive genetic material, but at some point, by as yet unspecified mechanisms, RNA evolved and took over the role of replicating and transferring information. Once RNA appeared, it was so much better as a genetic material that clay-based life was quickly out competed by RNA-based life and driven to extinction. This scenario is plausible, but critical experiments to test some of its key assumptions have not yet been performed.

Ribozymes

Gerald Joyce's lab at Scripts Research Institute in La Jolla California were working with synthetic RNAs. At first they thought the snippet of RNA had ruined their experiment. But this piece of RNA proved to be unusually talented. Within an hour of its formation, it had commandeered the proteins in the test tube and started making copies of itself. Before long, the copies began to make copies. Another piece of the puzzle was in place:

RNA + proteins made by inorganic processes cause the RNA to replicate and begin to produce proteins

Finally DNA favored because easier to repair.

RNA first hypothesis

The RNA World Hypothesis is a concept put forth in the 1960s by Carl Woese, Francis Crick and Leslie Orgel. It proposes that earlier life forms may have used RNA alone for the storage of genetic material.

Walter Gilbert, a Harvard molecular biologist, was the first to use the term "RNA World" in an article published in 1986. The hypothesis posists that DNA later became the genetic material as a result of evolution because RNA was a relatively unstable molecule. According to the RNA World Hypothesis, around 4 billion years ago, RNA was the primary living substance, largely due to RNA's ability to function as both genes and enzymes.

The main reasoning behind the hypothesis is that RNA is capable of self-replication and could therefore have carried genetic information across generations independently. This concept has been highly debated in the scientific world over the last 50 years.

Experts now generally agree that non-living chemicals could not have given rise to bacterial cells in a single step and that intermediate, pre-cellular life forms must therefore have existed. Of the possible pre-cellular life models considered, the most popular is the RNA World.

In 1968, Sir Francis Crick proposed that RNA must have been the primary genetic material as it is capable of self-replication, owing to its ability to act as an enzyme. Moreover, RNA can also be converted to DNA by reverse transcription, which further strengthens the idea that the RNA world could have been the initial pathway to cells.

Ribozymes and the RNA world

It was previously thought that the only biomolecules that could catalyze essential chemical reactions in cells were proteins. However, Sidney Altman, Thomas Cech and colleagues discovered a class of RNAs that is capable of catalyzing chemical reactions — ribozymes. Altman and Cech were awarded the Nobel Prize in Chemistry in 1989 for this discovery.

The discovery of ribozymes supported the RNA World Hypothesis. The strongest argument for proving the hypothesis is perhaps that the ribosome, which assembles proteins, is itself a ribozyme. Despite the fact that the ribosome is composed of both RNA and protein, the processes involved in translation are not catalyzed by protein, but by RNA, indicating that early life forms may have used RNA to catalyze chemical reactions before they used proteins.

Origin of photosynthesis

The **evolution of photosynthesis** refers to the origin and subsequent evolution of photosynthesis, the process by which light energy synthesizes sugars from carbon dioxide, releasing oxygen as a waste product. The process of Photosynthesis was discovered by Jan Ingenhousz, a Dutch-born British physician and scientist, first publishing about it in 1779.

The first photosynthetic organisms probably evolved early in the evolutionary history of life and most likely used reducing agents such as hydrogen or electrons, rather than water.

The biochemical capacity to use water as the source for electrons in photosynthesis evolved in a common ancestor of extant cyanobacteria.

The geological record indicates that this transforming event took place early in Earth's history, at least 2450–2320 million years ago (Ma), and, it is speculated, much earlier.

Available evidence from geobiological studies of Archean(>2500 Ma) sedimentary rocks indicates that life existed 3500 Ma, but the question of when oxygenic photosynthesis evolved is still unanswered. A clear paleontological window on cyanobacterial evolution opened about 2000 Ma, revealing an already-diverse biota of blue-greens.

Cyanobacteria remained principal primary producers throughout the Proterozoic Eon (2500–543 Ma), in part because the redox structure of the oceans favored photoautotrophs capable of nitrogen fixation

Green algae joined blue-greens as major primary producers on continental shelves near the end of the Proterozoic, but only with the Mesozoic (251–65 Ma) radiations of dinoflagellates, coccolithophorids, and diatoms did primary production in marine shelf waters take modern form. Cyanobacteria remain critical to marine ecosystems as primary producers in oceanic gyres, as agents of biological nitrogen fixation, and, in modified form, as the plastids of marine algae.[7]

Early photosynthetic systems, such as those from green and purple sulfur and green and purple nonsulfur bacteria, are thought to have been anoxygenic, using various molecules as electron donors. Green and purple sulfur bacteria are thought to have used hydrogen and sulfur as an electron donor. Green nonsulfur bacteria used various amino and other organic acids. Purple nonsulfur bacteria used a variety of nonspecific organic molecules.

The main source of oxygen in the atmosphere is oxygenic photosynthesis, and its first appearance is sometimes referred to as the oxygen catastrophe.

Geological evidence suggests that oxygenic photosynthesis, such as that in cyanobacteria, became important during the Paleoproterozoic era around 2 billion years ago. Modern photosynthesis in plants and most photosynthetic prokaryotes is oxygenic. Oxygenic photosynthesis uses water as an electron donor, which is oxidized to molecular oxygen

(O_2) in the photosynthetic reaction center.

Several groups of animals have formed symbiotic relationships with photosynthetic algae.

These are most common in corals, sponges and sea anemones. It is presumed that this is due to the particularly simple body plans and large surface areas of these animals compared to their volumes.

In addition, a few marine mollusks *Elysia viridis* and *Elysia chlorotica* also maintain a symbiotic relationship with chloroplasts they capture from the algae in their diet and then store in their bodies. This allows the mollusks to survive solely by photosynthesis for several months at a time.

Some of the genes from the plant cell nucleus have even been transferred to the slugs, so that the chloroplasts can be supplied with proteins that they need to survive.

Ozone and Oxygen

Stratospheric ozone was formed naturally by chemical reactions involving solar ultraviolet radiation (sunlight) and oxygen molecules, which make up 21% of the atmosphere. In the first step, solar ultraviolet radiation breaks apart one oxygen molecule ($O2$) to produce two oxygen atoms (2 O).

In the second step, each of these highly reactive atoms combines with an oxygen molecule to produce an ozone molecule ($O3$). These reactions occur continually whenever solar ultraviolet radiation is present in the stratosphere. As a result, the largest ozone production occurs in the tropical stratosphere.

The production of stratospheric ozone is balanced by its destruction in chemical reactions. Ozone reacts continually with sunlight and a wide variety of natural and human produced chemicals in the stratosphere. In each reaction, an ozone molecule is lost and other chemical compounds are produced. Important reactive gases that destroy ozone are hydrogen and nitrogen oxides and those containing chlorine and bromine.

Some stratospheric ozone is regularly transported down into the troposphere and can occasionally influence ozone amounts at Earth's surface, particularly in remote, unpolluted regions of the globe.

Tropospheric ozone-

Near Earth's surface, ozone is produced by chemical reactions involving naturally occurring gases and gases from pollution sources. Ozone production reactions primarily involve hydrocarbon and nitrogen oxide gases, as well as ozone itself, and all require sunlight for completion. Fossil fuel combustion is a primary source of pollutant gases that lead to tropospheric ozone production. The production of ozone near the surface does not significantly contribute to the abundance of stratospheric ozone. The amount of surface ozone is too small in comparison and the transport of surface air to the stratosphere is not effective enough. As in the stratosphere, ozone in the troposphere is destroyed by naturally occurring chemical reactions and by reactions involving human-produced chemicals. Tropospheric ozone can also be destroyed when ozone reacts with a variety of surfaces, such as those of soils and plants.

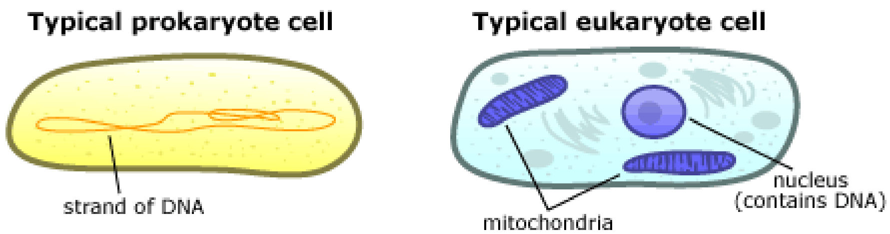
Stratosphere ozone is good ozone because it protect us from Sun's biologically harmful ultraviolet rays and also formed by reaction of natural components.

Tropospheric ozone is bad ozone, formed by the reaction of man made pollutants, harmful to plants and animals.

Cellular Evolution

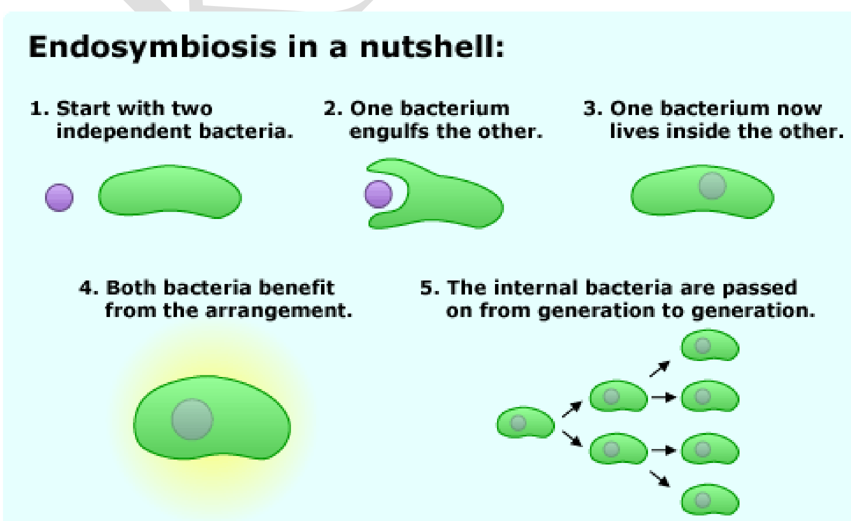
Living things have evolved into three large clusters of closely related organisms, called "domains": Archaea, Bacteria, and Eukaryota. Archaea and Bacteria are small, relatively simple cells surrounded by a membrane and a cell wall, with a circular strand of DNA containing their genes. They are called prokaryotes.

Virtually all the life we see each day — including plants and animals — belongs to the third domain, Eukaryota. Eukaryotic cells are more complex than prokaryotes, and the DNA is linear and found within a nucleus. Eukaryotic cells boast their own personal "power plants", called mitochondria. These tiny organelles in the cell not only produce chemical energy, but also hold the key to understanding the evolution of the eukaryotic cell.



The complex eukaryotic cell ushered in a whole new era for life on Earth, because these cells evolved into multicellular organisms. But how did the eukaryotic cell itself evolve? How did a humble bacterium make this evolutionary leap from a simple prokaryotic cell to a more complex eukaryotic cell? The answer seems to be symbiosis — in other words, teamwork.

Evidence supports the idea that eukaryotic cells are actually the descendents of separate prokaryotic cells that joined together in a symbiotic union. In fact, the mitochondrion itself seems to be the "great-great-great-great-great-great-great-great-great granddaughter" of a free-living bacterium that was engulfed by another cell, perhaps as a meal, and ended up staying as a sort of permanent houseguest. The host cell profited from the chemical energy the mitochondrion produced, and the mitochondrion benefited from the protected, nutrient-rich environment surrounding it. This kind of "internal" symbiosis — one organism taking up permanent residence inside another and eventually evolving into a single lineage — is called endosymbiosis.



Possible questions

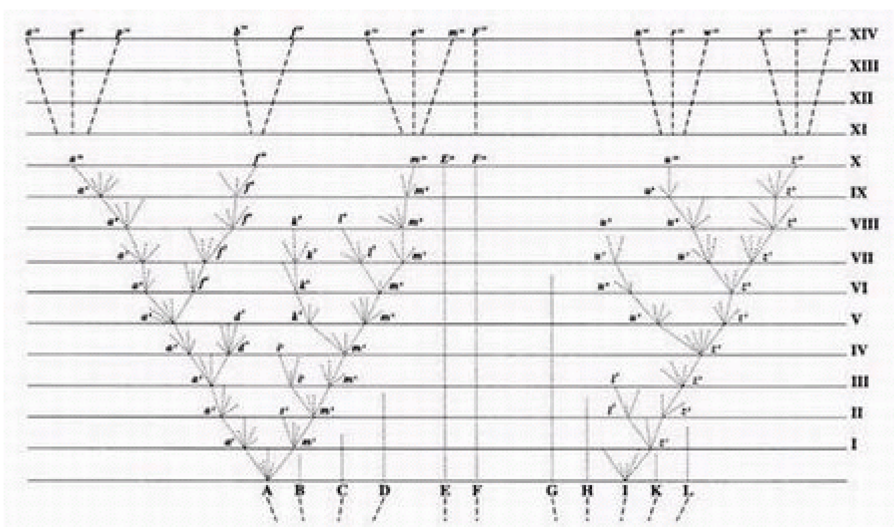
1. Explain Modern synthetic theory of evolution
2. Give a detailed account on Miler's experiment and its significance
3. Elaborate the endosymbiotic theory of evolution
4. Explain the evolution of eukaryotes form prokaryotes
5. Define fossils
6. What is microevolution?
7. Describe paleontology
8. Explain the origin of photosynthesis
9. What is a protocell model?
10. Discuss cellular evolution based on proto-cell model
11. Explain geographical timescale
12. Explain Modern synthetic theory of evolution
13. Discuss Miler's experiment and its significance
14. Describe in detail about the endosymbiotic theory
15. Explain the evolution of eukaryotes form prokaryotes

Paleobiological – Concept of Stratigraphy and geological timescale; fossil study). Anatomical – Vestigial organs; Homologous and Analogous organs (concept of parallelism and convergence in evolution). Taxonomic – Transitional forms/evolutionary intermediates; living fossils. Phylogenetic – a) Fossil based – Phylogeny of horse as a model. b) Molecule based – Protein model (Cytochrome C); gene model

THE EVIDENCE FOR EVOLUTION

Anatomy and embryology

Darwin thought of **evolution** as "descent with modification," a process in which species change and give rise to new species over many generations. He proposed that the evolutionary history of life forms a branching tree with many levels, in which all species can be traced back to an ancient common ancestor.



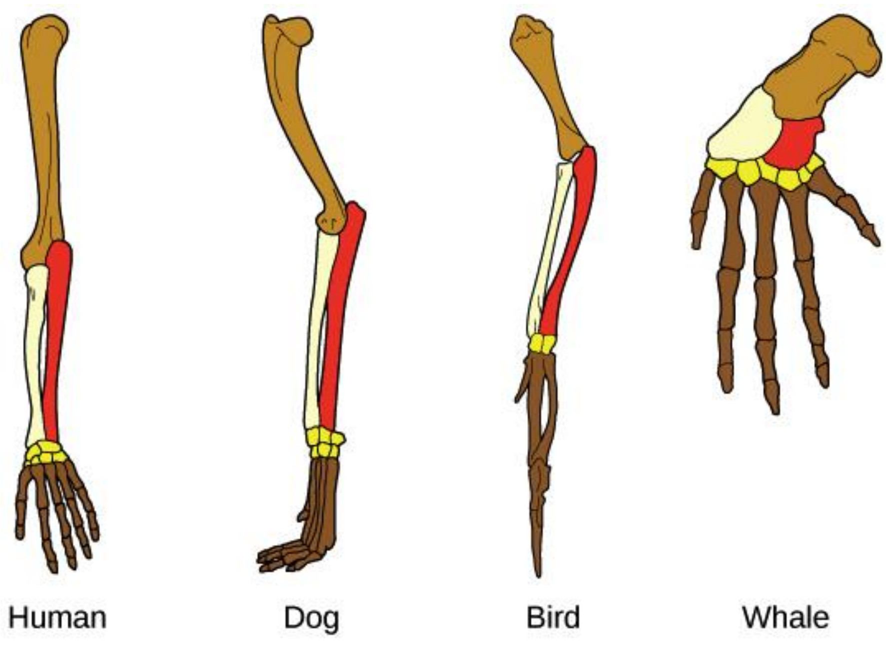
Branching diagram that appeared in Charles Darwin's *On the origin of species*, illustrating the idea that new species form from pre-existing species in a branching process that occurs over extended periods of time.

