Semester –I

18BTP103 ECOLOGY, EVOLUTIONARY AND DEVELOPMENTAL BIOLOGY 4H – 4C

Total hours/week: **L:4 T:0 P:0** **Marks:** Internal:**40** External:**60** Total: **100**

Course Objectives:

To make the students to:

I. Understand the principles and concepts about the evolution.

II. Understand the origin and evolution of biotic community.

III. Understand the significance of nature using scientific methods.

Course Outcomes:

On successful completion of course, students should be able to:

i. Learn the fundamental principles and concepts of evolutionary theory and ecology and they can use this knowledge to explore the evolution.

ii. Students will also learn basic ecological theory and can use these principles in understanding and proposing solutions to the major environmental problems facing the biosphere vii. Describe evolutionary and ecological patterns & processes related to the survival, diversity, relationships, distribution, abundance and interactions of organisms, their populations and environments.

UNIT-I

Ecological principles: The Environment: Physical, biotic environment; interactions. Habitat and Niche: Concepts, types. Population Ecology: Characteristics, growth curves; regulation; life history strategies (r and K selection); concept of metapopulations. Species Interactions: Types. Community Ecology, Ecological Succession: Types; mechanisms; changes, concept of climax.

UNIT – II

Ecosystem, Applied and conservation Ecology: Ecosystem structure; function; energy flow and mineral cycling (C,N,P), structure and function of some Indian ecosystems: terrestrial (forest, grassland) and aquatic (fresh water, marine, eustarine). Biogeography: Major terrestrial biomes; theory; biogeographical zones of India. Applied Ecology: pollution; global change; biodiversity: status, monitoring and documentation; major drivers, management approaches. Conservation Biology: Principles, approaches, Indian case studies on conservation/management strategy (Project Tiger, Biosphere reserves).

UNIT -III

Evolutionary Biology: Emergence,Lamarck; Darwin–concepts, Mendelism; Origin of cells and unicellular evolution: Concept of Oparin and Haldane; The first cell; Evolution of prokaryotes, eukaryotic, unicellular eukaryotes. Origins of unicellular and multi cellular organisms; plants and animals; Molecular Evolution: Concepts, tools.

UNIT – IV

Population genetics – Populations, Hardy-Weinberg Law, Speciation; Convergent evolution. Brain, Behavior and Evolution: Approaches, methods. Biological clocks;

Development of behavior; Social communication; Habitat, Domestication and behavioral changes

Developmental Biology: Concepts, determination and differentiation; morphogenetic gradients; genomic equivalence and the cytoplasmic determinants; imprinting; mutants and transgenics in analysis of development

UNIT -V

Gametogenesis, fertilization and early development: Production, development in animals, plants; formation, germination or establishment in plants, animals. Morphogenesis and organogenesis in animals : Cell aggregation and differentiation (Dictyostelium, Drosophila, amphibia and chick; organogenesis (Caenorhabditis elegans, vertebrates), development- environmental regulation of normal development; sex determination. Morphogenesis and organogenesis in plants: Organization, development and transition - shoot, root, leaf, floral in Arabidopsis and Antirrhinum

References

Eugene P Odum (1996) Fundamentals of Ecology, Nataraj Publishers.

K.V.Krishnamoorthy (2004) An advanced Text Book of Biodiversity, Oxford &IBH, New Delhi.

Joshi PC and Namitha Joshi (2004) Biodiversity and Conservation, APH Publishing Company, New Delhi.

Melchias (2001) Biodiversity and Conservation, Oxford and IBH Publishing Company Pvt. Ltd., New Delhi

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University Established Under Section 3 of UGC Act 1956)

Coimbatore – 641 021.

LECTURE PLAN
DEPARTMENT OF BIOTECHNOLOGY

STAFF NAME: J.ANBURAJ
SUBJECT NAME: ECOLOGY, EVOLUTIONARY AND DEVELOPMENTAL BIOLOGY SUB.CODE:18BTP103
SEMESTER: I CLASS: I M.Sc (Biotech)

S.No	Lecture Duration Period	Topics to be Covered	Support Material/Page Nos
		UNIT-I	
1	1	The Environment: Physical, biotic environment; interactions	R_1. 1
2	1	Habitat and Niche: Concepts, types	R_1. 05-09
3	1	Population Ecology: Characteristics, growth curves	R_1. 01-02
4	1	regulation; life history strategies (r and K selection)	R_1. 02-03
5	1	concept of metapopulations	R_1. 03-04
6	1	Species Interactions: Types	R_1. 04-05
7	1	Community Ecology, Ecological Succession	R_1. 05
8	1	Types; mechanisms; changes, concept of climax	R_1. 09-10
9	1	Recapitulation of Unit I	
	Total No of Hours Planned For Unit 1=9		

		UNIT-II	
1	1	Ecosystem structure; function; energy flow and mineral cycling (C,N,P), structure and function of some Indian ecosystems	R_1. 178-180
2	1	terrestrial (forest, grassland) and aquatic (fresh water, marine, eustarine)	R_1. 183
3	1	Biogeography: Major terrestrial biomes	R_1. 183-185
4	1	theory; biogeographical zones of India.	R_1. 199
5	1	Applied Ecology: pollution; global change;	T_1. 98
6	1	biodiversity: status, monitoring and documentation	R_1. 205
7	1	Major drivers, management approaches.	R_1. 205
8	1	Conservation Biology: Principles, approaches, Indian case studies on conservation/management strategy (Project Tiger, Biosphere reserves)	T_1. 69-86
9	1	Recapitulation of Unit II	
	Total No of Hours Planned For Unit II=9		
		UNIT-III	
1	1	Emergence,Lamarck	T_1. 101-103
2	1	Darwin–concepts, Mendelism	T_1. 101-103
3	1	Origin of cells and unicellular	R_1. 243

		evolution	
4	1	Concept of Oparin and Haldane	T_1. 243
5	1	The first cell	R_1. 254
6	1	Evolution of prokaryotes, eukaryotic, unicellular eukaryotes	R_2. 87-94
7	1	Origins of unicellular and multi cellular organisms	R_2. 87-94
8	1	plants and animals	T_1. 243
9	1	Molecular Evolution	R_1. 254
10	1	Concepts, tools	R_2. 87-94
11	1	Recapitulation of Unit III	R_2. 87-94
	Total No of Hours Planned For Unit III=11		
		UNIT-IV	
1	1	Populations, Hardy-Weinberg Law, Speciation; Convergent evolution	R_1. 181-185
2	1	Brain, Behavior and Evolution: Approaches, methods	R_1. 285-290
3	1	Biological clocks; Brain, Behavior and Evolution	R_1. 192-295
4	1	Development of behavior	R_1. 301
5	1	Social communication; Habitat, Domestication and behavioral changes	R_1. 296
6	1	Concepts, determination and differentiation	R_1. 305
7	1	Morphogenetic gradients	R_1. 305
8	1	genomic equivalence and the cytoplasmic determinants	T_2. 313-348

9	1	imprinting; mutants and transgenics in analysis of development	T_2. 313-348
10	1	Recapitulation of Unit IV	
	Total No of Hours Planned For Unit IV=10		
		UNIT-V	
1	1	Production, development in animals, plants	R_2. 145-150
2	1	formation, germination or establishment in plants, animals	R_2. 141-143
3	1	Morphogenesis and organogenesis in animals	R_2. 128-130
4	1	Cell aggregation and differentiation (Dictyostelium, Drosophila, amphibia and chick	R_2. 113-119
5	1	organogenesis (Caenorhabditis elegans, vertebrates)	R_2. 145-150
6	1	development- environmental regulation of normal development; sex determination	R_2. 141-143
7	1	Morphogenesis and organogenesis in plants	R_2. 128-130
8	1	Organization, development and transition	R_2. 113-119
9	1	shoot, root, leaf, floral in Arabidopsis and Antirrhinum	R_2. 113-119
10	1	Recapitulation of Unit V	
11	1	ESE question paper discussion	

12	1	ESE question paper discussion	
13	1	ESE question paper discussion	
	Total No of Hours Planned for unit V=13		
Total Planned Hours	**48**		

REFERENCES

Eugene P Odum (1996) Fundamentals of Ecology, Nataraj Publishers.

K.V.Krishnamoorthy (2004) An advanced Text Book of Biodiversity, Oxford &IBH, New Delhi.

Joshi PC and Namitha Joshi (2004) Biodiversity and Conservation, APH Publishing Company, New Delhi.