In this tree model, more closely related groups of species have more recent common ancestors, and each group will tend to share features that were present in its last common ancestor. We can use this idea to "work backwards" and figure out how organisms are related based on their shared features.

Homologous features

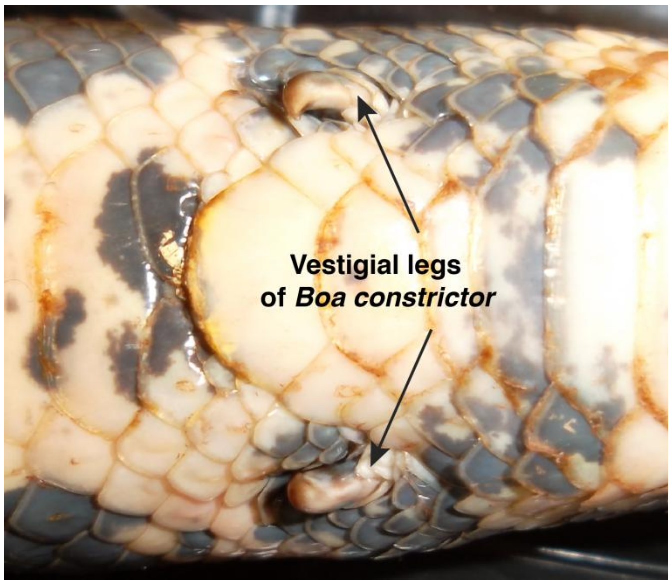
If two or more species share a unique physical feature, such as a complex bone structure or a body plan, they may all have inherited this feature from a common ancestor. Physical features shared due to evolutionary history (a common ancestor) are said to be **homologous**.

To give one classic example, the forelimbs of whales, humans, birds, and dogs look pretty different on the outside. That's because they're adapted to function in different environments. However, if you look at the bone structure of the forelimbs, you'll find that the pattern of bones is very similar across species. It's unlikely that such similar structures would have evolved independently in each species, and more likely that the basic layout of bones was already present in a common ancestor of whales, humans, dogs, and birds.



The similar bone arrangement of the human, bird, and whale forelimb is a structural homology. Structural homologies indicate a shared common ancestor.

Some homologous structures can be seen only in embryos. For instance, all vertebrate embryos (including humans) have gill slits and a tail during early development. The developmental patterns of these species become more different later on (which is why your embryonic tail is now your tailbone, and your gill slits have turned into your jaw and inner ear)^22start superscript, 2, end superscript. Homologous embryonic structures reflect that the developmental programs of vertebrates are variations on a similar plan that existed in their last common ancestor.



The small leg-like structures of some snakes species, like the*Boa constrictor*, are vestigial structures. These remnant features serve no present purpose in snakes, but did serve a purpose in the snakes' tetrapod ancestor (which walked on four limbs).

Sometimes, organisms have structures that serve no apparent function but are homologous to useful structures in other organisms. These reduced or nonfunctional structures, which appear to be evolutionary “leftovers," are called **vestigial structures**. Examples of vestigial structures include the tailbone of humans (a vestigial tail), the hind leg bones of whales, and the underdeveloped legs found in some snakes (see picture at right)^33start superscript, 3, end superscript.

Analogous features

To make things a little more interesting and complicated, not all physical features that look alike are marks of common ancestry. Instead, some physical similarities are **analogous**: they evolved independently in different organisms because the organisms lived in similar environments or experienced similar selective pressures. This process is called **convergent evolution**. (To *converge*means to come together, like two lines meeting at a point.)

For example, two distantly related species that live in the Arctic, the arctic fox and the ptarmigan (a bird), both undergo seasonal changes of color from dark to snowy white. This shared feature doesn't reflect common ancestry – i.e., it's unlikely that the last common ancestor of the fox and ptarmigan changed color with the seasons^44start superscript, 4, end superscript. Instead, this feature was favored separately in both species due to similar selective pressures. That is, the genetically determined ability to switch to light coloration in winter helped both foxes and ptarmigans survive and reproduce in a place with snowy winters and sharp-eyed predators.

Arctic fox and ptarmigan. Both are white-colored and shown in snowy winter landscapes.

Determining relationships from similar features

In general, biologists don't draw conclusions about how species are related on the basis of any single feature they think is homologous. Instead, they study a large collection of features (often, both physical features and DNA sequences) and draw conclusions about relatedness based on these features as a group. We will explore this idea further when we examine phylogenetic trees.

Molecular biology

Like structural homologies, similarities between biological molecules can reflect shared evolutionary ancestry. At the most basic level, all living organisms share:

- The same genetic material (DNA)
- The same, or highly similar, genetic codes
- The same basic process of gene expression (transcription and translation)
- The same molecular building blocks, such as amino acids

These shared features suggest that all living things are descended from a common ancestor, and that this ancestor had DNA as its genetic material, used the genetic code, and expressed its genes by transcription and translation. Present-day organisms all share these features because they were "inherited" from the ancestor (and because any big changes in this basic machinery would have broken the basic functionality of cells).

Although they're great for establishing the common origins of life, features like having DNA or carrying out transcription and translation are not so useful for figuring out *how* related particular organisms are. If we want to determine which organisms in a group are most closely related, we need to use different types of molecular features, such as the nucleotide sequences of genes.

Homologous genes

Biologists often compare the sequences of related genes found in different species (often called **homologous** or **orthologous** genes) to figure out how those species are evolutionarily related to one another.

The basic idea behind this approach is that two species have the "same" gene because they inherited it from a common ancestor. For instance, humans, cows, chickens, and chimpanzees all have a gene that encodes the hormone insulin, because this gene was already present in their last common ancestor.

In general, the more DNA differences in homologous genes (or amino acid differences in the proteins they encode) between two species, the more distantly the species are related. For instance, human and chimpanzee insulin proteins are much more similar (about 98% identical) than human and chicken insulin proteins (about 64% identical), reflecting that humans and chimpanzees are more closely related than humans and chickens^55start superscript, 5, end superscript.

Biogeography

The geographic distribution of organisms on Earth follows patterns that are best explained by evolution, in combination with the movement of tectonic plates over geological time. For example, broad groupings of organisms that had already evolved before the breakup of the supercontinent Pangaea (about 200200200 million years ago) tend to be distributed worldwide. In contrast, broad groupings that evolved after the breakup tend to appear uniquely in smaller regions of Earth. For instance, there are unique groups of plants and animals on northern and southern continents that can be traced to the split of Pangaea into two supercontinents (Laurasia in the north, Gondwana in the south).

Marsupial mammals on Australia likely evolved from a common ancestor. Because Australia's has remained isolated for an extended period time, these mammals have diversified into a variety of niches (without being outcompeted by placental mammals).

The evolution of unique species on islands is another example of how evolution and geography intersect. For instance, most of the mammal species in Australia are marsupials (carry young in a pouch), while most mammal species elsewhere in the world are placental (nourish young through a placenta). Australia's marsupial species are very diverse and fill a wide range of ecological roles. Because Australia was isolated by water for millions of years, these species were able to evolve without competition from (or exchange with) mammal species elsewhere in the world.

The marsupials of Australia, Darwin's finches in the Galápagos, and many species on the Hawaiian Islands are unique to their island settings, but have distant relationships to ancestral species on mainlands. This combination of features reflects the processes by which island species evolve. They often arise from mainland ancestors – for example, when a landmass breaks off or a few individuals are blown off course during a storm – and diverge (become increasingly different) as they adapt in isolation to the island environment.

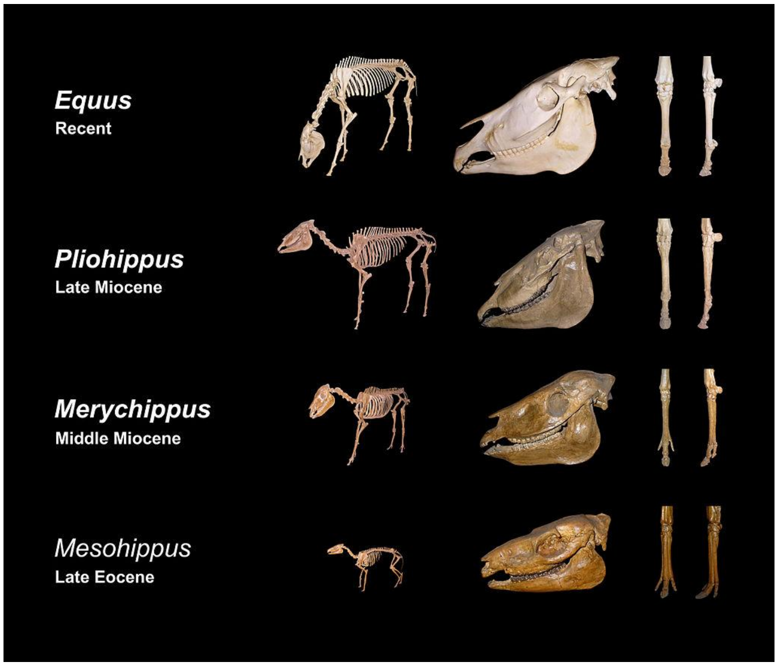
Fossil record

Fossils are the preserved remains of previously living organisms or their traces, dating from the distant past. The fossil record is not, alas, complete or unbroken: most organisms never fossilize, and even the organisms that do fossilize are rarely found by humans. Nonetheless, the fossils that humans have collected offer unique insights into evolution over long timescales.

Earth's rocks form layers on top of each other over very long time periods. These layers, called strata, form a convenient timeline for dating embedded fossils. Strata that are closer to the surface represent more recent time periods, whereas deeper strata represent older time periods.

How can the age of fossils be determined? First, fossils are often contained in rocks that build up in layers called **strata**. The strata provide a sort of timeline, with layers near the top being newer and layers near the bottom being older. Fossils found in different strata at the same site can be ordered by their positions, and "reference" strata with unique features can be used to compare the ages of fossils across locations. In addition, scientists can roughly date fossils using radiometric dating, a process that measures the radioactive decay of certain elements.

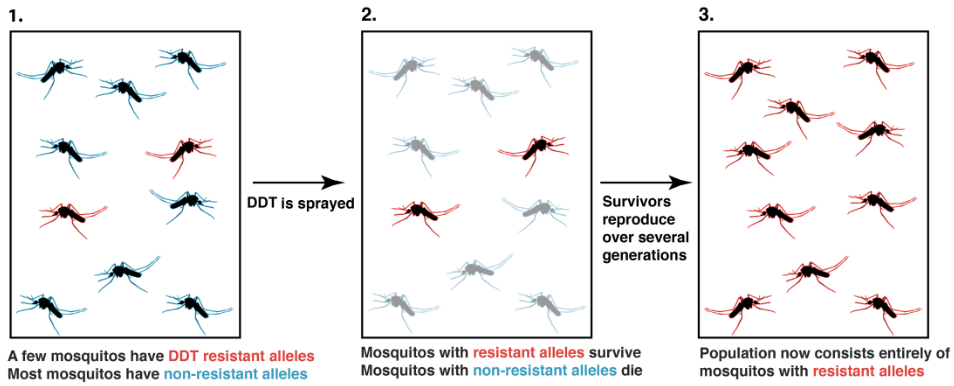
Fossils document the existence of now-extinct species, showing that different organisms have lived on Earth during different periods of the planet's history. They can also help scientists reconstruct the evolutionary histories of present-day species. For instance, some of the best-studied fossils are of the horse lineage. Using these fossils, scientists have been able to reconstruct a large, branching "family tree" for horses and their now-extinct relatives^66start superscript, 6, end superscript. Changes in the lineage leading to modern-day horses, such as the reduction of toed feet to hooves, may reflect adaptation to changes in the environment.



Direct observation of microevolution

In some cases, the evidence for evolution is that we can see it taking place around us! Important modern-day examples of evolution include the emergence of drug-resistant bacteria and pesticide-resistant insects.

For example, in the 1950s, there was a worldwide effort to eradicate malaria by eliminating its carriers (certain types of mosquitos). The pesticide DDT was sprayed broadly in areas where the mosquitoes lived, and at first, the DDT was highly effective at killing the mosquitos. However, over time, the DDT became less and less effective, and more and more mosquitoes survived. This was because the mosquito population evolved resistance to the pesticide.



The evolution of DDT resistance in mosquito populations was observed directly in the 1950s as a result of a campaign to eradicate malaria. Resistance to the pesticide evolved over a few years through natural selection:

1) Within mosquito populations, a few individuals had alleles that made them resistant to the pesticide, DDT. The majority of individuals had alleles that did not confer resistance.

2) When DDT was sprayed, individuals carrying the resistance allele survived, while those carrying the non-resistant allele died.

3) Over several generations, more resistant offspring were born and the population evolved. The population now contained more resistant than non-resistant individuals.

Emergence of DDT resistance is an example of evolution by natural selection^77start superscript, 7, end superscript. How would natural selection have worked in this case?

1. Before DDT was applied, a tiny fraction of mosquitos in the population would have had naturally occurring gene versions (**alleles**) that made them resistant to DDT. These versions would have appeared through random **mutation**, or changes in DNA sequence. Without DDT around, the resistant alleles would not have helped mosquitoes survive or reproduce (and might even have been harmful), so they would have remained rare.

2. When DDT spraying began, most of the mosquitos would have been killed by the pesticide. Which mosquitos would have survived? For the most part, only the rare individuals that happened to have DDT resistance alleles (and thus survived being sprayed with DDT). These surviving mosquitoes would have been able to reproduce and leave offspring.

3. Over generations, more and more DDT-resistant mosquitoes would have been born into the population. That's because resistant parents would have been consistently more likely to survive and reproduce than non-resistant parents, and would have passed their DDT resistance alleles (and thus, the capacity to survive DDT) on to their offspring. Eventually, the mosquito populations would have bounced back to high numbers, but would have been composed largely of DDT-resistant individuals.

In parts of the world where DDT has been used extensively in the past, many of the mosquitoes are now resistant. DDT can no longer be used to control the mosquito populations (and reduce malaria) in these regions.

Why are mosquito populations able to evolve rapid resistance to DDT? Two important factors are large population size (making it more likely that some individuals in the population will, by random chance, have mutations that provide resistance) and short lifecycle. Bacteria and viruses, which have even larger population sizes and shorter lifecycles, can evolve resistance to drugs very rapidly, as in antibiotic-resistant bacteria and drug-resistant HIV.

Summary

Multiple types of evidence support the theory of evolution:

- Homologous structures provide evidence for common ancestry, while analogous structures show that similar selective pressures can produce similar adaptations (beneficial features).
- Similarities and differences among biological molecules (e.g., in the DNA sequence of genes) can be used to determine species' relatedness.
- Biogeographical patterns provide clues about how species are related to each other.
- The fossil record, though incomplete, provides information about what species existed at particular times of Earth's history.
- Some populations, like those of microbes and some insects, evolve over relatively short time periods and can observed directly.

Possible questions

1. Give a detailed account on analogous, vestigial and homologous organs
2. Explain DNA based phylogeny
3. Explain in vestigial organs of animals
4. Explain protein and nucleic acid based phylogeny
5. Explain geological timescale
6. Define paleobiology
7. What are hologous organs
8. Define analogous organs
9. Elaborate transitional forms
10. Describe evolutionary intermediates
11. Explain protein based phylogeny
12. What is he function of cytochrome C
13. Explain the homology of hemoglobin gene family
14. Explain rRNA sequence homology
15. Discuss types of ribosomalRNAs and their importance in evolutionary studies

Sources of Evolution – Variations as Raw Materials of Change: Types of variations – Continuous and discontinuous; heritable and non-heritable. Causes, classification and contribution to evolution – Gene mutation; chromosomal aberrations; recombination and random assortment (basis of sexual reproduction); gene regulation. Concept of micro- and macro-evolution – A brief comparison

Genetic Variation

Populations exposed to selection often evolve rapidly. Alleles that confer increased survival and reproductive ability in the new conditions rapidly increase in frequency while alleles that were conditions rapidly increase in frequency, while alleles that were common decrease in frequency. How does the genetic variation arise?

One of the central tenets of the modern model of evolution is that variation does not arise in response to need. Instead, genetic variation is present in natural populations before it is exposed to 1 p pp p selection, in the form of rare alleles.

New sources of selection results in an increase in allele frequencies that confer high fitness. An alternative view is that new alleles that confer high fitness arise in response to exposure to selection. This is the "Neo-Lamarckian" view. Two different experiments with bacteria originally provided evidence that variation does not arise in response to need. Luria and Delbruck looked at variation among bacteria for resistance to a phage.

They reasoned that if variation arises in response to need, the incidence of new resistance in cultures of originally nonresistant bacteria should not vary greatly among independent cultures. should not vary greatly among independent cultures. They started multiple cultures of nonresistant bacteria, allowed them to multiply, and then exposed the bacteria to phage to test for resistance. Under the hypothesis that variation arises in response to need, they would expect all variation to arise after exposure.

As a result they'd expect little variation in the number of resistant colonies among cultures. Their expectation: 2 2 Under the hypothesis that variation arises randomly, not in response to need, resistance could appear in any generation, and thus some cultures would have many resistant

bacteria (as a result of early mutation) and some cultures would have none (as result of no mutation) yp g . They expected great variation in the number of resistant colonies among cultures: 3 This is what Luria and Delbruck found. In the second experiment, Joshua and Esther Lederberg used replica plating to determine if penicillin resistance in bacterial colonies was present before exposure to penicillin or only arose after exposure to penicillin.

They cultured nonresistant bacteria and then exposed them to penicillin. Their technique allowed them to determine if the original colonies from which the resistant bacteria were derived were resistant before exposure to penicillin. Their results showed that resistance did not arise during exposure t i illi 4 to penicillin. Resistance arose in the culture before exposure to penicillin. 3 Mutation - the alteration of a region of DNA or chromosome; and altered state of a region of DNA or chromosome Types of mutations: base pair substitution base pair substitution - a single base pair change in DNA also a single base pair change in DNA, also called a point mutation Point mutations can result in single amino acid changes (nonsynonymous 5 mutation) or no change in amino acid – (synonymous mutation)

Nonsynonymous mutations may have small or large effects on the properties of the protein product of the gene. A single base pair addition or deletion is a frameshift mutation - the result is a change in reading frame of RNA product of the gene and many amino acid changes in the protein product and many amino acid changes in the protein product - usually usually results in a nonfunctional protein product.

Intragenic recombination Original Sequence: ATTGATCGATCTATGC TAACTAGCTAGATACG Recombination can also result in sequence changes Mutation Sequence 1: ATGGATCGATCTATGC TACCTAGCTAGATACG Mutation Sequence 2: ATTGATCGATGGATGC TAACTAGCTACCTACG Recombination ATGGATCGATGGATGC 7 Sequence TACCTAGCTACCTACG

The amino acid changes resulting from the original two point mutations are combined in a single protein as a result of recombination. Unequal crossing-over results in sequence duplications and deletions. Unequal crossing-over usually occurs in regions where there are tandem repeats. The result can be a reduction in the number of repeats or an increase in the number of repeats. 8 High numbers of tandem repeats make a region liable to unequal crossing-over and additional duplications. It can give rise to gene families (multiple copies of variants of a single gene) and new functional genes.

5 Transposable elements - sequences of DNA that can be inserted into regions of the genome Insertion of a sequence of bases into a functional gene or the regulatory region of a functional gene can destroy normal functioning of that gene. Transposable elements can result in the movement of neighboring genes that were not initially part of the transposable elements.

Recombination between transposable elements 9 transposable elements can result in deletions or inversions of base pair sequences. Examples of mutations: Sickle-cell anemia - a single base pair substitution that results in a single amino acid change in the β chain of Hb Precocious puberty - a single amino acid change in the gene for the receptor for luteinizing hormone results in males that show signs of puberty as early as age

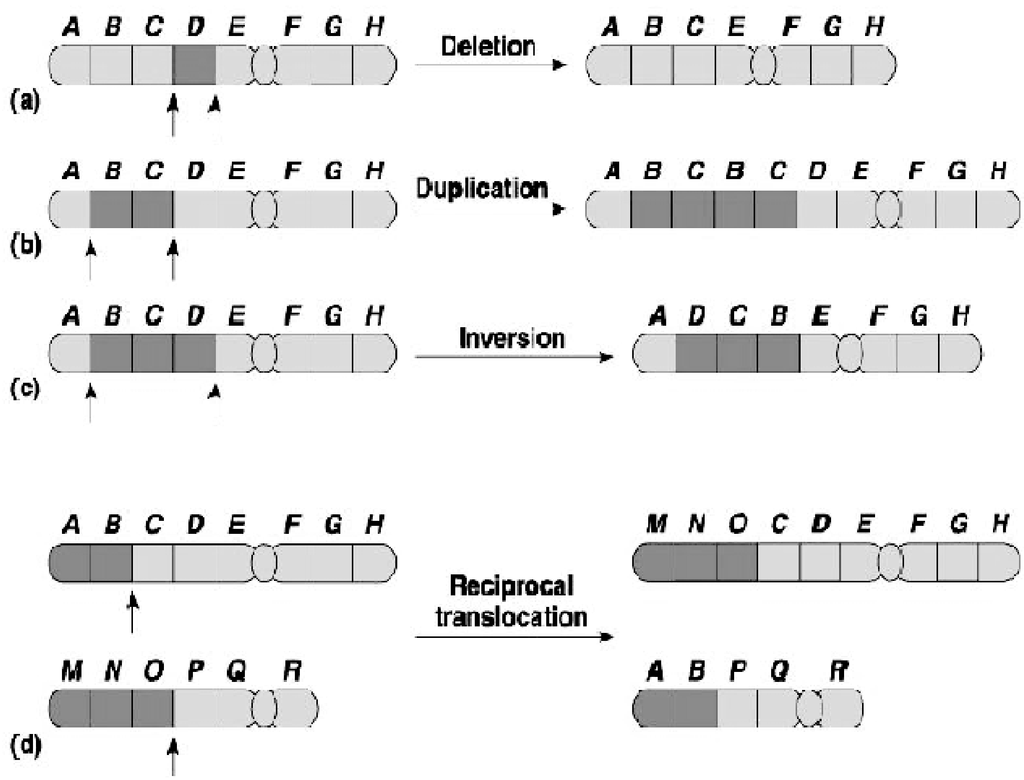
4. Cystic fibrosis - a fatal disease that occurs in 1 in every 2500 births among northern Europeans is due to a mutation in a chloride ion channel protein. Different mutations account for the same condition: a deletion of 3 base pairs results in the deletion of a single amino 10 p g acid, a conversion of an arginine codon into a stop codon, an alteration in a splicing enzyme has resulted

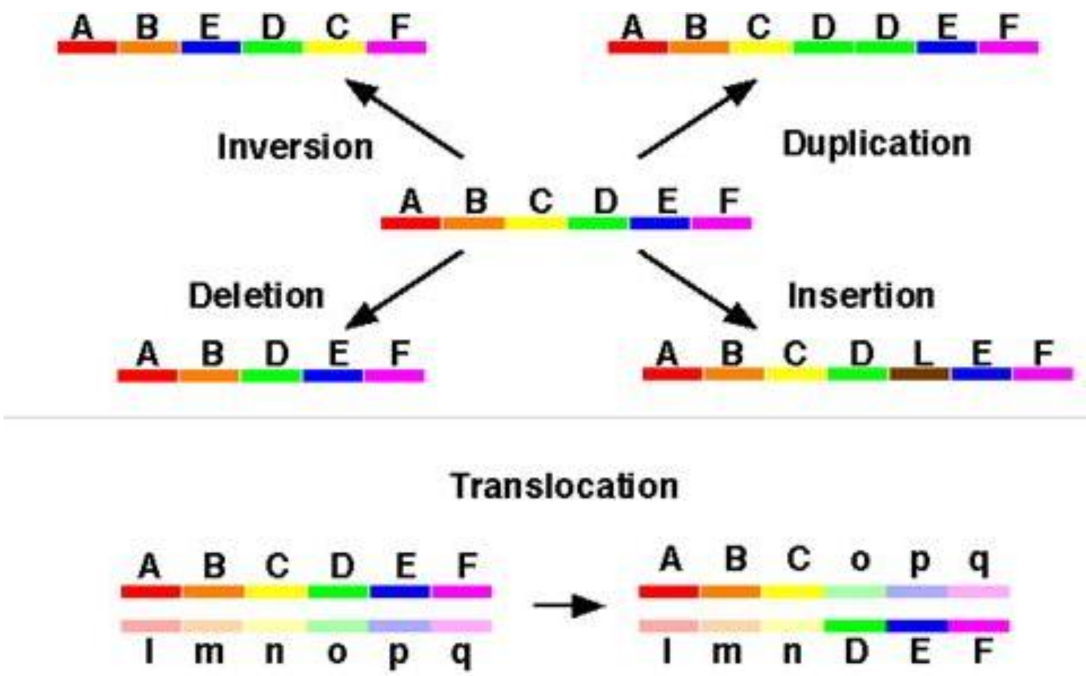
in the deletion of an exon from the mRNA transcribed from the gene. Retinitis pigmentosa - a degenerative disease of the retina - can be caused by mutations in at least 8 different genes.

6 Hemophilia - caused by mutations in two different genes for blood clotting proteins. The mutations can be base pair substitutions, small deletions, small duplications. Twenty percent of the cases of hemophilia A are caused by an inversion of a long sequence of bases within one of the genes. Huntington's disease - a fatal neurological disorder - is due to an excessive number of repeats of the sequence CAG - normal forms of the genes have 10 to 30 repeats, mutants have more than 75 Although most mutations are have deleterious effects on the 11 Although most mutations are have deleterious effects on the encoded protein some have beneficial effects and have been important in evolution FOXP2 - encodes a transcription factor - mutations in this gene can cause severe speech and language disorders. Humans differ from chimpanzees at two base pairs that result in nonsynonymous amino acid changes.

The amount of change in this gene is unusuallyg y y g g high relative to synonymous changes in the gene suggesting the gene may have been important in the evolution of human speech abilities. 12 7 Mutation rates can be estimated by their appearance in laboratory stocks or by counting the number of offspring born Estimating Mutation Rates in each generation with genetic disease caused by a dominant allele - these are likely to be underestimates of the frequency of point mutations because synonymous mutations result in the same phenotype as nonmutants. 13 Mutation rates can be estimated indirectly by counting the number of differences between two descendants of a common ancestor and counting the number of generations since their origin. This method assumes that no selection has been involved in the change in allele frequency with each species. Mutation rates can be estimated by assuming that deleterious mutations are removed by selection. The forward mutation rate (A a) is given the symbol μ. The reverse mutation rate (a A) is given the symbol.

The reverse mutation rate (a A) is given the symbol ν. Without mutation, deleterious dominant alleles should be removed by selection until they are absent from the μ A a ν 14 y y population. So the mutation rate is equal to the observed frequency of the deleterious dominant alleles (p) in the population. ν = p 8 Deleterious recessive mutations will be removed from the population very slowly once they become rare. The rate of removal is 2 2 spq Δ = p And, when the recessive allele is rare the p = f(A), q = f(a) Deleterious recessive alleles are reintroduced by mutation at rate μp So, in a population in which mutation adds the allele and selection removes it we should have 2 1 p − sq allele is rare the denominator is ~1. 2 μ p spq = 15 2 μ = sq If the deleterious recessive allele is lethal (s=1), the mutation rate is equal the observed frequency of homozygotes. Rates of mutation of individual base pairs are low but when summed over the entire genome the effect is considerable. With 1 6 i l i i h ff i 16 With 1.6 mutations per sexual generation in the effective genome, a population of 1 million humans will have 1.6 million new mutations in each generation. Although most will be deleterious or neutral, if only a small fraction were beneficial there would be considerable raw material for evolution. 9 Most mutations have little or no effect Mutations and Fitness on fitness. A few are beneficial and a few are very deleterious. 17 The effects of a mutation can vary among environments. An allele that increases fitness in a cool environment may decrease fitness in a warm environment.





The sickle-cell allele confers hig yg h fitness to the heterozygote where malaria is common but is neutral in heterozygotes where malaria is not common. Experiments with Drosophila showed that a mildly deleterious allele became up to 10 times more deleterious when populations were crowded and had fewer resources. 18 Thus, many alleles that have little or no effect on fitness in the current environment may be beneficial or harmful if the environment changes. For example, alleles for pesticide or antibiotic resistance may have little effect on fitness until the agent is applied.

The same is likely true for many other mutations. 10 The effects of slightly beneficial mutations in different genes can be combined to produce more adaptive combinations. Mutations in different individuals can be combi d i kl i l bined quickly in sexual species. In asexual species combination of mutations depends upon multiple independent mutations 19 within a genetic lineage.

Sex allows much faster adaptation through the rapid combination of slightly beneficial mutations. DDT resistance Changes in Karotype Karyotype - a description of the chromosomal constitution of and organism - number, size, shape, internal arrangement Changes in ploidy - the number of sets of chromosomes Aneuploidy - loss or gain of one or more chromosomes in a set -

this is usually deleterious because of genic imbalance- Down Syndrome in humans is the result of 3 copies of chromosome 21 - trisomy 21 Polyploidy - having one or more extra sets of chromosomes 2N diploid 3N triploid 4N tetraploid etc 20 - diploid, 3N - triploid, 4N - tetraploid, etc. Polyploid organisms can have problems with meiosis. An autopolyploid has multiple sets of chromosomes from the same species. An allopolyploid has multiple sets of chromosomes from different species.

11 An odd number of each set of chromosomes results in problems with synapsis and segregation . Many of the resulting cells receive an unbalanced (aneuploid) set of chromosomes. Aneuploid gametes 21 Aneuploid gametes produce aneuploid zygotes that usually have problems because of genic imbalance. Autopolyploids with even numbers of chromosomes can al d so produce aneuploid gametes.

22 12 Hybrid organisms receive two different sets of chromosomes, one from each parent species. They are usually sterile because differences in gene arrangements among chromosomes results in improper synapsis and aneuploid gametes. Duplication of Duplication of whole sets of chromosomes (allopolypoidy) may result in gametes that have balanced 23 have balanced sets of chromosomes. Allopolyploids with a diploid number of sets of chromosomes from each parent (2NA + 2NB) produce gametes that are euploid with one set of chromosomes from each parent (NA + NB). Such organisms are potentially interfertile or self-fertile but they can t' produce fertile offspring in backcrosses with either parent produce fertile offspring in backcrosses with either parent species.

Gamete (NA + NB) combined with gamete (NA) produces an allotriploid (2NA + NB) that produces unbalanced sets of genes in gametes. Thus, allopolyploids are reproductively isolated from each of 24 their parent species. They can only reproduce with other allopolyploids or through self-fertilization.