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UNIT-I

SYLLABUS

Unit – I

Ecological principles: The Environment: Physical, biotic environment; interactions. Habitat and Niche: Concepts, types. Population Ecology: Characteristics, growth curves; regulation; life history strategies (r and K selection); concept of metapopulations. Species Interactions: Types. Community Ecology, Ecological Succession: Types; mechanisms; changes, concept of climax.

Abiotic factors refer to non-living physical and chemical elements in the ecosystem. Abiotic resources are usually obtained from the lithosphere, atmosphere, and hydrosphere. Examples of abiotic factors are water, air, soil, sunlight, and minerals.

Biotic factors are living or once-living organisms in the ecosystem. These are obtained from the biosphere and are capable of reproduction. Examples of biotic factors are animals, birds, plants, fungi, and other similar organisms.

	Abiotic	Biotic
Introduction	In ecology and biology, abiotic components are non-living chemical and physical factors in the environment which affect ecosystems.	Biotic describes a living component of an ecosystem; for example organisms, such as plants and animals.
Examples	Water, light, wind, soil, humidity, minerals, gases.	All living things — autotrophs and heterotrophs — plants, animals, fungi, bacteria.
Factors	Affect the ability of organisms to survive, reproduce; help determine types and numbers of organisms able to exist in environment; limiting factors restrict growth.	Living things that directly or indirectly affect organisms in environment; organisms, interactions, waste; parasitism, disease, predation.
Affects	Individual of a species, population, community,	Individual of a species, population,

Abiotic	**Biotic**
ecosystem, biome, biosphere.	community, ecosystem, biome, biosphere.

Biotic components are living organisms in an ecosystem. A biotic factor is a living organism that affects another organism in its ecosystem. Examples include plants and animals that the organism consumes as food, and animals that consume the organism.

The following video covers the biotic and abiotic factors that influence most ecosystems, and introduces key vocabulary relevant to ecology:

Relevance

The scope of abiotic and biotic factors spans across the entire biosphere, or global sum of all ecosystems. Such factors can have relevance for an individual within a species, its community or an entire population. For instance, disease is a biotic factor affecting the survival of an individual and its community. Temperature is an abiotic factor with the same relevance.

Some factors have greater relevance for an entire ecosystem. Abiotic and biotic factors combine to create a system or, more precisely, an ecosystem, meaning a community of living and nonliving things considered as a unit. In this case, abiotic factors span as far as the pH of the soil and water, types of nutrients available and even the length of the day. Biotic factors such as the presence of autotrophs or self-nourishing organisms such as plants, and the diversity of consumers also affect an entire ecosystem.

Influencing Factors

Abiotic factors affect the ability of organisms to survive and reproduce. Abiotic limiting factors restrict the growth of populations. They help determine the types and numbers of organisms able to exist within an environment.

Biotic factors are living things that directly or indirectly affect organisms within an environment. This includes the organisms themselves, other organisms, interactions between living organisms and even their waste. Other biotic factors include parasitism, disease, and predation (the act of one animal eating another).

Interaction Examples

The significance of abiotic and biotic factors comes in their interaction with each other. For a community or an ecosystem to survive, the correct interactions need to be in place.

A simple example would be of abiotic interaction in plants. Water, sunlight and carbon dioxide are necessary for plants to grow. The biotic interaction is that plants use water, sunlight and carbon dioxide to create their own nourishment through a process called photosynthesis.

On a larger scale, abiotic interactions refer to patterns such as climate and seasonality. Factors such as temperature, humidity and the presence or absence of seasons affect the ecosystem. For instance, some ecosystems experience cold winters with a lot of snow. An animal such as a fox within this ecosystem adapts to these abiotic factors by growing a thick, white-colored coat in the winter.

Decomposers such as bacteria and fungi are examples of biotic interactions on such a scale. Decomposers function by breaking down dead organisms. This process returns the basic components of the organisms to the soil, allowing them to be reused within that ecosystem.

Habitat and Niche

Niche

Each organism plays a particular role in its ecosystem. A **niche** is the role a species plays in the ecosystem. In other words, a niche is how an organism "makes a living." A niche will include the organism's role in the flow of energy through the ecosystem. This involves how the organism gets its energy, which usually has to do with what an organism eats, and how the organism passes that energy through the ecosystem, which has to do with what eats the organism. An organism's niche also includes how the organism interacts with other organisms, and its role in recycling nutrients.

Once a niche is left vacant, other organisms can fill that position. For example when the Tarpan, a small wild horse found mainly in southern Russia, became extinct in the early 1900s, its niche was filled by a small horse breed, the Konik (**Figure** below). Often this occurs as a new species evolves to occupy the vacant niche.

A species' niche must be specific to that species; no two species can fill the same niche. They can have very similar niches, which can overlap, but there must be distinct differences between any two niches. If two species do fill the same niche, they will compete for all necessary resources. One species will out compete the other, forcing the other species to adapt or risk extinction. This is known as competitive exclusion.

When plants and animals are introduced, either intentionally or by accident, into a new environment, they can occupy the existing niches of native organisms. Sometimes new species out-compete native species, and the native species may go extinct. They can then become a serious pest. For example, kudzu, a Japanese vine, was planted in the southeastern United States in the 1870s to help control soil loss. Kudzu had no natural predators, so it was able to out-compete native species of vine and take over their niches

Habitat

The **habitat** is the physical area where a species lives. Many factors are used to describe a habitat. The average amount of sunlight received each day, the range of annual temperatures, and average yearly rainfall can all describe a habitat. These and other **abiotic factors** will affect the kind of traits an organism must have in order to survive there. The temperature, the amount of rainfall, the type of soil and other abiotic factors all have a significant role in determining the plants that invade an area. The plants then determine the animals that come to eat the plants, and so on. A habitat should not be confused with an ecosystem: the habitat is the actual place of the ecosystem, whereas the ecosystem includes both the **biotic** and abiotic factors in the habitat.

Habitat destruction means what it sounds like—an organism's habitat is destroyed. Habitat destruction can cause a population to decrease. If bad enough, it can also cause species to go extinct. Clearing large areas of land for housing developments or businesses can cause habitat destruction. Poor fire management, pest and weed invasion, and storm damage can also destroy habitats. National parks, nature reserves, and other protected areas all preserve habitats.

Population ecology

Population ecology, study of the processes that affect the distribution and abundance of animal and plant populations.

A population is a subset of individuals of one species that occupies a particular geographic area and, in sexually reproducing species, interbreeds. The geographic boundaries of a population are easy to establish for some species but more difficult for others. For example, plants or animals occupying islands have a geographic range defined by the perimeter of the island. In contrast, some species are dispersed across vast expanses, and the boundaries of local populations are more difficult to determine. A continuum exists from closed populations that are geographically isolated from, and lack exchange with, other populations of the same species to open populations that show varying degrees of connectedness.

Genetic variation within local populations

In sexually reproducing species, each local population contains a distinct combination of genes. As a result, a species is a collection of populations that differ genetically from one another to a greater or lesser degree. These genetic differences manifest themselves as differences among populations in morphology, physiology, behaviour, and life histories; in other words, genetic characteristics (genotype) affect expressed, or observed, characteristics (phenotype). Natural selection initially operates on an individual organismal phenotypic level, favouring or discriminating against individuals based on their expressed characteristics. The gene pool (total aggregate of genes in a population at a certain time) is affected as organisms with phenotypes that are compatible with the environment are more likely to survive for longer periods, during which time they can reproduce more often and pass on more of their genes.

The amount of genetic variation within local populations varies tremendously, and much of the discipline of conservation biology is concerned with maintaining genetic diversity within and among populations of plants and animals. Some small isolated populations of asexual species often have little genetic variation among individuals, whereas large sexual populations often have great variation. Two major factors are responsible for this variety: mode of reproduction and population size.

Effects of mode of reproduction: sexual and asexual

In sexual populations, genes are recombined in each generation, and new genotypes may result. Offspring in most sexual species inherit half their genes from their mother and half from their father, and their genetic makeup is therefore different from either parent or any other individual in the population. In both sexually and asexually reproducing species, mutations are the single most important source of genetic variation. New favourable mutations that initially appear in separate individuals can be recombined in many ways over time within a sexual population.

In contrast, the offspring of an asexual individual are genetically identical to their parent. The only source of new gene combinations in asexual populations is mutation. Asexual populations accumulate genetic variation only at the rate at which their genes mutate. Favourable mutations arising in different asexual individuals have no way of recombining and eventually appearing together in any one individual, as they do in sexual populations.

Effects of population size

Over long periods of time, genetic variation is more easily sustained in large populations than in small populations. Through the effects of random genetic drift, a genetic trait can be lost from a small population relatively quickly (*see* biosphere: Processes of evolution). For example, many populations have two or more forms of a gene, which are called alleles. Depending on which allele an individual has inherited, a certain phenotype will be produced. If populations remain small for many generations, they may lose all but one form of each gene by chance alone.