They are new species as soon as they are formed. Many species of plants and some animals are polyploid. At least 50% of all flowering plants are polyploid. 13 Chromosome rearrangements Breakage and reunion of chromosomes can change gene order or change the distribution of genes among chromosomes. Such changes generally have little or no effect on the phenotype of the org g qy anism.

Some rearrangements can have effects on the frequency of recombination and fertility. An inversion of gene order: ABCDEFG ABEDCFG results in a loop arrangement in the 25 arrangement in the chromosomes during synapsis A paracentric inversion is an inversion of a portion of a chromosome that does not include the centromere. In a heterozygote, synapsis of the genes within the inversion is only possible if one of the homologs forms a loop.

Cross-overs can occur within the inversion, but the chromatids involved in the cross-over will be genetically imbalanced and either be dicentric or acentric. They will have problems during 26 acentric. They will have problems during segregation and the gametes that receive them will not be viable. Only the non-recombinant chromatids will produce viable gametes - thus preserving the original gene combinations.

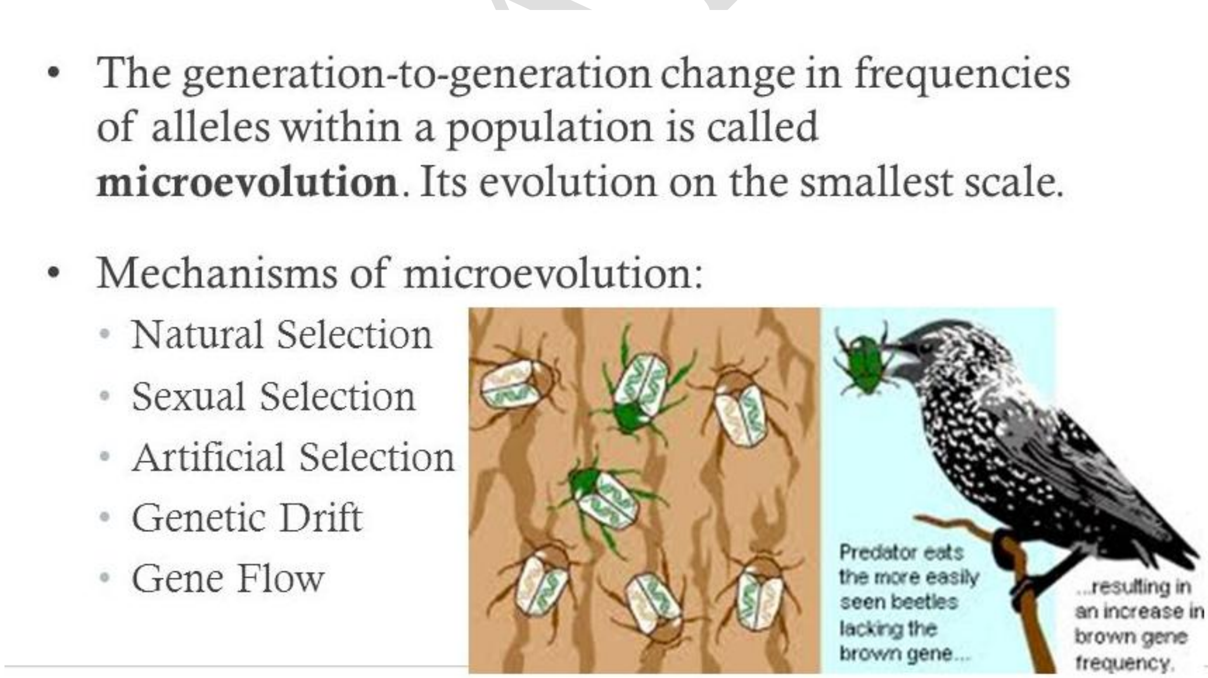
A pericentric inversion is an inversion of a portion of a chromosome that includes the centromere. In a heterozygote, synapsis of the genes within the inversion is only possible if one of the homologs forms a loop. Cross-overs can occur within the inversion, but the chromatids involved in the cross-over will be genetically imbalanced. They will have problems during segregation and the gametes that 27 during segregation and the gametes that receive them will not be viable. Only the non-recombinant chromatids will produce viable gametes - thus preserving the original gene combinations.

A translocation is a movement of genes from one chromosome to another. Reciprocal translocations involve a swap of genes between two chromosomes. A heterozygote for a reciprocal translocation is genetically balanced and viable, but during gamete production synapsis of the chromosomes produces a cross-shaped pattern. 28 15 At anaphase centromeres are pulled to opposite poles. There are three possible ways the centromeres can associate - alternate, adjacent-1, and adjacent-2.

Only alternate segregation will result in genetically balanced gametes. balanced gametes. Thus, the only viable gametes from a translocation heterozygote will have chromosomes identical in genetic constitution to the sets received from its parents. Thus, translocation heterozygotes will not exhibit independent assortment of these pairs of 29 independent assortment of these pairs of chromosomes.

This also preserves gene combinations. Translocation heterozygotes are partially sterile and this may form the basis for partial post-zygotic isolation between closely related species. Chromosome number can change through fission or fusion of chromosomes or pieces of chromosomes. 30 16 Karyotypic changes through fission and fusion can be dramatic. Such changes can be the cause of reproductive isolation between related species. 31 The karyotypes of primates differ by gene rearrangements within chromosomes (as shown by banding patterns) and difference in chromosome number due to fusion or fission of chromosomes.

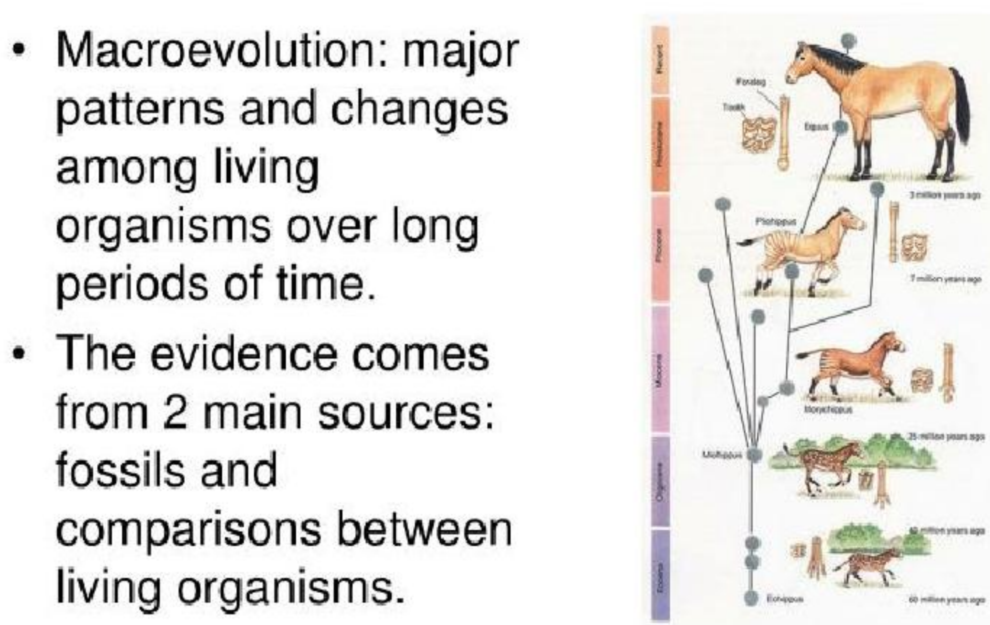
Microevolution:



Change in allele frequencies resulting from natural selection, genetic drift, gene flow, and mutation. Macroevolution: The large-scale patterns, trends, and rates of change among families and other more inclusive groups of species.

Macroevolution is evolution on a scale at or above the level of species, in contrast with microevolution which refers to smaller evolutionary changes of allele frequencies within a species or population. Macroevolution and microevolution describe fundamentally identical processes on different time scales.

The process of speciation may fall within the purview of either, depending on the forces thought to drive it. Paleontology, evolutionary developmental biology, comparative genomics and genomic phylostratigraphy contribute most of the evidence for macroevolution's patterns and processes



Possible questions

1. Give note son point mutation
2. What are the different types of chromosomal aberrations?
3. Elaborate RNA first hypothesis
4. What are genetic variations? Give examples
5. Define recombination and random assortment
6. Explain macroevolution
7. Write notes on recombination
8. What is polymorphism?
9. What are the causes of genetic variations?
10. Write short notes on no inheritable variations
11. Explain the role of variations in evolution?
12. Explain chromosomal aberrations

Natural selection as a guiding force – Its attributes and action Basic characteristics of natural selection. Colouration, camouflage and mimicry, Co-adaptation and co-evolution, Man-made causes of change – Industrial melanism; brief mention of drug, pesticide, antibiotic and herbicide resistance in various organisms. Modes of selection, Polymorphism, Heterosis and Balanced lethal systems. Genetic Drift

Forces of evolution

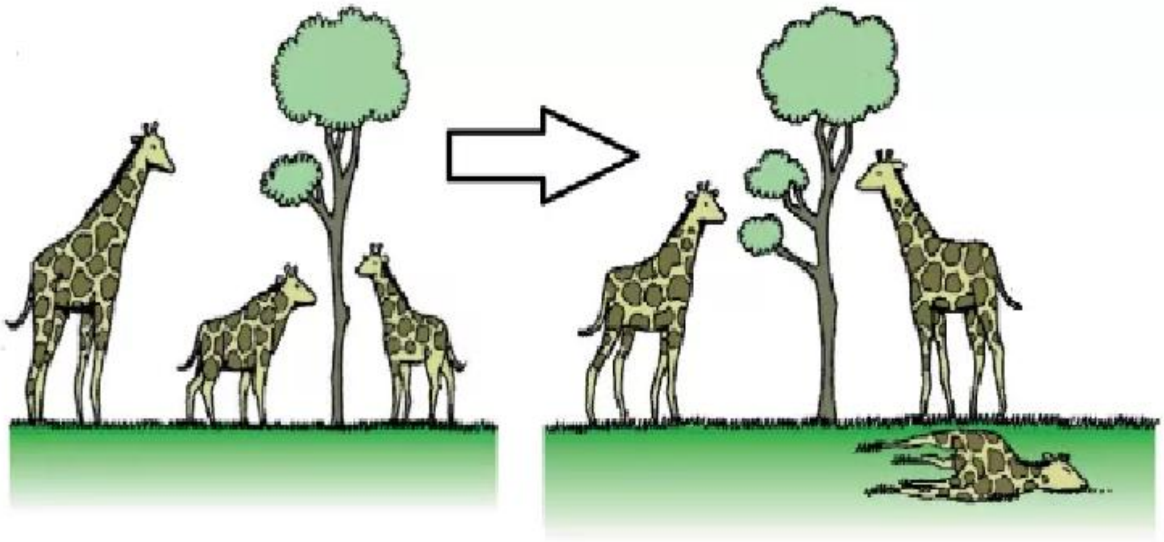
Natural Selection:

According to Darwin 'the fittest' forms that are allowed to survive are chosen by 'Natural Selection' (an imaginative concept which includes all real aspects of the natural environment that supports the life of organisms). The forces of natural selection will encourage only those that have suitable variations as adaptive features, to survive. Darwin designated them as 'fittest' forms. All other organisms having non adaptive or deleterious modifications shall be disqualified. Natural selection will eliminate such organisms from the populations. The selected group of modified individuals will occupy the next level in the evolutionary ladder. Darwin strongly believed that using the natural selection concept, all evolutionary processes in the living world can be explained. As an example he differed from the explanation provided by Lamarck while explaining the lengthening of neck in giraffe. According to Darwin the population of giraffes had individuals having varying neck lengths. Those that had longer necks had more survival value, since they had more food and remained healthy. Gradually natural selection encouraged them to survive. Thus in course of time the average length of the neck increased.

Objections to Darwinism

While the ideas of Darwin, related to reproductive capability, prevalence of variations, concept of struggle and survival of suitable forms are all commonly accepted, there are certain drawbacks in his original theory.

1. Darwin could not explain, the origin and cause for variations while insisting their importance in progressive evolution.
2. He overemphasized the importance of the 'fittest' organisms. During later periods it has been suggested that 'fit' and fitter forms can also exist along with the fittest.



3. As the principle of inheritance as explained in the later years were not available during Darwin’s time. Hence he believed in the theory of ‘pangenesis’. According to this concept from every organ in the body very minute such replicate structures will orginate. Later they are transferred to
the gonads for transmission to future generations.
4. ‘Over-specialization’ as in Irish deer and its consequent harmful effect on animals had not been accounted for by Darwin

The Evolution of Theory

The theory of evolution is one of the great intellectual revolutions of human history, drastically changing our perception of the world and of our place in it. Charles Darwin put forth a coherent theory of evolution and amassed a great body of evidence in support of this theory. In Darwin's time, most scientists fully believed that each organism and each adaptation was the work of the creator. Linneaus established the system of biological classification that we use today, and did so in the spirit of cataloguing God's creations.

In other words, all of the similarities and dissimilarities among groups of organisms that are the result of the branching process creating the great tree of life (*see Figure 1*), were viewed by early 19th century philosophers and scientists as a consequence of omnipotent design.

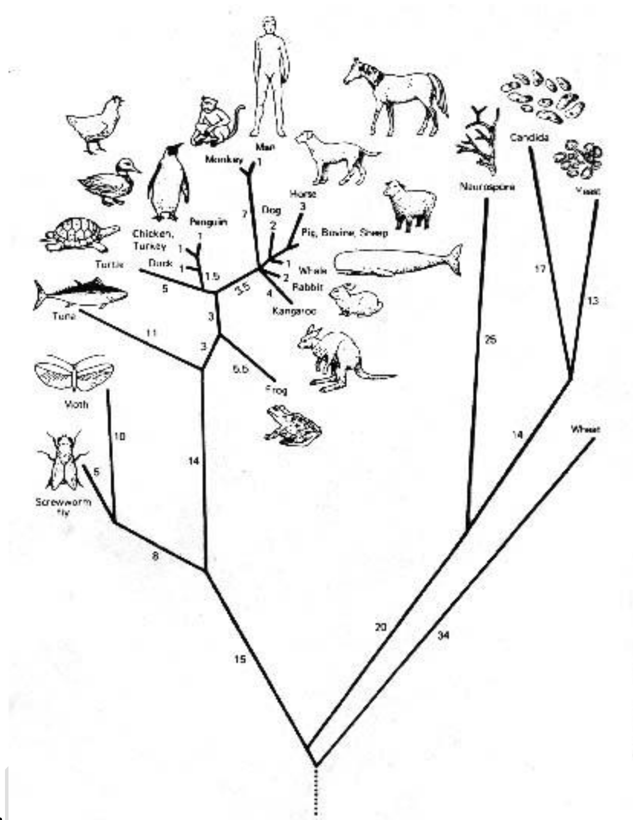


Figure: A phylogenetic "tree of life" constructed by computer analysis of cyochrome c molecules in the organisms shown; there are as many different trees of life as there are methods of analysis for constructing them

However, by the 19th Century, a number of natural historians were beginning to think of evolutionary change as an explanation for patterns observed in nature. The following ideas were part of the intellectual climate of Darwin's time.

- No one knew how old the earth was, but geologists were beginning to make estimates that the earth was considerably older than explained by biblical creation. Geologists were learning more about**strata**, or layers formed by successive periods of the deposition of sediments. This suggested a time sequence, with younger strata overlying older strata.

- A concept called **uniformitarianism**, due largely to the influential geologist Charles Lyell, undertook to decipher earth history under the working hypothesis that present conditions and processes are the key to the past, by investigating ongoing, observable processes such as erosion and the deposition of sediments.
- Discoveries of fossils were accumulating during the 18th and 19th centuries. At first naturalists thought they were finding remains of unknown but still living species. As fossil finds continued, however, it became apparent that nothing like giant dinosaurs was known from anywhere on the planet. Furthermore, as early as 1800, Cuvier pointed out that the deeper the strata, the less similar fossils were to existing species.
- Similarities among groups of organisms were considered evidence of relatedness, which in turn suggested evolutionary change. Darwin's intellectual predecessors accepted the idea of evolutionary relationships among organisms, but they could not provide a satisfactory explanation for how evolution occurred.
- Lamarck is the most famous of these. In 1801, he proposed organic evolution as the explanation for the physical similarity among groups of organisms, and proposed a mechanism for adaptive change based on the inheritance of acquired characteristics. He wrote of the giraffe:

"We know that this animal, the tallest of mammals, dwells in the interior of Africa, in places where the soil, almost always arid and without herbage, obliges it to browse on trees and to strain itself continuously to reach them. This habit sustained for long, has had the result in all members of its race that the forelegs have grown longer than the hind legs and that its neck has become so stretched, that the giraffe, without standing on its hind legs, lifts its head to a height of six meters."

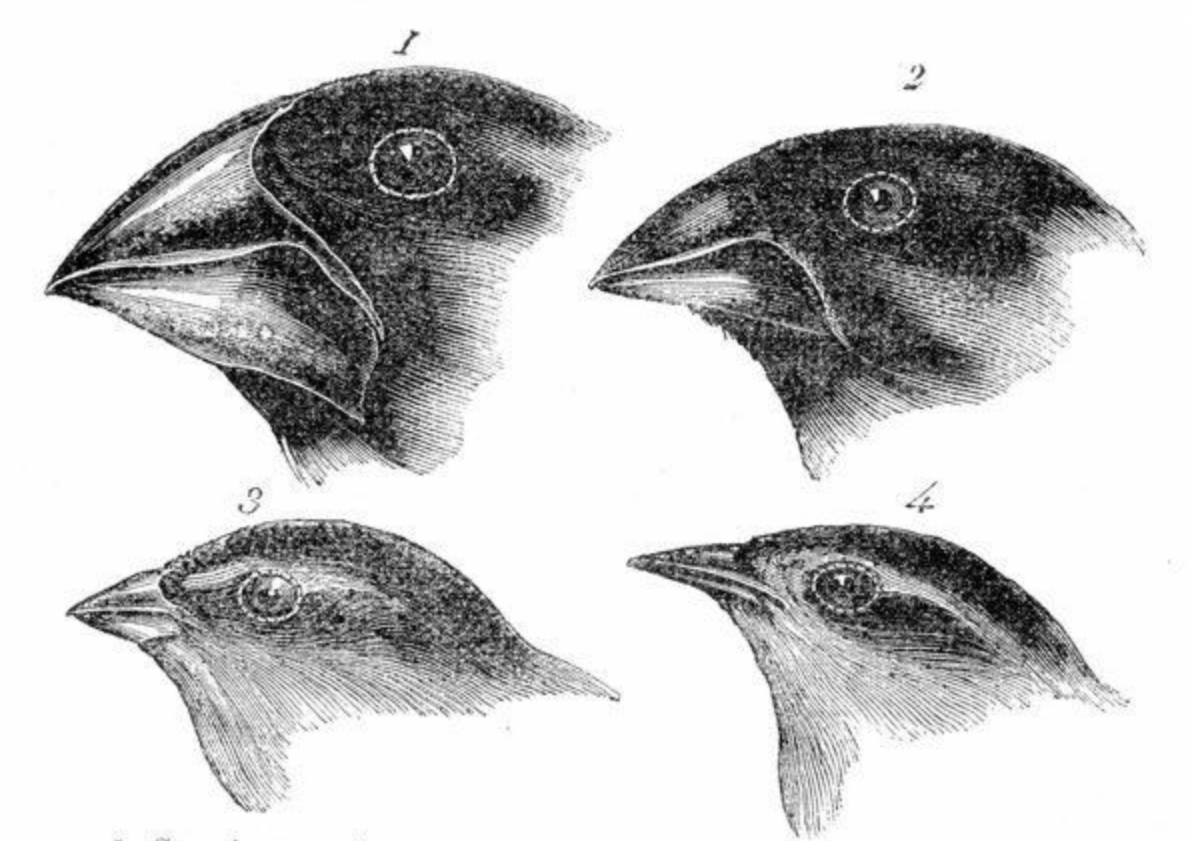
In essence, this says that the necks of Giraffes became long as a result of continually stretching to reach high foliage. Larmarck was incorrect in the hypothesized mechanism, of course, but his example makes clear that naturalists were thinking about the possibility of evolutionary change in the early 1800's.

- Darwin was influenced by observations made during his youthful voyage as naturalist on the survey ship *Beagle*. On the Galapagos Islands he noticed the slight variations that made tortoises from different islands recognizably distinct. He also observed a whole array of unique finches, the famous "Darwin's finches," that exhibited slight differences from island to island. In addition, they all appeared to resemble, but differ from, the common finch on the mainland of Ecuador, 600 miles to the east. Patterns in the distribution and similarity of organisms had an important influence of Darwin's thinking. The picture at the top of this page is of Darwin's own sketches of finches in his Journal of Researches.
- In 1859, Darwin published his famous *On the Origin of Species* by Means of Natural Selection, a tome of over 500 pages that marshalled extensive evidence for his theory. Publication of the book caused a furor - every copy of the book was sold the day that it was released. Members of the religious community, as well as some scientific peers, were outraged by Darwin's ideas and protested. Most scientists, however, recognized the power of Darwin's arguments. Today, school boards still debate the validity and suitability of Darwin's theory in science curricula, and a whole body of debate has grown up around the controversy (see the WWW site Talk.Origins for an ongoing dialogue). We do not have time to cover all of Darwin's evidence and arguments, but we can examine the core ideas. *What does this theory of evolution say?*

Darwin's Theory

Darwin’s theory of evolution entails the following fundamental ideas. The first three ideas were already under discussion among earlier and contemporaneous naturalists working on the “species problem” as Darwin began his research. Darwin’s original contributions were the mechanism of natural selection and copious amounts of evidence for evolutionary change from many sources. He also provided thoughtful explanations of the consequences of evolution for our understanding of the history of life and modern biological diversity.

- Species (populations of interbreeding organisms) change over time and space. The representatives of species living today differ from those that lived in the recent past, and populations in different geographic regions today differ slightly in form or



1. Geospiza magnirostris.
3. Geospiza parvula.
2. Geospiza fortis.
4. Certhidea olivasca.

- behavior. These differences extend into the fossil record, which provides ample support for this claim.

- All organisms share common ancestors with other organisms. Over time, populations may divide into different species, which share a common ancestral population. Far enough back in time, any pair of organisms shares a common ancestor. For example, humans shared a common ancestor with chimpanzees about eight million years ago, with whales about 60 million years ago, and with kangaroos over 100 million years ago. Shared ancestry explains the similarities of organisms that are classified together: their similarities reflect the inheritance of traits from a common ancestor.

- Evolutionary change is gradual and slow in Darwin's view. This claim was supported by the long episodes of gradual change in organisms in the fossil record and the fact that no naturalist had observed the sudden appearance of a new species in Darwin's time. Since then, biologists and paleontologists have documented a broad spectrum of slow to rapid rates of evolutionary change within lineages.

The primary mechanism of change over time is natural selection, elaborated below. This mechanism causes changes in the properties (traits) of organisms within lineages from generation to generation.

The Process of Natural Selection

Darwin's process of natural selection has four components.

1. Variation. Organisms (within populations) exhibit individual variation in appearance and behavior. These variations may involve body size, hair color, facial markings, voice properties, or number of offspring. On the other hand, some traits show little to no variation among individuals—for example, number of eyes in vertebrates.
2. Inheritance. Some traits are consistently passed on from parent to offspring. Such traits are heritable, whereas other traits are strongly influenced by environmental conditions and show weak heritability.
3. High rate of population growth. Most populations have more offspring each year than local resources can support leading to a struggle for resources. Each generation experiences substantial mortality.
4. Differential survival and reproduction. Individuals possessing traits well suited for the struggle for local resources will contribute more offspring to the next generation.

From one generation to the next, the struggle for resources (what Darwin called the "struggle for existence") will favor individuals with some variations over others and thereby change the frequency of traits within the population. This process is natural selection. The traits that confer an advantage to those individuals who leave more offspring are called adaptations.

In order for natural selection to operate on a trait, the trait must possess heritable variation and must confer an advantage in the competition for resources. If one of these requirements does not occur, then the trait does not experience natural selection. (We now know that such traits may change by other evolutionary mechanisms that have been discovered since Darwin's time.)

Natural selection operates by comparative advantage, not an absolute standard of design. "…*as natural selection acts by competition for resources, it adapts the inhabitants of each country only in relation to the degree of perfection of their associates*" (Charles Darwin, On the Origin of Species, 1859).

During the twentieth century, genetics was integrated with Darwin's mechanism, allowing us to evaluate natural selection as the differential survival and reproduction of genotypes, corresponding to particular phenotypes. Natural selection can only work on existing variation within a population. Such variations arise by mutation, a change in some part of the genetic code for a trait. Mutations arise by chance and without foresight for the potential advantage or disadvantage of the mutation. In other words, variations do not arise because they are needed.

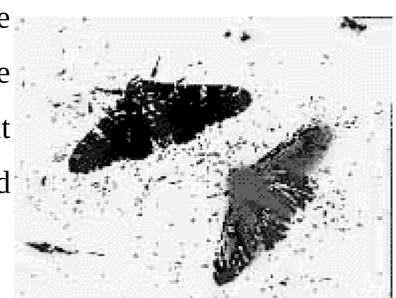
Evidence of Natural Selection

Let's look at an example to help make natural selection clear.

Industrial melanism is a phenomenon that affected over 70 species of moths in England. It has been best studied in the peppered moth, *Biston betularia*. Prior to 1800, the typical moth of the species had a light pattern (*see Figure 2*). Dark colored or melanic moths were rare and were therefore collectors' items.

Figure 2. Image of Peppered Moth

During the Industrial Revolution, soot and other industrial wastes darkened tree trunks and killed off lichens. The light-colored morph of the moth became rare and the dark morph became abundant. In 1819, the first melanic morph was seen; by 1886, it was far more common -- illustrating rapid evolutionary change.



Eventually light morphs were common in only a few locales, far from industrial areas. The cause of this change was thought to be selective predation by birds, which favored camouflage coloration in the moth.

In the 1950's, the biologist Kettlewell did release-recapture experiments using both morphs. A brief summary of his results are shown below. By observing bird predation from blinds, he could confirm that conspicuousness of moth greatly influenced the chance it would be eaten.

Recapture Success

	light moth	**dark moth**
non-industrial woods	14.6 %	4.7 %
industrial woods	13 %	27.5 %

Local Adaptation - More Examples

So far in today's lecture we have emphasized that natural selection is the cornerstone of evolutionary theory. It provides the mechanism for adaptive change. Any change in the environment (such as a change in the background color of the tree trunk that you roost on) is likely to lead to local adaptation. Any widespread population is likely to experience different environmental conditions in different parts of its range. As a consequence it will soon consist of a number of sub-populations that differ slightly, or even considerably.

The following are examples that illustrate the adaptation of populations to local conditions.

- The rat snake, *Elaphe obsoleta*, has recognizably different populations in different locales of eastern North America (*see Figure 3*). Whether these should be called geographic "races" or subspecies is debatable. These populations all comprise one species, because mating can occur between adjacent populations, causing the species to share a common gene pool

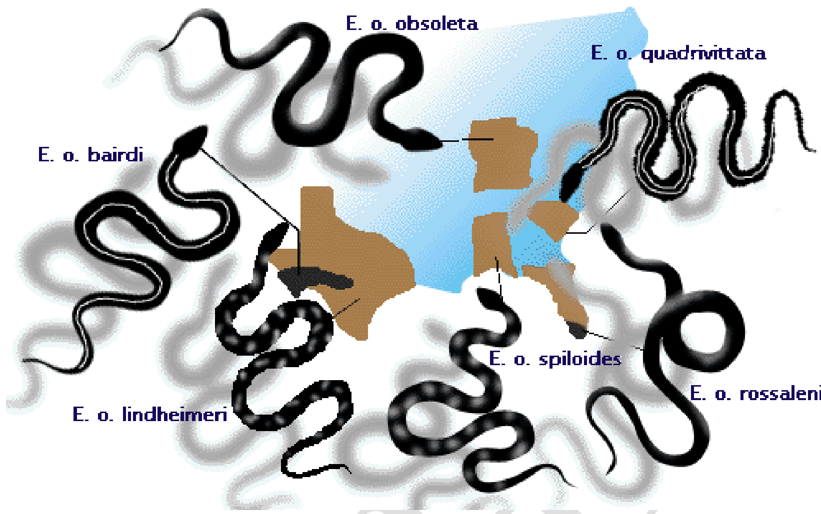
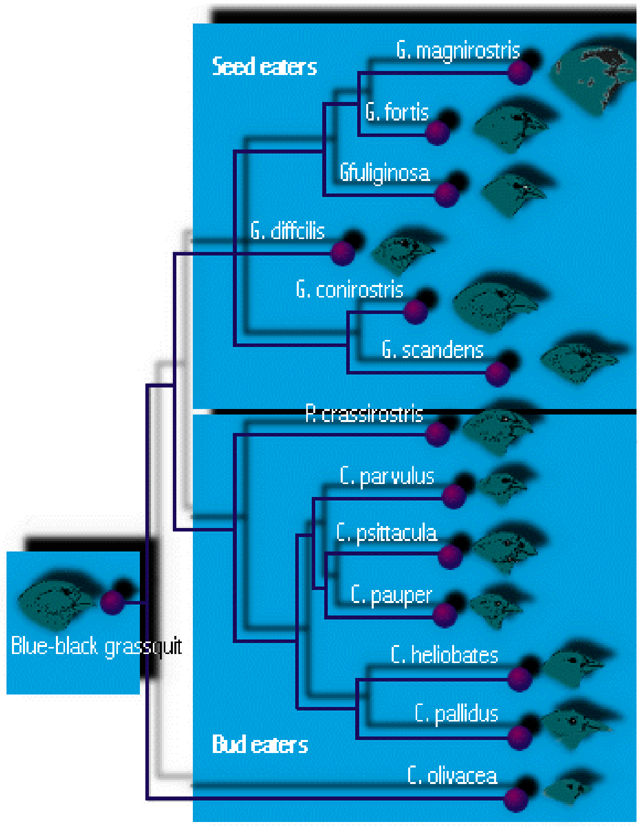


Figure : Subspecies of the rat snake Elaphe obsoleta, which interbreed where their ranges meet

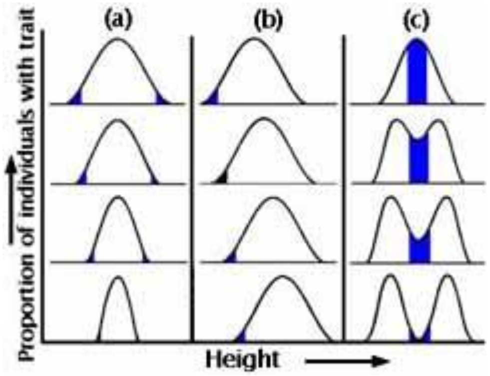
- Galapagos finches are the famous example from Darwin's voyage. Each island of the Galapagos that Darwin visited had its own kind of finch (14 in all), found nowhere else in the world. Some had beaks adapted for eating large seeds, others for small seeds, some had parrot-like beaks for feeding on buds and fruits, and some had slender beaks for feeding on small insects (*see Figure 4*). One used a thorn to probe for insect larvae in wood, like some woodpeckers do. (Six were ground-dwellers, and eight were tree finches.) (This diversification into different ecological roles, or **niches**, is thought to be necessary to permit the coexistence of multiple species, a topic we will examined in a later lecture.) To Darwin, it appeared that each was slightly modified from an original colonist, probably the finch on the mainland of South America, some 600 miles to the east. It is probable that adaptive radiation led to the formation of so many species because other birds were few or absent, leaving empty niches to fill; and because the numerous islands of the Galapagos provided ample opportunity for geographic isolation.