This loss of alleles happens from sampling error. As individuals mate, they exchange genes. Imagine that initially half of the population has one form of a particular gene, and the other half of the population has another form of the gene. By chance, in a small population the exchange of genes could result in all individuals of the next generation having the same allele. The only way for this population to contain a variation of this gene again is through mutation of the gene or immigration of individuals from another population (*see* evolution: Genetic variation in populations).

Minimizing the loss of genetic variation in small populations is one of the major problems faced by conservation biologists. Environments constantly change, and natural selection continually sorts through the genetic variation found within each population, favouring those individuals with phenotypes best suited for the current environment. Natural selection, therefore, continually works to reduce genetic variation within populations, but populations risk extinction without the genetic variation that allows populations to respond evolutionarily to changes in the physical environment, diseases, predators, and competitors.

Population density and growth

Life histories and the structure of populations

An organism's life history is the sequence of events related to survival and reproduction that occur from birth through death. Populations from different parts of the geographic range that a species inhabits may exhibit marked variations in their life histories. The patterns of demographic variation seen within and among populations are referred to as the structure of populations. These variations include breeding frequency, the age at which reproduction begins, the number of times an individual reproduces during its lifetime, the number of offspring produced at each reproductive episode (clutch or litter size), the ratio of male to female offspring produced, and whether reproduction is sexual or asexual. These differences in life history characteristics can have profound effects on the reproductive success of individuals and the dynamics, ecology, and evolution of populations.

Of the many differences in life history that occur among populations, age at the time of first reproduction is one of the most important for understanding the dynamics and evolution of a population. All else being equal, natural selection will favour, within species, individuals that reproduce earlier than other individuals in the population, because by reproducing earlier an individual's genes enter the gene pool (the sum of a population's genetic material at a given time) sooner than those of other individuals that were born at the same time but have not reproduced. Nonetheless, the "all else being equal" qualification is an important one because delayed reproductive strategies that ensure larger and more-robust offspring may be selected for in some species of long-lived organisms. Precocial development (unusually early maturation) to reproduction may be favoured, however, if the genes of early reproducers begin to spread throughout the population. Individuals whose genetic makeup allows them to reproduce earlier in life will come to dominate a population if there is no counterbalancing advantage to those individuals that delay reproduction until later in life.

Not all populations, however, are made up of individuals that reproduce very early in life. In the course of a lifetime, an individual must devote energy and resources to physiological demands other than reproduction. This is referred to as the cost of reproduction. To reproduce successfully, a plant first may have to grow to a certain height and outcompete its neighbours, and an animal may have to devote energy to growth so that it can reach a size at which it can fend off predators and successfully compete for mates. In many populations, individuals that delay reproduction have a better chance of surviving and leaving offspring than those that attempt to reproduce early. The opposing demands of growth, defense, and reproduction are balanced within the constraints of different environments to produce populations that have a diverse range of life history strategies.

Populations often can be divided into one of two extreme types based on their life history strategy. Some populations, called *r*-selected, are considered opportunistic because their reproductive behaviour involves a high intrinsic rate of growth (*r*)—individuals give birth once at an early age to many offspring. Populations that exhibit this strategy often have been shaped by an extremely variable and uncertain environment. Because mortality occurs randomly in this setting, quantity of progeny rather than quality of care serves the species better. In another strategy, called *K*-selected, populations tend to remain near the carrying capacity (*K*), the maximum number of individuals that the environment can sustain. Individuals in a *K*-selected population give birth at a later age to fewer offspring. This equilibrial life history is exhibited in more stable environments where reproductive success depends more on the fitness of the offspring than on their numbers.

Population Growth Curves | Ecology

Type # 1. J – Shaped Curve:

In the case of J-shaped growth form, the population grows exponentially, and after attaining the peak value, the population may abruptly crash. This increase in population is continued till large amount of food materials exist in the habitat.

After some time, due to increase in population size, food supply in the habitat becomes limited which ultimately results in decrease in population size. For example, many insect populations show explosive increase in numbers during the rainy season, followed by their disappearance at the end of the season.

The following equation exhibits J-shaped growth:

$dN/dt = rN$

Here dN/dt represents rate of change in population size, r is biotic potential and N stands for population size.

Type # 2. S – Shaped or Sigmoid Curve:

When a few organisms are introduced in an area, the population increase is very slow in the beginning, i.e., positive acceleration phase or lag phase, in the middle phase, the population increase becomes very rapid, i.e., logarithmic phase, and finally in the last phase the population increase is slowed down, i.e., negative acceleration phase, until an equilibrium is attained around which the population size fluctuates according to variability of environment.

Population Growth Curves | Ecology

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The level beyond which no major increase can occur is referred to as saturation level or carrying capacity (K). In the last phase the new organisms are almost equal to the number of dying individuals and thus there is no more increase in population size.

The S-shaped sigmoid growth form is represented by the following equation:

$dN/dt = rN (K – N/K) = rN (1 – N/K)$

where, dN/dt is the rate of change in population size,

r is biotic potential

N is population size,

$K – N/K$ or $1 – (N/K)$ is for environmental resistance.

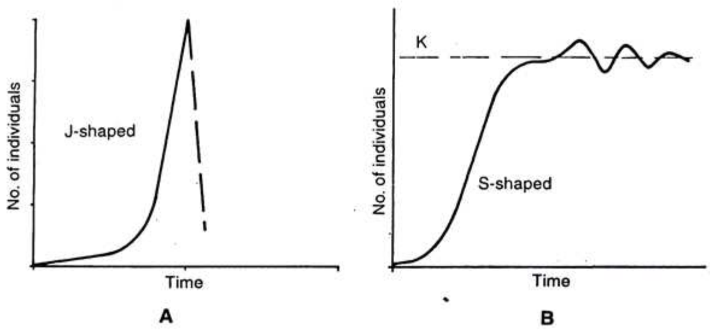


Fig. 11·2. Population growth curves. A. J-shaped; B. S-shaped (sigmoid) curve. K stands for carrying capacity.

Population Growth and Regulation

Population ecologists make use of a variety of methods to model population dynamics. An accurate model should be able to describe the changes occurring in a population and predict future changes.

Population Growth

The two simplest models of population growth use deterministic equations (equations that do not account for random events) to describe the rate of change in the size of a population over time. The first of these models, **exponential growth**, describes populations that increase in numbers without any limits to their growth. The second model, **logistic growth**, introduces limits to reproductive growth that become more intense as the population size increases. Neither model adequately describes natural populations, but they provide points of comparison.

Exponential Growth

Charles Darwin, in developing his theory of natural selection, was influenced by the English clergyman Thomas Malthus. Malthus published his book in 1798 stating that populations with abundant natural resources grow very rapidly. However, they limit further growth by depleting their resources. The early pattern of accelerating population size is called exponential growth (Figure 1).

The best example of exponential growth in organisms is seen in bacteria. Bacteria are prokaryotes that reproduce quickly, about an hour for many species. If 1000 bacteria are placed in a large flask with an abundant supply of nutrients (so the nutrients will not become quickly depleted), the number of bacteria will have doubled from 1000 to 2000 after just an hour. In another hour, each of the 2000 bacteria will divide, producing 4000 bacteria. After the third hour, there should be 8000 bacteria in the flask. The important concept of exponential growth is that the growth rate—the number of organisms added in each reproductive generation—is itself increasing; that is, the population size is increasing at a greater and greater rate. After 24 of these cycles, the population would have increased from 1000 to more than 16 billion bacteria. When the population size, *N*, is plotted over time, a J-shaped growth curve is produced (Figure 1).

The bacteria-in-a-flask example is not truly representative of the real world where resources are usually limited. However, when a species is introduced into a new habitat that it finds suitable, it may show exponential growth for a while. In the case of the bacteria in the flask, some bacteria will die during the experiment and thus not reproduce; therefore, the growth rate is lowered from a maximal rate in which there is no mortality.

Logistic Growth

Extended exponential growth is possible only when infinite natural resources are available; this is not the case in the real world. Charles Darwin recognized this fact in his description of the "struggle for existence," which states that individuals will compete, with members of their own or other species, for limited resources. The successful ones are more likely to survive and pass on the traits that made them successful to the next generation at a greater rate (natural selection). To model the reality of limited resources, population ecologists developed the logistic growth model.

Carrying Capacity and the Logistic Model

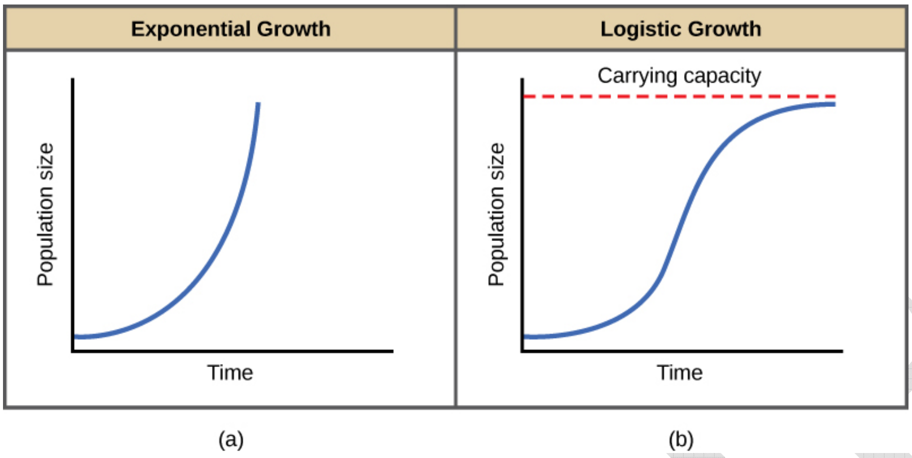


Figure 1. When resources are unlimited, populations exhibit (a) exponential growth, shown in a J-shaped curve. When resources are limited, populations exhibit (b) logistic growth. In logistic growth, population expansion decreases as resources become scarce, and it levels off when the carrying capacity of the environment is reached. The logistic growth curve is S-shaped.

In the real world, with its limited resources, exponential growth cannot continue indefinitely. Exponential growth may occur in environments where there are few individuals and plentiful resources, but when the number of individuals gets large enough, resources will be depleted and the growth rate will slow down. Eventually, the growth rate will plateau or level off (Figure 1). This population size, which is determined by the maximum population size that a particular environment can sustain, is called the **carrying capacity**, symbolized as *K*. In real populations, a growing population often overshoots its carrying capacity and the death rate increases beyond the birth rate causing the population size to decline back to the carrying capacity or below it. Most populations usually fluctuate around the carrying capacity in an undulating fashion rather than existing right at it.

A graph of logistic growth yields the S-shaped curve (Figure 1). It is a more realistic model of population growth than exponential growth. There are three different sections to an S-shaped curve. Initially, growth is exponential because there are few individuals and ample resources available. Then, as resources begin to become limited, the growth rate decreases. Finally, the growth rate levels off at the carrying capacity of the environment, with little change in population number over time.

Examples of Logistic Growth

Yeast, a unicellular fungus used to make bread and alcoholic beverages, exhibits the classical S-shaped curve when grown in a test tube (Figure 2a). Its growth levels off as the population depletes the nutrients that are necessary for its growth. In the real world, however, there are variations to this idealized curve.

Examples in wild populations include sheep and harbor seals (Figure 2b). In both examples, the population size exceeds the carrying capacity for short periods of time and then falls below the carrying capacity afterwards. This fluctuation in population size continues to occur as the population oscillates around its carrying capacity. Still, even with this oscillation the logistic model is confirmed.

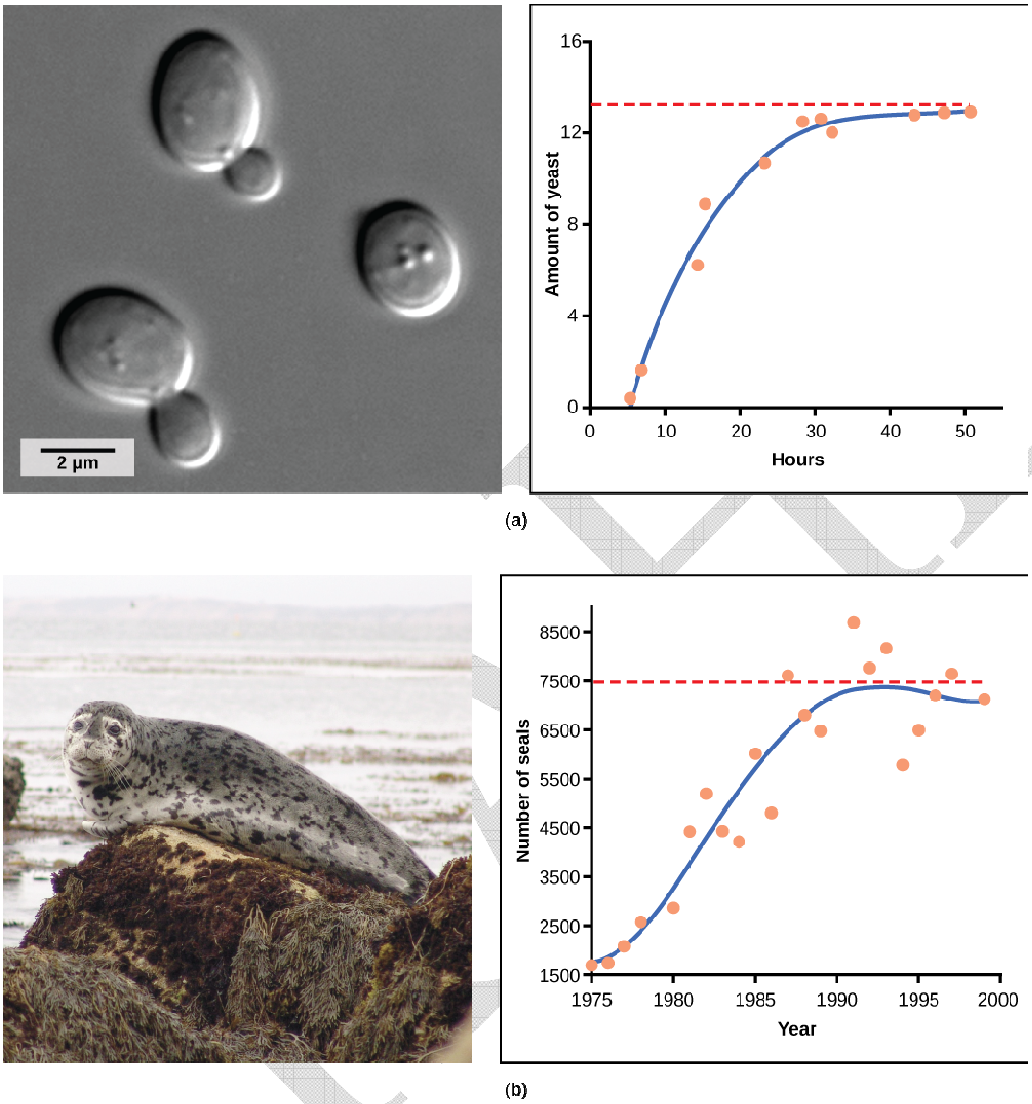


Figure 2. (a) Yeast grown in ideal conditions in a test tube shows a classical S-shaped logistic growth curve, whereas (b) a natural population of seals shows real-world fluctuation. The yeast is visualized using differential interference contrast light micrography. (credit a: scale-bar data from Matt Russell)

Population Dynamics and Regulation

The logistic model of population growth, while valid in many natural populations and a useful model, is a simplification of real-world population dynamics. Implicit in the model is that the carrying capacity of the environment does not change, which is not the case. The carrying capacity varies annually. For example, some summers are hot and dry whereas others are cold and wet; in many areas, the carrying capacity during the winter is much lower than it is during the summer. Also, natural events such as earthquakes, volcanoes, and fires can alter an environment and hence its carrying capacity. Additionally, populations do not usually exist in isolation. They share the environment with other species, competing with them for the same resources (interspecific competition). These factors are also important to understanding how a specific population will grow.

Why Did the Woolly Mammoth Go Extinct?

(a)

(b) (c)

Figure 3. The three images include: (a) 1916 mural of a mammoth herd from the American Museum of Natural History, (b) the only stuffed mammoth in the world is in the Museum of Zoology located in St. Petersburg, Russia, and (c) a one-month-old baby mammoth, named Lyuba, discovered in Siberia in 2007. (credit a: modification of work by Charles R. Knight; credit b: modification of work by "Tanapon"/Flickr; credit c: modification of work by Matt Howry)

Most populations of woolly mammoths went extinct about 10,000 years ago, soon after paleontologists believe humans began to colonize North America and northern Eurasia (Figure 3). A mammoth population survived on Wrangel Island, in the East Siberian Sea, and was isolated from human contact until as recently as 1700 BC. We know a lot about these animals from carcasses found frozen in the ice of Siberia and other northern regions.