Stabilizing, Directional, and Diversifying Selection

Finally, we will look at a statistical way of thinking about selection. Suppose that each population can be portrayed as a frequency distribution for some trait -- beak size, for instance. Note again that variation in a trait is the critical raw material for evolution to occur.

What will the frequency distribution look like in the next generation?



First, the proportion of individuals with each value of the trait (size of beak, or body weight) might be exactly the same. Second, there may be directional change in just one direction. Third (and with such rarity that its existence is debatable), there might be simultaneous change in both directions (e.g. both larger and smaller beaks are favored, at the expense of those of intermediate size). Figures 5a-c capture these three major categories of natural selection.

Figures 5a-c

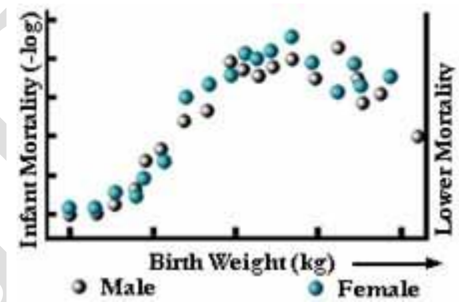
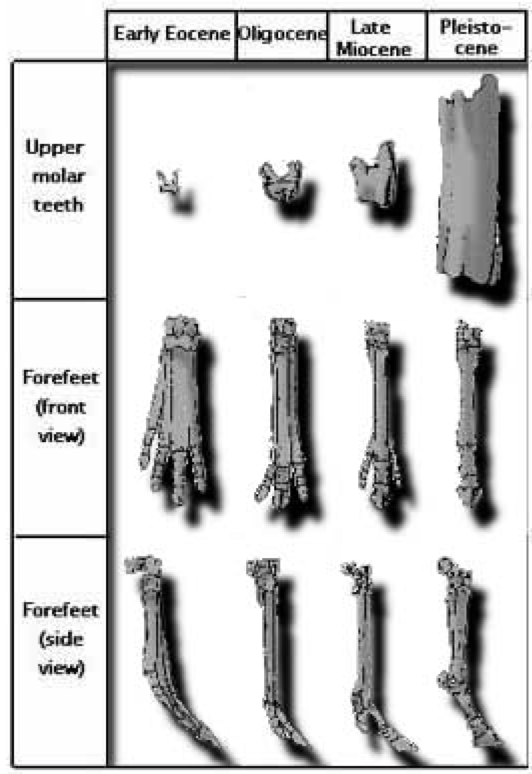


Figure 6

Under **stabilizing selection**, extreme varieties from both ends of the frequency distribution are eliminated. The frequency distribution looks exactly as it did in the generation before (*see Figure 5a*). Probably this is the most common form of natural selection, and we often mistake it for no selection. A real-life example is that of birth weight of human babies

Under **directional selection**, individuals at one end of the distribution of beak sizes do especially well, and so the frequency distribution of the trait in the subsequent generation is shifted from where it was in the parental generation . This is what we usually think of as natural selection. Industrial melanism was such an example.

The fossil lineage of the horse provides a remarkable demonstration of directional succession. The full lineage is quite complicated and is not just a simple line from the tiny dawn horse *Hyracotherium*of the early Eocene, to today's familiar *Equus*. Overall, though, the horse has evolved from a small-bodied ancestor built for moving through woodlands and thickets to its long- legged descendent built for speed on the open grassland. This evolution has involved well-documented changes in teeth, leg length, and toe structure (*see Figure 7*).



Under **diversifying (disruptive) selection**, both extremes are favored at the expense of intermediate varieties. This is uncommon, but of theoretical interest because it suggests a mechanism for species formation without geographic isolation

1. Explain natural selection
2. Discuss genetic drift with example
3. What is camouflage?
4. Elaborate the characteristics of natural selection
5. Explain co-adaptation and co evolution
6. Explain industrial melanism
7. Illustrate bottle neck effect
8. Explain the evolution of antibiotic and pesticide resistance
9. Define adaptation
10. Describe mimicry
11. Differentiate co-adaptation and co evolution
12. What is polymorphism?
13. What is a protocell model?
14. Describe survival of fittest
15. Define Parallelism of evolution
16. Define co-evolution

The Neo-Darwinian synthesis reco	natural selection and orthogenesi:	neo-Larmarckism and natural selection	genetics and mutationism	natural selection and genetics	natural selection and genetics
Your friend remarks, "The gira	Overproduction of offspring le:	Only favorable adaptations have survival value.	Characteristics acquired during	genes to its offspring	Characteristics acquired during a
Which of the following principl	Evolution is a gradual process t	Variation occurs among individuals in a population	Mutations are the ultimate sou	More individuals are born than	Mutations are the ultimate sou
The *more* closely related two d	more similar their habitats are	less similar their DNA sequences are	more recently they shared a co	less likely they are to have the :	more recently they shared a co
For a population in Hardy-Weir	increases with each generation	decreases with each generation until it reaches 25%	remains the same in every gen	increases due to the occurrenc	remains the same in every gene
An organism's *relative fitness* i	Mutation rate	Health and stability in the face of environmental change	Contribution to the gene pool c	Genetic variability	Mutation rate
Genomic studies of the chromc	Acquired Characteristics	Common Ancestry	Adaptive Radiation	Artificial Selection	Common Ancestry
What is the only factor that cai	gene flow	non-random mating	genetic drift	selection	selection
Hybridization between differer	polyploidy	gametic isolation	hybrid viability	mutation	polyploidy
The age of earth is estimate to b	a)10000 years old	b)4-5 billion years ago	c)600 million year old	d)10-20	b)4-5 billion years ago
Which one of the following are	a)Actinomycetes	b)Pseudomonas	c)Rickettisae	d)Methanogens	d)Methanogens
Formation of most amino acids .	a) Hugo de vries	b) Urey and Miller	c) Oparin and Haldane	d)Pasteur	b) Urey and Miller
The most primitive extant eukar	a)plasmodium	b)tetrahymena	c)chlamydomonas	d)Giardia	d)Giardia
Cambrian Explosion refers to	a) Origin of life	b)Origin of phyla	c) Origin of man	d)extinction of Dinosaurs	b)Origin of phyla
Which of the following stateme	a)Mitochondria DNA has a circ	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	c)mitochondrial genes code for	d)mitochondrial ribosomes are 7	c)mitochondrial genes code for e
Aerobic respiration is thought to	a)1.0-1.5bp	b) 2.0-2.5bp	c)3.0-3.5bp	d)3.5-4.0bp	b) 2.0-2.5bp
Which of the following process	a)exon shuffling	b)intron excisions	c)transposons insertions	d)DNA amplification	a)exon shuffling
The correct chronological seque	a) Devonian, Carboniferous, Cre	b) Eocene, Devonian, Carboniferous, Cretaceous	c) Devonian, Carboniferous, Eo	d) Carboniferous, Devonian, Cre	a) Devonian, Carboniferous, Cre
The extant bacterial group that i	a)purple photosynthetic bacteria	b)archaebacteria	c)cyanobacteia	d)methanogens	a)purple photosynthetic bacteria
The first domes cated animal by	a) Cat	b) Dog	c) Horse	d) Cow	b) Dog
Which of the following is an exa	a) Pinus	b) Riccia	c) Ginkgo	d) Gnetum	c) Ginkgo
First life on earth was	a) Cyanobacteria	b) Autographs	c) Chemoheterotrophs	d) Photoautotrophs	c) Chemoheterotrophs
Most abundant organic compou	a) Protein	b) Cellulose	c) Steroids	d) Lipids	b) Cellulose
Which is not a ves gial organ of	a) Nails	b) Third molar	c) Coccyx	d) Segmented muscles of abdon	a) Nails
Gene c dri7 operates only in	a) Large popula ons	b) Smaller popula ons	c) Island popula ons	d) Mendealian popula ons	b) Smaller popula ons
The animals of cold countries ha	a) Cope's law	b) Dollo's law	c) Bergmann's law	d) Allen's law	d) Allen's law
Phenomenon of 'Industrial mela	a) Geographical isola on	b) Natural Selec on	c) Reproduc ve isola on	d) Induced muta on	b) Natural Selec on
Convergent evolu on is illustrat	a) Rat and Dog	b) Bacterium and Protozoan	c) Starfish and Cu@le fish	d) Dogfish and Whale	d) Dogfish and Whale
Correct order is	a) Paleozoic-> Mesozoic-> Coe	b) Archaeozoic-> Coenozoic ->Paleozoic	c) Coenozoic ->Paleozoic-> Arc	d) Mesozoic-> Archaeozoic-> C	a) Paleozoic-> Mesozoic-> Coe
First life on earth was	a) cyanobacteria	b) autotrophs	c) photo autotrophs	d) chemoheterotrophs	d) chemoheterotrophs
One of the possible early source	a) green plants	b) carbon dioxide	c) chlorophyll	d) UV rays and lightening	d) UV rays and lightening
First experiment regarding evolu	a) Watson and Crick	b) Oparin and Haldane	c) Urey and Miller	d) Meselson and Stahl	c) Urey and Miller
Coacervates were formed by	a) DNA	b) radiations	c) polymerisation	d) polymerisation and aggregati	d) polymerisation and aggregatio
Miller and Urey performed an e	a) N and H O	b) H O and CH	c) CO and N	d) CH and N	b) H O and CH
According to Oparin, which one	a) methane	b) hydrogen	c) water vapour	d) oxygen	d) oxygen
Swan neck flask experiment wa	a) Oparin and Haldane	b) Darwin	c) Aristotle	d) Louis Pasteur	d) Louis Pasteur
Coacervates were experimentall	a) Urey and Miller	b) Jacob and Monad	c) Oparin	d) Fischer and Huxley	c) Oparin
Finding of Miller's experiment c	a) theory of special creation	b) theory of biogenesis	c) theory of abiogenesis	d) theory of organic evolution	c) theory of abiogenesis
Theory of abiogenesis was put f	a) Spallanzani	b) F.Redi	c) Van Helmont	d) Pasteur	c) Van Helmont
A species inhabiting different ge	a) sympatric	b) allopatric	c) sibling	d) biospecies	b) allopatric
According to De Vries theory, e	a) jerky	b) discontinuous	c) continuous and smooth	d) both a and b	d) both a and b
Mutation may be described as	a) Continuous genetic variation	b) Phenotypic change	c) Discontinuous genetic variati	d) change due to hybridisation	c) Discontinuous genetic variatic
The theory of use and disuse wa	a) Stebbins	b) Lamarck	c) Aristotle	d) Vavilox	b) Lamarck
The evolution of a species is bas	a) natural selection	b) isolation	c) speciation	d) human conservation	b) isolation
Genetic drift is on account of	a) variations	b) mutation	c) increase in population	d) decrease in population	d) decrease in population
According to Neo- Darwinism,	a) Fighting between organisms	b) Variations	c) Killing weaker organism	d) Differential reproduction	d) Differential reproduction
Sympatric speciation develops r	a) Geographic barrier	b) barrier to mating	c) barrier to gene flow	d) genetic change	a) Geographic barrier
Quick change in phenotypes in a	a) Founder effect	b) Genetic bottle neck	c) Genetic grift	d) Gene flow	a) Founder effect
Genetic drift is found in	a) Small population with or witl	b) large population with random mating	c) plant population	d) animal population	a) Small population with or with
Which is related to reproduce is	a) genetic isolation	b)temporal isolation	c) behavioural isolation	d) all of these.	d) all of these.
In which condition gene ratio re	a) gene flow	b) mutation	c) random mating	d) sexual selection	c) random mating
Lamarck theory of organic evol	a) Natural selection	b) Inheritance of acquired characters	c) Descent with change	d) continuity of fermplasm	b) Inheritance of acquired charac
Which one is used for knowing	a) Degree of evolution	b) Genetic drift	c) Proportion between acquired	d) Hardy Weinberg equation	d) Hardy Weinberg equation
Balancing selection is concernec	a) Homozygous recessives	b) homozygous indivduals	c) heterozygous individuals	d) all of the above	c) heterozygous individuals
During which geological period	a) Orosirian period	b) Ediacaran period	c) Devonian period	d) Ordovician period	a) Orosirian period
The first green plants and fungi	a) Ediacaran period	b) Devonian period	c) Orosirian period	d) Ordovician period	d) Ordovician period
Flowering plants first appeared	a) Jurassic period	b) Carboniferous period	c) Cretaceous period	d) Silurian	c) Cretaceous period
The present epoch in the Earth's	a) Holocene	b) Miocene	c) Pleistocene	d) Pliocene	a) Holocene
A method for constructing phyloge	cladistics	phenetics	polyphenetics	numerology	phenetics
A species that changes morphology	evolutionary species	chronospecies	living fossil	stagnant species	chronospecies
Unit II					
According to Oparin, which one	a) methane	b) hydrogen	c) water vapour	d) oxygen	d) oxygen
Swan neck flask experiment wa	a) Oparin and Haldane	b) Darwin	c) Aristotle	d) Louis Pasteur	d) Louis Pasteur
Coacervates were experimentall	a) Urey and Miller	b) Jacob and Monad	c) Oparin	d) Fischer and Huxley	c) Oparin
Finding of Miller's experiment c	a) theory of special creation	b) theory of biogenesis	c) theory of abiogenesis	d) theory of organic evolution	c) theory of abiogenesis
Theory of abiogenesis was put f	a) Spallanzani	b) F.Redi	c) Van Helmont	d) Pasteur	c) Van Helmont
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Quick change in phenotypes in a	a) Founder effect	b) Genetic bottle neck	c) Genetic grift	d) Gene flow	a) Founder effect
Genetic drift is found in	a) Small population with or witl	b) large population with random mating	c) plant population	d) animal population	a) Small population with or with
Which is related to reproduce is	a) genetic isolation	b)temporal isolation	c) behavioural isolation	d) all of these.	d) all of these.
In which condition gene ratio re	a) gene flow	b) mutation	c) random mating	d) sexual selection	c) random mating
Lamarck theory of organic evol	a) Natural selection	b) Inheritance of acquired characters	c) Descent with change	d) continuity of fermplasm	b) Inheritance of acquired charac
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Balancing selection is concernec	a) Homozygous recessives	b) homozygous indivduals	c) heterozygous individuals	d) all of the above	c) heterozygous individuals
During which geological period	a) Orosirian period	b) Ediacaran period	c) Devonian period	d) Ordovician period	a) Orosirian period
The first green plants and fungi	a) Ediacaran period	b) Devonian period	c) Orosirian period	d) Ordovician period	d) Ordovician period
Flowering plants first appeared	a) Jurassic period	b) Carboniferous period	c) Cretaceous period	d) Silurian	c) Cretaceous period
The present epoch in the Earth's	a) Holocene	b) Miocene	c) Pleistocene	d) Pliocene	a) Holocene
The rise of human civiliza#on is	a) Holocene	b) Pleistocene	c) Pliocene	d) miocene	a) Holocene
Which geological period in the a	a) Orosirian period	b) Devonian period	c) Ediacaran period	d) Ordovician period	b) Devonian period
As per the latest radiometric da	a) 4 billion years	b) 4.54 billion years	c) 4.45 billion years	d) 4.64 billion years	b) 4.54 billion years
During which period in the age	a) Pleistocene period	b) Jurassic period	c) Carboniferous period	d) cretaceous	c) Carboniferous period
First birds and lizards appeared	a) Jurassic period	b) Carboniferous period	c) Pleistocene period	d) cretaceous	a) Jurassic period
Angiosperm originated during	a) upper cretaceous	b) lower Jurassic	c) mid cretaceous	d) carboniferous	c) mid cretaceous
During evolu#on the first mul#c	a) 1 billion years ago	b) 2 billion	c) 600 million	d) 200 millions	a) 1 billion years ago
Maximum diversity of rep#les v	a) Jurassic	b) Ordovician	c) Triassic	d) Cretaceous	d) Cretaceous
Which of the following stateme	a)Mitochondria DNA has a circ	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	c)mitochondrial genes code for	d)mitochondrial ribosomes are 7	c)mitochondrial genes code for e
A method for constructing phylo	cladistics	phenetics	polyphenetics	numerology	phenetics
A species that changes morphol	evolutionary species	chronospecies	living fossil	stagnant species	chronospecies
Mutation may be described as	a) Continuous genetic variation	b) Phenotypic change	c) Discontinuous genetic variati	d) change due to hybridisation	c) Discontinuous genetic variatic
Genetic drift is found in	a) Small population with or witl	b) large population with random mating	c) plant population	d) animal population	a) Small population with or with
Which of the following is the m	Egg	Sperm	Primary Oocyte	All of the above	Sperm
Normal mammalian gametes are	Haploid	Monoploid	Tetraploid	Both A & B	Both Haploid and Monoploid
The male sex organs and female	Ovaries	Govarestes	Testes	Gonads	Gonads
Which of the following describe	Transcription	Translation	Replication	All of the above	Replication
The yolky side of an egg is calle	Animal side	Vegetal side	Vegetable side	Vegan side	Vegetal side
______ is the process of structu	Spermatogenesis	Spermiogenesis	Spermatoformicon	All of the above	Spermatogenesis
Oocytes that are discarded in th	Antigens	Epitopes	Non-polar bodies	Polar bodies	Polar bodies
The correct order of the stages	Fertilization-->Gametogenesis--	Gametogenesis-->Fertilization-->Blastulation-->Gastrulation	Fertilization-->Gametogenesis--	Gametogenesis-->Fertilization--	Gametogenesis-->Fertilization-->
Cytoplasmic tunnels between ce	Chorionomeres	Cytochannels	Gap Junctions	Ring canals	Ring canals
The tissue layer with loosely pa	Mezzanine	Monoploid	Mesenchyme	Stepintyme	Mesenchyme
The imaginal discs of drosophila	Gonads	Eyes	Legs	All of the above	All of the above
Pigment granules in amphibian e	Animal	Vegetable	Mineral	Vegetal	Animal
Which structure of the amphibia	Dorsal lip	Blastopore	Ventral lip	Blastocoelum	Dorsal lip
The cells in an amphibian blastu	early blastula stage	mid blastula stage	late blastula stage	post-modern blastula stage	late blastula stage
The placenta is NOT responsible	Excretion	Gas exchange	Nutrition supply	Hormone production	Hormone production
The default state of ectoderm is	skin tissue	cartilage tissue	vascular tissue	neural tissue	Neural tissue
Which of the following is an end	Kidneys	Heart	Pancreas	Muscle	pancreas
The first blood and vascular tiss	As extraembryonic blood island	By the process of angiogenesis	As embryonic blood islands nea	As a maternal mesoderm comin	As extraembryonic blood island
Which animal served as a usefu	Grouse	Quail	Peacocks	Snakes	Quail
The anterior-most region of the	Stomach region	Cloacal region	Pharyngeal region	Pancreal reagion	Pharyngeal region
Which of the following is the ho	Ecdyson	Thyroxin	Juvenile Hormone	Pax 6	Juvenile Hormone
The normal function of the prom	Bind the small subunit of the ril	Serve as an origin of replication	Serve as an acceptor for transfe	Serve as a binding site for RNA	Serve as a binding site for RNA
For some traits (such as birth	diversifying selection	directional selection	adaptive radiation	stabilizing selection	stabilizing selection