It is commonly thought that climate change and human hunting led to their extinction. A 2008 study estimated that climate change reduced the mammoth's range from 3,000,000 square miles 42,000 years ago to 310,000 square miles 6,000 years ago.[2] Through archaeological evidence of kill sites, it is also well documented that humans hunted these animals. A 2012 study concluded that no single factor was exclusively responsible for the extinction of these magnificent creatures.[3] In addition to climate change and reduction of habitat, scientists demonstrated another important factor in the mammoth's extinction was the migration of human hunters across the Bering Strait to North America during the last ice age 20,000 years ago.

The maintenance of stable populations was and is very complex, with many interacting factors determining the outcome. It is important to remember that humans are also part of nature. Once we contributed to a species' decline using primitive hunting technology only.

Demographic-Based Population Models

Population ecologists have hypothesized that suites of characteristics may evolve in species that lead to particular adaptations to their environments. These adaptations impact the kind of population growth their species experience. Life history characteristics such as birth rates, age at first reproduction, the numbers of offspring, and even death rates evolve just like anatomy or behavior, leading to adaptations that affect population growth. Population ecologists have described a continuum of life-history "strategies" with *K*-selected species on one end and *r*-selected species on the other. ***K*-selected species** are adapted to stable, predictable environments. Populations of *K*-selected species tend to exist close to their carrying capacity. These species tend to have larger, but fewer, offspring and contribute large amounts of resources to each offspring. Elephants would be an example of a *K*-selected species. ***r*-selected species** are adapted to unstable and unpredictable environments. They have large numbers of small offspring. Animals that are *r*-selected do not provide a lot of resources or parental care to offspring, and the offspring are relatively self-sufficient at birth. Examples of *r*-selected species are marine invertebrates such as jellyfish and plants such as the dandelion. The two extreme strategies are at two ends of a continuum on which real species life histories will exist. In addition, life history strategies do not need to evolve as suites, but can evolve independently of each other, so each species may have some characteristics that trend toward one extreme or the other.

r- and K-selection

Introduction: An organism's Darwinian fitness is calculated as the number of offspring it leaves behind that, themselves, survive to reproduce. In evolutionary terms, it is of no consequence if an organism is a fine, fully mature, physical specimen, or the dominant member of the herd, or even that an individual produces a lot of young but none of them survive. In the relay race of evolution, getting as many copies of your genes into the next generation as possible is the only goal. As you might imagine, there are many ways to be reproductively successful. One way is to become the dominant animal in a pack, and to monopolize mating opportunities, but another way is to be submissive and sneaky, mating with others when the dominant animal is not around to stop you. There are no moral judgements. It's just biology. Now imagine that you're an animal faced with the following choice: given limited resources, should you put them all into producing one or a few offspring, and protect them with great ferocity, or should you put a small amount of effort into a much larger number of offspring, and let them each take their chances? Should you measure out your reproductive effort over many seasons, or save it all up for a one-time mating frenzy as soon as you're able? These trade-offs relate to the r/K selection theory of life history strategies.

A mouse produces a large litter. A whale tends for a single calf.

r-selection: On one extreme are the species that are highly r-selected. r is for reproduction. Such a species puts only a small investment of resources into each offspring, but produces many such low effort babies. Such species are also generally not very invested in protecting or rearing these young. Often, the eggs are fertilized and then dispersed. The benefit of this strategy is that if resources are limited or unpredictable, you can still produce some young. However, each of these young has a high probability of mortality, and does not benefit from the protection or nurturing of a caring parent or parents. r-selected babies grow rapidly, and tend to be found in less competitive, low quality environments. Although not always the case, r-selection is more common among smaller animals with shorter lifespans and, frequently, non-overlapping generations, such as fish or insects. The young tend to be precocial (rapidly maturing) and develop early independence.

K-selection: On the other extreme are species that are highly K-selected. K refers to the carrying capacity, and means that the babies are entering a competitive world, in a population at or near its carrying capacity. K-selected reproductive strategies tend towards heavy investment in each offspring, are more common in long-lived organisms, with a longer period of maturation to adulthood, heavy parental care and nurturing, often a period of teaching the young, and with fierce protection of the babies by the parents. K-selected species produce offspring that each have a higher probability of survival to maturity. Although not always the case, K-selection is more common in larger animals, like whales or elephants, with longer lifespans and overlapping generations. The young tend to be altricial (immature, requiring extensive care).

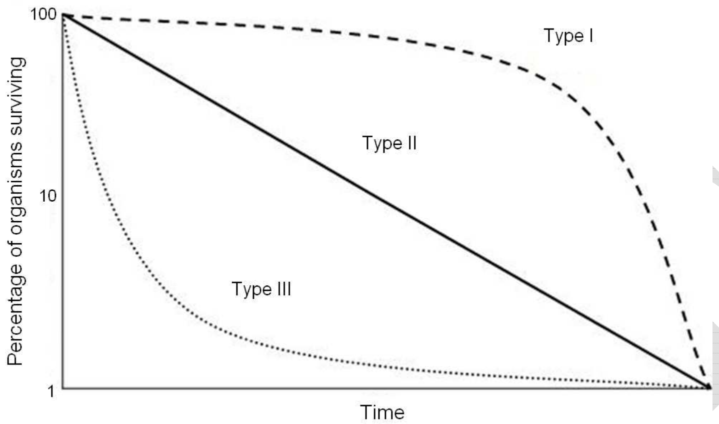
You can see r- and K-selected strategies clearly by looking at different organisms within a phylogenetic group, such as the mammals. For example, elephants are highly K-selected, whereas mice are much more r-selected. Among the fishes, most, like the salmon, are r-selected. Some species will even inadvertently eat their own young if they are not immediately dispersed, but a few species, such as the cichlids, are K-selected and provide prolonged care and protection of the eggs and hatchlings. Even among humans, there are a range of strategies toward one or the other extreme. In one family, with ten children, for example, there is no way for the parents to put as much time, energy, or resources into all of them as could be done with an only child. But, with humans, it gets complicated by the fact that others, including siblings, grandparents, blood-relatives, and the larger community all play a role in the nurturing and education of children.

Even plants are capable of r- and K-selected reproductive strategies. Wind pollinated species produce much more pollin that insect pollinated ones, for example, because the pollin has to be carried at random by the wind to a receptive female flower. Eggs too, can be r- or K-selected. The amount of nutrient energy placed in an egg gives it a lesser or greater ability to survive in adverse conditions. One can even compare the reproductive stragies of males and females within a species, when sperm and egg represent different levels of energy investment. Often sperm are resource poor, and produced in large quantities, while eggs are resource rich and produced in smaller numbers. This can lead to differences in behavior between the sexes, often with the result that the female is the choosier sex when it comes to reproduction. This trend is further extended if the female also carries the young (in the case of internal fertilization) or has a greater role in parental care once the babies are born. There are some interesting exceptions that illustrate the rule. Male seahorses are the choosier sex, and they are the ones that incubate the young. In a small fish called the stickleback, the male is also choosier, it is believed, because the female lays her eggs in a nest he constructed and then leaves. The male guards the nest and tends the young for an extended period.

It should be noted that r- and K-selection are the extremes at both ends of a continuum and that most species fall somewhere inbetween.

Characteristic	r	K
Number of offspring	high	low
Parental care	low	high
Reproductive Maturity	early	late
Size of offspring	small	large
Independence at birth	early	late

Ability to learn	low	high
Lifespan	short	long
Early mortality	high	low



Metapopulation

Metapopulation, in ecology, a regional group of connected populations of a species. For a given species, each metapopulation is continually being modified by increases (births and immigrations) and decreases (deaths and emigrations) of individuals, as well as by the emergence and dissolution of local populations contained within it. As local populations of a given species fluctuate in size, they become vulnerable to extinction during periods when their numbers are low. Extinction of local populations is common in some species, and the regional persistence of such species is dependent on the existence of a metapopulation. Hence, elimination of much of the metapopulation structure of some species can increase the chance of regional extinction of species.

The structure of metapopulations varies among species. In some species one population may be particularly stable over time and act as the source of recruits into other, less stable populations. For example, populations of the checkerspot butterfly (*Euphydryas editha*) in California have a metapopulation structure consisting of a number of small satellite populations that surround a large source population on which they rely for new recruits. The satellite populations are too small and fluctuate too much to maintain themselves indefinitely. Elimination of the source population from this metapopulation would probably result in the eventual extinction of the smaller satellite populations.