How does artificial selection produce rapid changes in the phenotype of organisms?	by changing the frequency of al	by stimulating the species to increase the production of new mutations	by changing the number of chro	by selecting only dominant geno	by changing the frequency of all
How does natural selection affe	Under conditions of high select	Natural selection does not affect the frequency of mutations	All mutations increase when sel	When there is no selection press	Natural selection does not affect

UNIT III

Which of the following is an exa	a) Pinus	b) Riccia	c) Ginkgo	d) Gnetum	c) Ginkgo
First life on earth was	a) Cyanobacteria	b) Autographs	c) Chemoheterotrophs	d) Photoautotrophs	c) Chemoheterotrophs
Most abundant organic compou	a) Protein	b) Cellulose	c) Steroids	d) Lipids	b) Cellulose
Which is not a ves gial organ of	a) Nails	b) Third molar	c) Coccyx	d) Segmented muscles of abdon	a) Nails
Gene c dri7 operates only in	a) Large popula ons	b) Smaller popula ons	c) Island popula ons	d) Mendealian popula ons	b) Smaller popula ons
The animals of cold countries ha	a) Cope's law	b) Dollo's law	c) Bergmann's law	d) Allen's law	d) Allen's law
Phenomenon of 'Industrial mela	a) Geographical isola on	b) Natural Selec on	c) Reproduc ve isola on	d) Induced muta on	b) Natural Selec on
Convergent evolu on is illustrate	a) Rat and Dog	b) Bacterium and Protozoan	c) Starfish and Cu@le fish	d) Dogfish and Whale	d) Dogfish and Whale
Correct order is	a) Paleozoic-> Mesozoic-> Coe	b) Archaeozoic-> Coenozoic ->Paleozoic	c) Coenozoic ->Paleozoic-> Arc	d) Mesozoic-> Archaeozoic-> C	a) Paleozoic-> Mesozoic-> Coen
First life on earth was	a) cyanobacteria	b) autotrophs	c) photo autotrophs	d) chemoheterotrophs	d) chemoheterotrophs
One of the possible early source	a) green plants	b) carbon dioxide	c) chlorophyll	d) UV rays and lightening	d) UV rays and lightening
First experiment regarding evolu	a) Watson and Crick	b) Oparin and Haldane	c) Urey and Miller	d) Meselson and Stahl	c) Urey and Miller
Coacervates were formed by	a) DNA	b) radiations	c) polymerisation	d) polymerisation and aggregati	d) polymerisation and aggregatio
Miller and Urey performed an e	a) N and H O	b) H O and CH	c) CO and N	d) CH and N	b) H O and CH
According to Oparin, which one	a) methane	b) hydrogen	c) water vapour	d) oxygen	d) oxygen
Which one of the following are	a)Actinomycetes	b)Pseudomonas	c)Rickettisae	d)Methanogens	d)Methanogens
Formation of most amino acids	a) Hugo de vries	b) Urey and Miller	c) Oparin and Haldane	d)Pasteur	b) Urey and Miller
The most primitive extant eukar	a)plasmodium	b)tetrahymena	c)chlamydomonas	d)Giardia	d)Giardia
Cambrian Explosion refers to	a) Origin of life	b)Origin of phyla	c) Origin of man	d)extinction of Dinosaurs	b)Origin of phyla
Which of the following stateme	a)Mitochondria DNA has a circ	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	c)mitochondrial genes code for	d)mitochondrial ribosomes are 7	c)mitochondrial genes code for e
Aerobic respiration is thought to	a)1.0-1.5bp	b) 2.0-2.5bp	c)3.0-3.5bp	d)3.5-4.0bp	b) 2.0-2.5bp
Which of the following process	a)exon shuffling	b)intron excisions	c)transposons insertions	d)DNA amplification	a)exon shuffling
The correct chronological seque	a) Devonian, Carboniferous, Cre	b) Eocene, Devonian, Carboniferous, Cretaceous	c) Devonian, Carboniferous, Eo	d) Carboniferous, Devonian, Cre	a) Devonian, Carboniferous, Cre
The extant bacterial group that i	a)purple photosynthetic bacteria	b)archaebacteria	c)cyanobacteia	d)methanogens	a)purple photosynthetic bacteria
The first domes cated animal by	a) Cat	b) Dog	c) Horse	d) Cow	b) Dog
The normal function of the pron	Bind the small subunit of the rib	Serve as an origin of replication	Serve as an acceptor for transfe	Serve as a binding site for RNA	Serve as a binding site for RNA
Protein molecules are polymers	DNA moelcule	Amino acid molecules	Fatty acid molecules	Sucrose moelcules	Amino acid molecules
The peptide bond is -----	A covalent joing simple sugars	A covalent bond joining nucleotides together to form a nucleic acid	A hydrogen bond joing nucleotid	A covalent bond joining aminoac	A covalent bond joining aminoac
In prokaryotes, the ribosomal bi	Hogness sequence	Shine-Dalgarno sequence	Pribnow Sequence	TATA box	Shine-Dalgarno sequence
During translation, the role of en	transfer of phosphate group	amino acid activation	peptide bond formation between	binding of ribosome subunits to	peptide bond formation between
Polysomes are	Aggregation of ribosomes	aggregation of lysosomes	mRNA molecules to which man	a strech of tRNA assemblies	mRNA molecules to which man
Translation is the	Synthesis of DNA from a mRN	Synthesis of protein from a mRNA template	Synthesis of RNA from a mRN	Synthesis of RNA from a DNA	Synthesis of protein from a mRN
During translation, proteins are s	by ribosomes using the informa	by lysosome using the information on DNA	by ribosomes using the informat	by ribosomes using the informat	by ribosomes using the informat
The enzyme involved in amino a	ATP synthetase	aminoacyl tRNA synthetase	aminoacyl mRNA synthetase	aminoacyl rRNA synthetase	aminoacyl tRNA synthetase
Which of the following RNA m	rRNA	mRNA	tRNA	tRNA and mRNA	tRNA
In eukaryotes, translation is initi	Pribnow box	Hogness box	5' CAP	poly A tail	5' CAP
Which is the energy rich molecu	ATP synthetase	GTP	CTP	AMP	GTP
Which of the following best exp	DNA makes RNA makes Prote	RNA makes DNAmakes Proteins	DNA makes proteins makes RN	Protein makes DNA makes RNA	DNA makes RNA makes Protei
Many primary transcripts of nor	translated	polyadenylated	processed	replicated	processed
RNA polymerase used for the tr	rRNA	DNA	RNA	mRNA	DNA
Which of the following stateme	Transcription but not translation	Bacterial non coding RNAs mus t be processed by cleavage to form functional molecules	The regulation of the transcripti	Linking of exons must precede t	Transcription but not translation
Regarding RNA polymerase in I	The holoenzyme is used to synt	The holoenzyme consists of five subunits including σ, while the core enzyme lacks σ	The core enzyme and not the ho	The holoenzyme binds to DNA	The holoenzyme consists of five
RNA polymerase II transcribes	rRNAs	proteins	snRNAs	miRNAs	rRNAs
The recognition sequence to wh	downstream of the promoter ta	b)upstream of the gene to be transcribed	withinthe first intron	downstream of the transcription	upstream of the gene to be transc
Which of the following best des	An element that promotes term	A regulatory protein that accelerates mRNA turnover	A specific target sequence to wh	An extracellular environmental i	A specific target sequence to wh
Some eukaryotic promoters con	the TATA box	the pribnow box	an initiator (Inr) sequence	an inverted repeat	an initiator Inr sequence
"Null" genes are characterized b	transcription by RNA polymera	possession of neither TATA box nor an Inr sequence	Invariable start position of trans	inability to be transcribed	possession of neither TATA box
Fossil specimens are often class	biological species concept	typological species concept	phylogenetic species concept	morphospecies concept	morphospecies concept
Examples of behavioral isolatio	habitat selection	different mating seasons	species specific courtship displa	competition	species specific courtship display
Darwin was influenced by readi	stasis	uniformitarianism	gradualism	habitat selection	growth
Which of the following would y	Guppies would become more co	Guppies would become less colorful	Guppies would not change in co	Guppies would evolve to have f	Guppies would become more co
What determines which traits w	Mendelian genetics of the trait	random mutations in the trait	the species in which the trait oc	the fit of the trait to the environ	the fit of the trait to the environ
Natural selection is BEST descr	able to generate new traits that l	increasing the perfection of a species	working on existing variation of	causing the death of a significan	working on existing variation of
Which of these actually evolves	individuals	populations	communities	mutations	populations
In a population of 50 squirrels o	0.15	0.25	0.3	0.55	0.55
If the weather in Richmond, Vir	The cold weather would cause a	If a mutation occurred which caused white fur to develop, such white squirrels would have a better chance to survive and produce	Evolution would definitely occu	Natural selection would cause a	If a mutation occurred which cau
Which of the following is NOT	Plants with thorns are less likely	Bacterial populations in hospitals develop resistance to drugs used to combat infection by them	Scientists breed cows that give g	Fruit fly larvae with an enzyme	Scientists breed cows that give g
For some traits (such as birth weight in mammals), natural selection favors individuals that are average and the extremes are selected against. This is known as	diversifying selection	directional selection	adaptive radiation	stabilizing selection	stabilizing selection
How does artificial selection produce rapid changes in the phenotype of organisms?	by changing the frequency of al	by stimulating the species to increase the production of new mutations	by changing the number of chro	by selecting only dominant geno	by changing the frequency of all
How does natural selection affe	Under conditions of high select	Natural selection does not affect the frequency of mutations	All mutations increase when sel	When there is no selection press	Natural selection does not affect

Unit IV

Which of the following is the ho	Ecdyson	Thyroxin	Juvenile Hormone	Pax 6	Juvenile Hormone
The normal function of the pron	Bind the small subunit of the rib	Serve as an origin of replication	Serve as an acceptor for transfe	Serve as a binding site for RNA	Serve as a binding site for RNA
Protein molecules are polymers	DNA moelcule	Amino acid molecules	Fatty acid molecules	Sucrose moelcules	Amino acid molecules
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Polysomes are	Aggregation of ribosomes	aggregation of lysosomes	mRNA molecules to which man	a strech of tRNA assemblies	mRNA molecules to which man
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During translation, proteins are s	by ribosomes using the informa	by lysosome using the information on DNA	by ribosomes using the informat	by ribosomes using the informat	by ribosomes using the informat
The enzyme involved in amino a	ATP synthetase	aminoacyl tRNA synthetase	aminoacyl mRNA synthetase	aminoacyl rRNA synthetase	aminoacyl tRNA synthetase
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The recognition sequence to wh	downstream of the promoter ta	b)upstream of the gene to be transcribed	withinthe first intron	downstream of the transcription	upstream of the gene to be transc
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"Null" genes are characterized b	transcription by RNA polymera	possession of neither TATA box nor an Inr sequence	Invariable start position of trans	inability to be transcribed	possession of neither TATA box
The conversion of a clsoed rpon	the activity of alternative prom	hydrogen bond breakage of base pairs around the initiation site	a G-C rich sequence around to t	strong interaction between the c	hydrogen bond breakage of base
An improtant difference betwee	only prokaryotic genes use upst	only eukaryotic RNA polymerase possess a σ subunit	eukaryotic promoters indirectly	d)only prokaryotes cells alter th	eukaryotic promoters indirectly r
Each time a ribonucleotide is ad	deoxy ribonucleotide	sugar-base component	c)pyrophosphate	phosphate	pyrophosphate
The 5'end of mRNAs made by F	7-MeGppNpN	7-MeGpppNpN	pppN-7MeGppppNpN	pppNpN	7-MeGpppNpN
The formation of hairpin loops a	stabilization of DNA:RNA pair	activation of poly (polymerase	a reduction in base pairing betw	Rho-dependent activation of tra	a reduction in base pairing betw
Which of the following stateme	The poly (tail is located at the	The poly (tract is transcribed from the DNA template	poly (tails are found on transcri	Tissue specific gene expression	The poly (tract is transcribed fro
Translation occurs in the	nucleus	cytoplasm	nucleolus	lysosome	cytopalsm
What is the main function of tRI	inhibits protein synthesis	proof reading	identifies amino acids and trans	promoter binding	identifies amino acids and trans
Which site of tRNA molecule h	codon	anticodon	5, ends of the tRNA molecule	3' ends of the tRNA molecule	anticodon
In the context of prokaryotic ge	A cluster of genes that are rqgu	A DNA-binding protein that regulates gene expression	A non-coding regulatory DNA s	A non-coding regulatory DNA	A non-coding regulatory DNA s
In terms of lac operon regulatio	Both CAP and the lac represso	CAP is bound to the DNA but the lac repressor is not	Lac repressor is bound to the D	d)Neither CAP nor the *lac repr*	Neither CAP nor the lac represso
In the Ames test:	mutagens cause lethal mutation	Mutagens cause mutations that disrupt the ability of the cell to produce histidine	Mutagens will cause an increas	only mutagens that cause transit	Mutagens will cause an increas
Which of the following forms o	Direct DNA repair	Base excision repair	Nucleotide excision repair	Mismatch repair	Direct DNA repair
Why is alkyltransferase only abl	The protein is hydrolyzed in the	The protein is chemically changed by the addition of a methyl group	The protein becomes attached to	Inability to bind to another regio	The protein is chemically change
how does recombinational repai	Unlike NER, recombinational r	NER replaces the thymine dimer while recombinational repair leaves it in place	NER requires DNA polymerase	NER involves nick translation, w	NER replaces the thymine dimer
A point mutation that replaces a	Transition	Transversion	c)Nonsense	Missense mutation	Transition
A point mutation that involves a	Transition	Transversion	Nonsense	Silent mutation	Transversion
A change in a DNA sequence th	Transition	Transversion	Nonsense	silent mutation	silent mutation
An alteration in a nucleotide seq	Transition	Transversion	missense	Silent mutation	missense
An alteration to the normal cher	Transition	Transversion	c)Lesion	Missense mutation	Lesion
5-bromouracil is an analog of ---	Thymine	Guanine	cytosine	Uracil	Thymine
All transposons encode a ----wh	DNA glycosylase	Excisionase	Transposase	d)integrase	Transposase
Small DNA sequences that can	Exons	introns	LTRs	Transposons	Transposons
In base excision repair, the lesio	DNA glycosylase	Transposase	Excisionsase	DNA polymerase	DNA glycosylase
The exchange of non homologu	IS elements	Illegitimate recombination	Retrotransposons	RecA	RecA
Cyclobuitane pyrimidine dimers	Exonuclease	DNA photolyases	Transposases	DNA polymerase	DNA photolyases
The dispersed repetitive sequen	Transposition	homologus recombination	site specific recombination	General recombination	Transposition

The enzyme of E.Coli is a nucle	RNA polymerase	b)DNA polymerase	RecBCD	DNA ligase	RecBCD
Which of the following DNA m	Transition	Transversion	Nonsense	Missense mutation	Nonsense
Which type of mutation is most	deletion	translocation	inversion	transition	inversion
Which type of mutation is least	Deletion	translocation	inversion	transition	deletion
The hydrolysis of an -NH2 grou	deamination; transversions	deamination; deletions or insertions	excision repair; deletion or inser	excision repair; transversions	deamination; deletions or insertic
ultraviolet radiation is most like	deaminations	b)depurination	double stranded breaks	thymine dimers	thymine dimers
Duplication of multiple three- n	Sickel cell anemia	b)trisomy 21	alkaptonuria	xeroderma pigmentosum	alkaptonuria
Errors in DNA replication are m	SOS systems	Base excision repair	Nucleotide excision repair	methyl-directed mismatch repai	Base excision repair
A mutation in the UvrC protein	an increase in overall mutation r	a decrease in over allmutation rate	an increase in transposition ever	a decrease in transposition even	a decrease in transposition event
The---------- are heritable chang	mutation	duplication	replication	d)transcription	mutation
A mutation that changes a wild	forward	reverse	inversion	deletion	forward
A -------mutation causes a novel	forward	reverse	inversion	deletion	reverse

Unit V

Virginia, changed to very cold (snow on the ground 8 months	a mutation in squirrels which causes their fur to be white	If a mutation occurred which caused white fur to develop, such white squirrels would have a better chance to survive and produce more offspring with the characteristic	occur resulting in white squirrels	a new genotype to appear in the population, resulting in	caused white fur to develop, such white squirrels would
an example of natural selection?	likely to be eaten by herbivores than other members of the	Bacterial populations in hospitals develop resistance to drugs used to combat infection by them	greater amounts of milk than their ancestors	to break down alcohol are better able to feed on	greater amounts of milk than their ancestors
weight in mammals), natural selection favors individuals that	diversifying selection	directional selection	adaptive radiation	stabilizing selection	stabilizing selection
produce rapid changes in the phenotype of organisms?	alleles and selecting for new combinations of traits	by stimulating the species to increase the production of new mutations	by changing the number of chromosomes	by selecting only dominant genotypes	alleles and selecting for new combinations of traits
affect the frequency of mutations?	selection pressure, beneficial mutations occur more	Natural selection does not affect the frequency of mutations	All mutations increase when selection pressure is high	pressure, mutations do not occur	affect the frequency of mutations
chromosomal fusion in chimpanzees provided an	Acquired Characteristics	Common Ancestry	Adaptive Radiation	Artificial Selection	Common Ancestry
can change allele frequencies in populations to produce	gene flow	non-random mating	genetic drift	selection	selection
different plant species producing more than two sets	polyploidy	gametic isolation	hybrid viability	mutation	polyploidy
The age of earth is estimate to be about	a)10000 years old	b)4-5 billion years ago	c)600 million year old	d)10-20	b)4-5 billion years ago
Which one of the following are Archaebacteria?	a)Actinomycetes	b)Pseudomonas	c)Rickettisae	d)Methanogens	d)Methanogens
as well as adenine andother nucleic acid bases from	a) Hugo de vries	b) Urey and Miller	c) Oparin and Haldane	d)Pasteur	b) Urey and Miller
The most primitive extant eukaryotes belong to the genus	a)plasmodium	b)tetrahymena	c)chlamydomonas	d)Giardia	d)Giardia
Cambrian Explosion refers to	a) Origin of life	b)Origin of phyla	c) Origin of man	d)extinction of Dinosaurs	b)Origin of phyla
statement cannot be support the endosymbiotic theory for	a)Mitochondria DNA has a circular genome	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	enzymes of oxidative respiration	d)mitochondrial ribosomes are 70s	enzymes of oxidative respiration
to have first appeared in some organisms of approximate age	a)1.0-1.5bp	b) 2.0-2.5bp	c)3.0-3.5bp	d)3.5-4.0bp	b) 2.0-2.5bp
process offers the greatest opportunities for accelerating	a)exon shuffling	b)intron excisions	c)transposons insertions	d)DNA amplification	a)exon shuffling
sequences of geological times is	a) Devonian, Carboniferous, Cretaceous, Eocene	b) Eocene, Devonian, Carboniferous, Cretaceous	c) Devonian, Carboniferous, Eocene ,Cretaceous	d) Carboniferous, Devonian, Cretaceous, Eocene	a) Devonian, Carboniferous, Cretaceous, Eocene
is most closely related to the ancestor from which	a)purple photosynthetic bacteria	b)archaebacteria	c)cyanobacteia	d)methanogens	a)purple photosynthetic bacteria
The first domes cated animal by primi ve man was	a) Cat	b) Dog	c) Horse	d) Cow	b) Dog
Which of the following is an example of living fossils?	a) Pinus	b) Riccia	c) Ginkgo	d) Gnetum	c) Ginkgo
First life on earth was	a) Cyanobacteria	b) Autographs	c) Chemoheterotrophs	d) Photoautotrophs	c) Chemoheterotrophs
Most abundant organic compound on earth is	a) Protein	b) Cellulose	c) Steroids	d) Lipids	b) Cellulose
Which is not a ves gial organ of man?	a) Nails	b) Third molar	c) Coccyx	d) Segmented muscles of abdomen	a) Nails
Gene c dri7 operates only in	a) Large popula ons	b) Smaller popula ons	c) Island popula ons	d) Mendealian popula ons	b) Smaller popula ons
have relavely shorter and poorly developed ears, eyes,	a) Cope's law	b) Dollo's law	c) Bergmann's law	d) Allen's law	d) Allen's law
Phenomenon of 'Industrial melanism' demonstrates	a) Geographical isola on	b) Natural Selec on	c) Reproduc ve isola on	d) Induced muta on	b) Natural Selec on
Convergent evolu on is illustrated by	a) Rat and Dog	b) Bacterium and Protozoan	c) Starfish and Cu@le fish	d) Dogfish and Whale	d) Dogfish and Whale
Correct order is	a) Paleozoic-> Mesozoic-> Coenozoic	b) Archaeozoic-> Coenozoic ->Paleozoic	c) Coenozoic ->Paleozoic-> Archaeozoic	d) Mesozoic-> Archaeozoic-> Coenozoic	a) Paleozoic-> Mesozoic-> Coenozoic
First life on earth was	a) cyanobacteria	b) autotrophs	c) photo autotrophs	d) chemoheterotrophs	d) chemoheterotrophs
One of the possible early sources of energy were/ was	a) green plants	b) carbon dioxide	c) chlorophyll	d) UV rays and lightening	d) UV rays and lightening
evolution of life was performed by	a) Watson and Crick	b) Oparin and Haldane	c) Urey and Miller	d) Meselson and Stahl	c) Urey and Miller
Coacervates were formed by	a) DNA	b) radiations	c) polymerisation	d) polymerisation and aggregation	d) polymerisation and aggregation
experiment to prove origin of life. They look for gases NH	a) N and H O	b) H O and CH	c) CO and N	d) CH and N	b) H O and CH
one of the following was not present in the primitive	a) methane	b) hydrogen	c) water vapour	d) oxygen	d) oxygen
Swan neck flask experiment was performed by	a) Oparin and Haldane	b) Darwin	c) Aristotle	d) Louis Pasteur	d) Louis Pasteur
Coacervates were experimentally produced by	a) Urey and Miller	b) Jacob and Monad	c) Oparin	d) Fischer and Huxley	c) Oparin
on origin of life has provided evidence for the	a) theory of special creation	b) theory of biogenesis	c) theory of abiogenesis	d) theory of organic evolution	c) theory of abiogenesis
Theory of abiogenesis was put forward by	a) Spallanzani	b) F.Redi	c) Van Helmont	d) Pasteur	c) Van Helmont
A species inhabiting different geographical areas is known as	a) sympatric	b) allopatric	c) sibling	d) biospecies	b) allopatric
According to De Vries theory, evolution is	a) jerky	b) discontinuous	c) continuous and smooth	d) both a and b	d) both a and b
Mutation may be described as	a) Continuous genetic variation	b) Phenotypic change	c) Discontinuous genetic variation	d) change due to hybridisation	c) Discontinuous genetic variation
The theory of use and disuse was given by	a) Stebbins	b) Lamarck	c) Aristotle	d) Vavilox	b) Lamarck
based upon sum total of adaptive changes preserved by	a) natural selection	b) isolation	c) speciation	d) human conservation	b) isolation
Genetic drift is on account of	a) variations	b) mutation	c) increase in population	d) decrease in population	d) decrease in population
natural selection operates through	a) Fighting between organisms	b) Variations	c) Killing weaker organism	d) Differential reproduction	d) Differential reproduction
Sympatric speciation develops reproductive isolation without	a) Geographic barrier	b) barrier to mating	c) barrier to gene flow	d) genetic change	a) Geographic barrier
a small band of colonisers is called	a) Founder effect	b) Genetic bottle neck	c) Genetic grift	d) Gene flow	a) Founder effect
Genetic drift is found in	a) Small population with or without mutated genes	b) large population with random mating	c) plant population	d) animal population	a) Small population with or without mutated genes
Which is related to reproduce isolation	a) genetic isolation	b)temporal isolation	c) behavioural isolation	d) all of these.	d) all of these.
In which condition gene ratio remains constant in a species?	a) gene flow	b) mutation	c) random mating	d) sexual selection	c) random mating
Lamarck theory of organic evolution is usually known as	a) Natural selection	b) Inheritance of acquired characters	c) Descent with change	d) continuity of fermplasm	b) Inheritance of acquired characters
whether or not a population is evolving?	a) Degree of evolution	b) Genetic drift	c) Proportion between acquired variations	d) Hardy Weinberg equation	d) Hardy Weinberg equation
concerned with successful reproduction of	a) Homozygous recessives	b) homozygous indivduals	c) heterozygous individuals	d) all of the above	c) heterozygous individuals
period did the earth become oxygen rich?	a) Orosirian period	b) Ediacaran period	c) Devonian period	d) Ordovician period	a) Orosirian period

appeared on land during which period?	a) Ediacaran period	b) Devonian period	c) Orosirian period	d) Ordovician period	d) Ordovician period
Flowering plants first appeared during........... Period?	a) Jurassic period	b) Carboniferous period	c) Cretaceous period	d) Silurian	c) Cretaceous period
The present epoch in the Earth's age is known as	a) Holocene	b) Miocene	c) Pleistocene	d) Pliocene	a) Holocene
is the main characteris#cs of.............	a) Holocene	b) Pleistocene	c) Pliocene	d) miocene	a) Holocene
age of earth is also known as the Age of Fish?	a) Orosirian period	b) Devonian period	c) Ediacaran period	d) Ordovician period	b) Devonian period
da#ng, what is the age of the earth?	a) 4 billion years	b) 4.54 billion years	c) 4.45 billion years	d) 4.64 billion years	b) 4.54 billion years
of earth did terrestrial life was well established?	a) Pleistocene period	b) Jurassic period	c) Carboniferous period	d) cretaceous	c) Carboniferous period
First birds and lizards appeared on Earth during .... period?	a) Jurassic period	b) Carboniferous period	c) Pleistocene period	d) cretaceous	a) Jurassic period
Angiosperm originated during	a) upper cretaceous	lower Jurassic	c) mid cretaceous	d) carboniferous	c) mid cretaceous
mul#cellular organism appeared during	a) 1 billion years ago	2 billion	c) 600 million	d) 200 millions	a) 1 billion years ago
Maximum diversity of rep#les was during	a) Jurassic	b) Ordovician	c) Triassic	d) Cretaceous	d) Cretaceous
statement cannot be support the endosymbiotic theory for	a)Mitochondria DNA has a circular genome	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	enzymes of oxidative respiration	d)mitochondrial ribosomes are 70s	enzymes of oxidative respiration
phylogenies based on the numerical ranking of the	cladistics	phenetics	polyphenetics	numerology	phenetics
morphology over time without diversifying into separate	evolutionary species	chronospecies	living fossil	stagnant species	chronospecies
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an organism's life are generally not passed on through
rce of genetic variation
mmon ancestor
eration

enzymes of oxidative respiration

etaceous, Eocene

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out mutated genes

cters

enzymes of oxidative respiration

on
out mutated genes

>Blastulation-->Gastrulation

formation near the yolk sac

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ny ribosomes are attached simultaneously
NA template
tion on mRNA

ns

is regulated in bacteria
subunits including σ, while the core enzyme lacks σ

cribed
hich RNA polymeraase binds

nor an Inr sequence

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traits to favor those better suited to the organism's environment.

used white fur to develop, such white squirrels would have a better chance to survive and produce more offspring with the characteristic
greater amounts of milk than their ancestors

eles and selecting for new combinations of traits
the frequency of mutations

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ns

is regulated in bacteria
subunits including σ, while the core enzyme lacks σ

cribed
hich RNA polymeraase binds

nor an Inr sequence
e pairs around the initiation site
recognize core promoter sequences

een the template strand and the RNA transcript
om the DNA template

port them to ribosomes

sequence that is bound by a repressor protein
or are bound to the DNA
in the number of revertants

ed by the addition of a methyl group
r while recombinational repair leaves it in place

ons

s