In other species, metapopulations may have a shifting source. Any one local population may temporarily be the stable source population that provides recruits to the more unstable surrounding populations. As conditions change, the source population may become unstable, as when disease increases locally or the physical environment deteriorates. Meanwhile, conditions in another population that had previously been unstable might improve, allowing this population to provide recruits.

Five Types of Ecological Relationships

Organisms occupy what are called niches. A niche includes the physical space in which they live, how they use the resources that are in that space, and how they interact with other organisms in that space. The interaction among organisms within or between overlapping niches can be characterized into five types of relationships: competition, predation, commensalism, mutualism and parasitism. The last three subtypes are classically defined as relationships exhibiting symbiosis, but predation and competition can also be considered as forms of symbiosis. Symbiosis refers to a close relationship in which one or both organisms obtain a benefit.

Competition & Predation

Predation is when one organism eats another organism to obtain nutrients. The organism that is eaten is called the prey. Examples of predation are owls that eat mice, and lions that eat gazelles. Competition is when individuals or populations compete for the same resource, and can occur within or between species. When organisms compete for a resource (such as food or building materials) it is called consumptive or exploitative competition. When they compete for territory, it is called interference competition. When they compete for new territory by arriving there first, it is called preemptive competition. An example is lions and hyenas that compete for prey.

Commensalism

Commensalism is a relationship in which one organism benefits while the other is neither helped nor harmed. Examples are barnacles that grow on whales and other marine animals. The whale gains no benefit from the barnacle, but the barnacles gain mobility, which helps them evade predators, and are exposed to more diverse feeding opportunities. There are four basic types of commensal relationships. Chemical commensalism occurs when one bacteria produces a chemical that sustains another bacteria. Inquilinism is when one organism lives in the nest, burrow, or dwelling place of another species. Metabiosis is commensalism in which one species is dependent on the other for survival. Phoresy is when one organism temporarily attaches to another organism for the purposes of transportation.

Parasitism

Parasitism is a relationship in which one organism benefits and the other organism is harmed, but not always killed. The organism that benefits is called the parasite, and the one that is harmed is the host. Parasitism is different from parasitoidism, which is when the host is always killed, such as when one organism lays its egg inside another organism that is later eaten by the hatchlings. Parasites can be ectoparasites -- such as ticks, fleas, and leeches -- that live on the surface of the host. Parasites can also be endoparasites -- such as intestinal worms – that live inside the host. Endoparasites can be further categorized into intercellular parasites, that live in the space between cells, or intracellular parasites, which live inside of cells. There is also something called hyperparasitism, which is when a parasite is infected by another parasite, such as a microorganism living in a flea, which lives on a dog. Lastly, a relationship called social parasitism is exemplified by an ant species that does not have worker ants, living among another ant species that do, by using the host species' workers.

Mutualism

Mutualism is a relationship in which both species benefit. Mutualistic interaction patterns occur in three forms. Obligate mutualism is when one species cannot survive apart from the other. Diffusive mutualism is when one organism can live with more than one partner. Facultative mutualism is when one species can survive on its own under certain conditions. On top of these, mutualistic relationships have three general purposes. Trophic mutualism is exemplified in lichens, which consist of fungi and either algae or cyanobacteria. The fungi's partners provide sugar from photosynthesis and the fungi provide nutrients from digesting rock. Defensive mutualism is when one organism provides protection from predators while the other provides food or shelter: an example is ants and aphids. Dispersive mutualism is when one species receives food in return for transporting the pollen of the other organism, which occurs between bees and flowers

Community Ecology

1) Definition: A community is defined as an assemblage of species living close enough together for potential interaction.

2) Populations may be linked by competition, predation, mutualism and commensalism

- Competition.
  - **Interspecific competition** for resources can occur when resources are in short supply.
    - There is potential for competition between any two species that need the same limited resource.
  - The **competitive exclusion principle**: two species with similar needs for same limiting resources cannot coexist in the same place.
  - The **ecological niche** is the sum total of an organism’s use of abiotic/biotic resources in the environment.
    - An organism’s niche is its role in the environment.
    - The **competitive exclusion principle** can be restated to say that two species cannot coexist in a community if their niches are identical.
    - **Resource partitioning** is the differentiation of niches that enables two similar species to coexist in a community.

- **Character displacement** is the tendency for characteristics to be more divergent in sympatric populations of two species than in allopatric populations of the same two species.

3) Trophic structure is a key factor in community dynamics

- The trophic structure of a community is determined by the feeding relationships between organisms.
- The transfer of food energy from its source in photosynthetic organisms through herbivores and carnivores is called the food chain.
- Charles Elton first pointed out that the length of a food chain is usually four or five links, called **trophic levels**.

4) Dominant species and keystone species exert strong controls on community structure

- **Keystone species** exert an important regulating effect on other species in a community.

5) Ecological succession is the sequence of community changes after a disturbance

- **Ecological succession** is the transition in species composition over ecological time.
- **Primary succession** begins in a lifeless area where soil has not yet formed.
- **Secondary succession** occurs where an existing community has been cleared by some event, but the soil is left intact.
- Soil concentrations of nutrients show changes over time.

6) Community biodiversity measures the number of species and their relative abundance

7) Species richness generally declines along an equatorial-polar gradient

8) Species richness is related to a community's geographic size

9) Species richness on an island depends on island size and distance from the mainland

Ecological Succession Definition

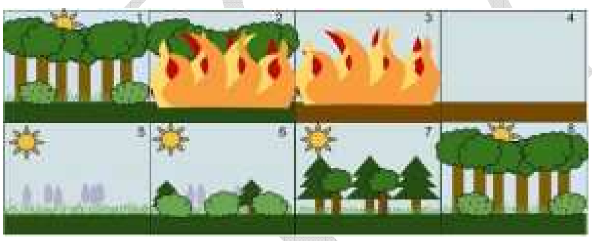
Ecological succession is a term developed by botanists to describe the change in structure of a community of different species, or *ecosystem*. The concept of ecological succession arose from a desire to understand how large and complex ecosystems like forests can exist in places known to be recently formed, such as volcanic islands. The different types of ecological succession exists during different phases of an ecosystem, and depend on how developed that ecosystem is. In the concept of ecological succession, ecosystems advance until they reach a *climax community*. In the climax community, all of the resources are efficiently used and the total mass of vegetation maxes out. Many forests that have not been disturbed in many years are examples of a climax community.

Types of Ecological Succession

Primary Succession

When the planet first formed, there was no soil. Hot magma and cold water make hard rocks, as seen by newly formed islands. Primary ecological succession is the process of small organisms and erosion breaking down these rocks into soil. Soil is then the foundation for higher forms of plant life. These higher forms can produce food for animals, which can then populate the area as well. Eventually, a barren landscape of rocks will progress through primary ecological succession to become a climax community. After years and years, the soil layer increases in thickness and harbors many nutrients and beneficial bacteria that are required to support advanced plant life. If this primary ecosystem is disturbed and wiped out, secondary succession can take place.

Secondary Succession



The above graphic is an example of secondary ecological succession. The first picture displays a climax community. As the frames progress, the community is destroyed by a fire. As long as the fire does not burn hot enough to destroy the soil and the organisms it harbors, secondary ecological succession will take place. As seen in frame 5, small plants will come back first. After they create a solid layer of vegetation, larger plants will be able to take root and become established. At first, small shrubs and trees will dominate. As the trees grow, they will begin to block the light from most of the ground, which will change the structure of the species below the canopy. Eventually (frame 8), the ecosystem will arrive at a climax community, which may or may not be the similar to the original community. It all depends on which species colonize the area, and which seeds are able to germinate and thrive.

Cyclic Succession

Cyclic ecological succession happens within established communities and is merely a changing of the structure of the ecosystem on a cyclical basis. Some plants thrive at certain times of the year, and lay dormant the rest. Other organism, like cicadas, lay dormant for many years and emerge all at once, drastically changing the ecosystem.

Examples of Ecological Succession

Acadia National Park

Acadia National Park, in Maine, suffered a large wildfire in 1947 of over 10,000 acres. Being nearly 20% of the parks size, many were concerned that the park would be destroyed forever. Restoration efforts were left to nature however, and many think that the choice to not intervene paid off. While the first years were ugly, and only small plants could colonize the burnt soil, many years has led to a great amount of diversity in the tree species. While the trees before the fire were mostly evergreen trees, deciduous forests now dominate the landscape. This example shows how quickly secondary ecological succession can change a landscape.

Coral Reef Ecological Succession

While ecological succession is a term coined by botanist, it also applies heavily to animal population that go through a disruption. Take, for instance, a coral reef. The coral reef as an ecosystem did not just pop into existence, but like many plant communities had to be formed over time through ecological succession. The primary ecological succession in a coral reef is the colonizing of rocks by small coral polyps. These polyps will grow and divide many times to create coral colonies. The shapes and shelter of the coral colonies eventually attract small fish and crustaceans that live in an around the coral. Smaller fish are food for larger fish, and eventually a fully functioning coral reef exists. The principles of ecological succession, while developed in context to plants, exists in all established ecosystems.

UNIT-II

SYLLABUS

Unit – II

Ecosystem, Applied and conservation Ecology: Ecosystem structure; function; energy flow and mineral cycling (C,N,P), structure and function of some Indian ecosystems: terrestrial (forest, grassland) and aquatic (fresh water, marine, eustarine). Biogeography: Major terrestrial biomes; theory; biogeographical zones of India. Applied Ecology: pollution; global change; biodiversity: status, monitoring and documentation; major drivers, management approaches. Conservation Biology: Principles, approaches, Indian case studies on conservation/management strategy (Project Tiger, Biosphere reserves).

Ecosystems: Concept, Structure and Functions!

Concept of an Ecosystem:

Living organisms cannot live isolated from their non-living environment because the latter provides materials and energy for the survival of the former i.e. there is interaction between a biotic community and its environment to produce a stable system; a natural self-sufficient unit which is known as an ecosystem.

An ecosystem is, therefore, defined as a natural functional ecological unit comprising of living organisms (biotic community) and their non-living (abiotic or physio chemical) environment that interact to form a stable self-supporting system. A pond, lake, desert, grassland, meadow, forest etc. are common examples of ecosystems.

Structure and Function of an Ecosystem:

Each ecosystem has two main components:

(1) Abiotic

(2) Biotic

(1) Abiotic Components:

The non living factors or the physical environment prevailing in an ecosystem form the abiotic components. They have a strong influence on the structure, distribution, behaviour and inter-relationship of organisms.

Abiotic components are mainly of two types:

(a) Climatic Factors:

Which include rain, temperature, light, wind, humidity etc.

(b) Edaphic Factors:

Which include soil, pH, topography minerals etc.?

The functions of important factors in abiotic components are given below:

Soils are much more complex than simple sediments. They contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic matter, and living organisms. Soils provide nutrients, water, a home, and a structural growing medium for organisms. The vegetation found growing on top of a soil is closely linked to this component of an ecosystem through nutrient cycling.

The atmosphere provides organisms found within ecosystems with carbon dioxide for photosynthesis and oxygen for respiration. The processes of evaporation, transpiration and precipitation cycle water between the atmosphere and the Earth's surface.

Solar radiation is used in ecosystems to heat the atmosphere and to evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis. Photosynthesis provides the energy for plant growth and metabolism, and the organic food for other forms of life.

Most living tissue is composed of a very high percentage of water, up to and even exceeding 90%. The protoplasm of a very few cells can survive if their water content drops below 10%, and most are killed if it is less than 30-50%.

Water is the medium by which mineral nutrients enter and are trans-located in plants. It is also necessary for the maintenance of leaf turgidity and is required for photosynthetic chemical reactions. Plants and animals receive their water from the Earth's surface and soil. The original source of this water is precipitation from the atmosphere.

(2) Biotic Components:

The living organisms including plants, animals and micro-organisms (Bacteria and Fungi) that are present in an ecosystem form the biotic components.

On the basis of their role in the ecosystem the biotic components can be classified into three main groups:

(A) Producers

(B) Consumers

(C) Decomposers or Reducers.

(A) Producers:

The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. This process is known as photosynthesis. As the green plants manufacture their own food they are known as Autotrophs (i.e. auto = self, trophos = feeder)

The chemical energy stored by the producers is utilised partly by the producers for their own growth and survival and the remaining is stored in the plant parts for their future use.

(B) Consumers:

The animals lack chlorophyll and are unable to synthesise their own food. Therefore, they depend on the producers for their food. They are known as heterotrophs (i.e. heteros = other, trophos = feeder)

The consumers are of four types, namely:

(a) Primary Consumers or First Order Consumers or Herbivores:

These are the animals which feed on plants or the producers. They are called herbivores. Examples are rabbit, deer, goat, cattle etc.

(b) Secondary Consumers or Second Order Consumers or Primary Carnivores:

The animals which feed on the herbivores are called the primary carnivores. Examples are cats, foxes, snakes etc.

(c) Tertiary Consumers or Third Order Consumers:

These are the large carnivores which feed on the secondary consumers. Example are Wolves.

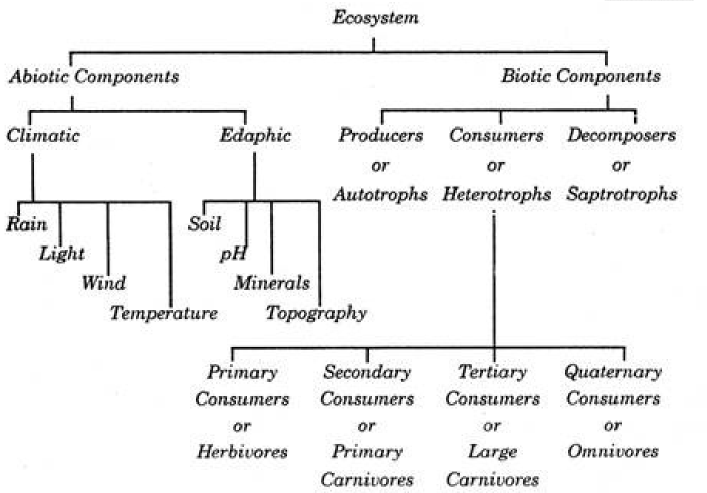
(d) Quaternary Consumers or Fourth Order Consumers or Omnivores:

These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.

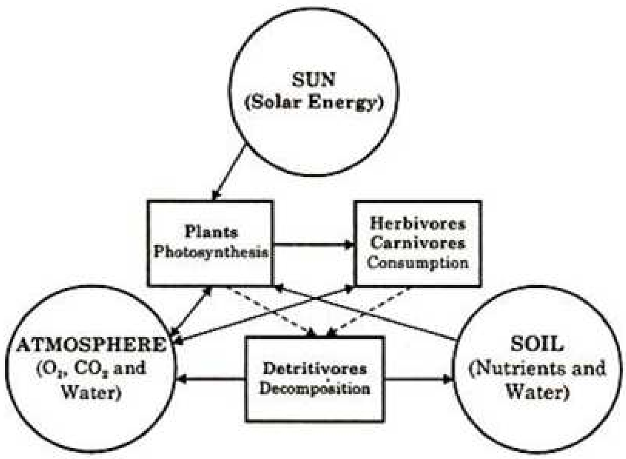
(C) Decomposers or Reducers:

Bacteria and fungi belong to this category. They breakdown the dead organic materials of producers (plants) and consumers (animals) for their food and release to the environment the simple inorganic and organic substances produced as by-products of their metabolisms.

These simple substances are reused by the producers resulting in a cyclic exchange of materials between the biotic community and the abiotic environment of the ecosystem. The decomposers are known as Saprotrophs (i.e., sapros = rotten, trophos = feeder)



Schematic Representation of the Structure of an Ecosystem.



Relationship within an Ecosystem.

Energy Flow Through Ecosystems

Ecosystems maintain themselves by cycling energy and nutrients obtained from external sources. At the first trophic level, primary producers (plants, algae, and some bacteria) use solar energy to produce organic plant material through photosynthesis. Herbivores—animals that feed solely on plants—make up the second trophic level. Predators that eat herbivores comprise the third trophic level; if larger predators are present, they represent still higher trophic levels. Organisms that feed at several trophic levels (for example, grizzly bears that eat berries and salmon) are classified at the highest of the trophic levels at which they feed. Decomposers, which include bacteria, fungi, molds, worms, and insects, break down wastes and dead organisms and return nutrients to the soil.

On average about 10 percent of net energy production at one trophic level is passed on to the next level. Processes that reduce the energy transferred between trophic levels include respiration, growth and reproduction, defecation, and nonpredatory death (organisms that die but are not eaten by consumers). The nutritional quality of material that is consumed also influences how efficiently energy is transferred, because consumers can convert high-quality food sources into new living tissue more efficiently than low-quality food sources.

The low rate of energy transfer between trophic levels makes decomposers generally more important than producers in terms of energy flow. Decomposers process large amounts of organic material and return nutrients to the ecosystem in inorganic form, which are then taken up again by primary producers. Energy is not recycled during decomposition, but rather is released, mostly as heat (this is what makes compost piles and fresh garden mulch warm). Figure 6 shows the flow of energy (dark arrows) and nutrients (light arrows) through ecosystems.

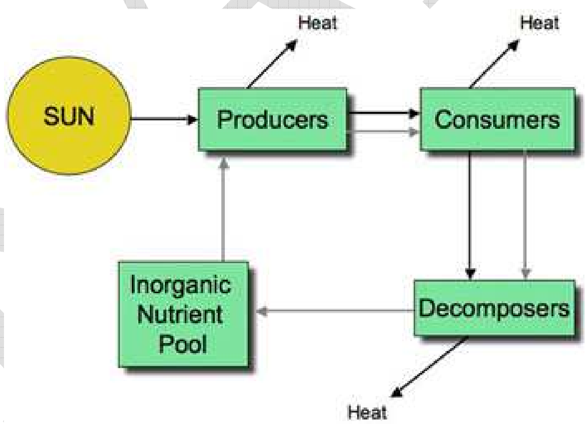


Figure 6. Energy and nutrient transfer through ecosystems
See larger image

Source: � Ohio Environmental Protection Agency. Nature Connections.

An ecosystem's gross primary productivity (GPP) is the total amount of organic matter that it produces through photosynthesis. Net primary productivity (NPP) describes the amount of energy that remains available for plant growth after subtracting the fraction that plants use for respiration. Productivity in land ecosystems generally rises with temperature up to about 30°C, after which it declines, and is positively correlated with moisture. On land primary productivity thus is highest in warm, wet zones in the tropics where tropical forest biomes are located. In contrast, desert scrub ecosystems have the lowest productivity because their climates are extremely hot and dry (Fig. 7).

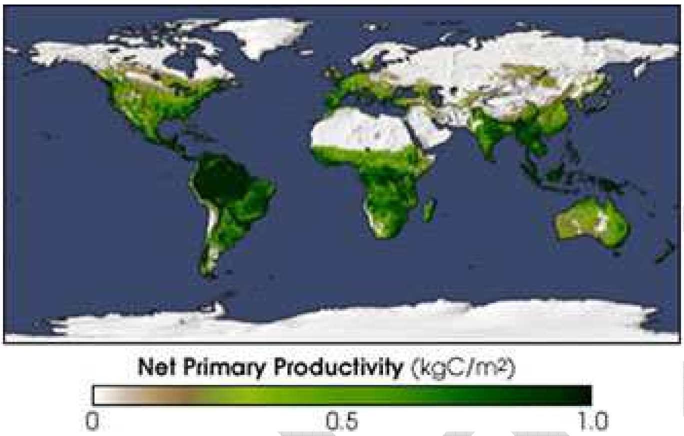


Figure 7. Terrestrial net primary productivity
See larger image

Source: � National Aeronautics and Space Administration.

In the oceans, light and nutrients are important controlling factors for productivity. As noted in Unit 3, "Oceans," light penetrates only into the uppermost level of the oceans, so photosynthesis occurs in surface and near-surface waters. Marine primary productivity is high near coastlines and other areas where upwelling brings nutrients to the surface, promoting plankton blooms. Runoff from land is also a source of nutrients in estuaries and along the continental shelves. Among aquatic ecosystems, algal beds and coral reefs have the highest net primary production, while the lowest rates occur in the open due to a lack of nutrients in the illuminated surface layers (Fig. 8).

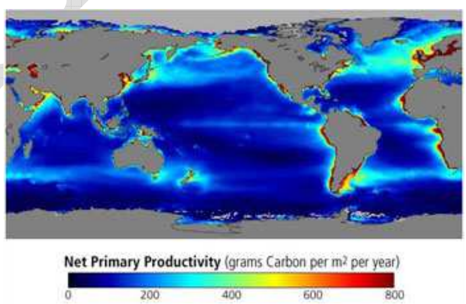


Figure 8. Ocean net primary productivity, 1997-2002
See larger image

Source: � National Aeronautics and Space Administration.

How many trophic levels can an ecosystem support? The answer depends on several factors, including the amount of energy entering the ecosystem, energy loss between trophic levels, and the form, structure, and physiology of organisms at each level. At higher trophic levels, predators generally are physically larger and are able to utilize a fraction of the energy that was produced at the level beneath them, so they have to forage over increasingly large areas to meet their caloric needs.

Because of these energy losses, most terrestrial ecosystems have no more than five trophic levels, and marine ecosystems generally have no more than seven. This difference between terrestrial and marine ecosystems is likely due to differences in the fundamental characteristics of land and marine primary organisms. In marine ecosystems, microscopic phytoplankton carry out most of the photosynthesis that occurs, while plants do most of this work on land. Phytoplankton are small organisms with extremely simple structures, so most of their primary production is consumed and used for energy by grazing organisms that feed on them. In contrast, a large fraction of the biomass that land plants produce, such as roots, trunks, and branches, cannot be used by herbivores for food, so proportionately less of the energy fixed through primary production travels up the food chain.

Growth rates may also be a factor. Phytoplankton are extremely small but grow very rapidly, so they support large populations of herbivores even though there may be fewer algae than herbivores at any given moment. In contrast, land plants may take years to reach maturity, so an average carbon atom spends a longer residence time at the primary producer level on land than it does in a marine ecosystem. In addition, locomotion costs are generally higher for terrestrial organisms compared to those in aquatic environments.

The simplest way to describe the flux of energy through ecosystems is as a food chain in which energy passes from one trophic level to the next, without factoring in more complex relationships between individual species. Some very simple ecosystems may consist of a food chain with only a few trophic levels. For example, the ecosystem of the remote wind-swept Taylor Valley in Antarctica consists mainly of bacteria and algae that are eaten by nematode worms (footnote 2). More commonly, however, producers and consumers are connected in intricate food webs with some consumers feeding at several trophic levels (Fig. 9).

Figure 9. Lake Michigan food web
See larger image

Source: Courtesy of NOAA Great Lakes Environmental Research Laboratory and the Great Lakes Fishery Commission.

An important consequence of the loss of energy between trophic levels is that contaminants collect in animal tissues—a process called bioaccumulation. As contaminants bioaccumulate up the food web, organisms at higher trophic levels can be threatened even if the pollutant is introduced to the environment in very small quantities.

The insecticide DDT, which was widely used in the United States from the 1940s through the 1960s, is a famous case of bioaccumulation. DDT built up in eagles and other raptors to levels high enough to affect their reproduction, causing the birds to lay thin-shelled eggs that broke in their nests. Fortunately, populations have rebounded over several decades since the pesticide was banned in the United States. However, problems persist in some developing countries where toxic bioaccumulating pesticides are still used.

Bioaccumulation can threaten humans as well as animals. For example, in the United States many federal and state agencies currently warn consumers to avoid or limit their consumption of large predatory fish that contain high levels of mercury, such as shark, swordfish, tilefish, and king mackerel, to avoid risking neurological damage and birth defects.

Nutrient Cycling

The nutrient cycle is a system where energy and matter are transferred between living organisms and non-living parts of the environment. This occurs as animals and plants consume nutrients found in the soil, and these nutrients are then released back into the environment via death and decomposition. In forest environments, there is an exchange of nutrient elements such as hydrogen, nitrogen and oxygen among the soil, plants and animals living within the environment.

What are the Essential Nutrients?

Non-mineral elements make up 95% of the mass of all living organisms

- The non-mineral elements are Carbon (C), Hydrogen (H), Oxygen (O)
- These nutrients are often obtained from carbon dioxide (CO_2) in the air and water (H_2O)

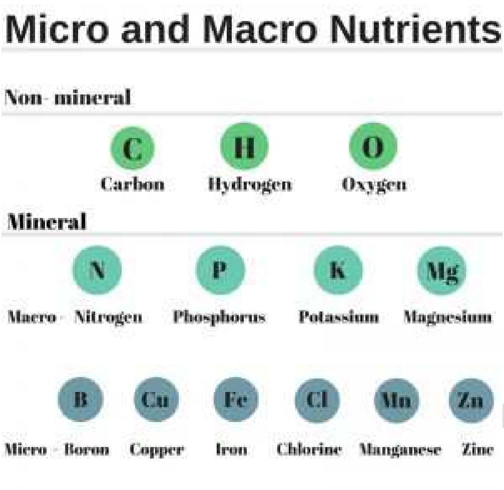
Mineral Elements: Macronutrients and Micronutrients

Macronutrients are chemical elements that plants need in large quantities to perform basic functions, and their availability can limit the growth of organisms.

- They include the elements (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg)

Micronutrients are taken up in much smaller amounts than macronutrients, but are still vital for growth and metabolism.

- The micronutrients include boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn).



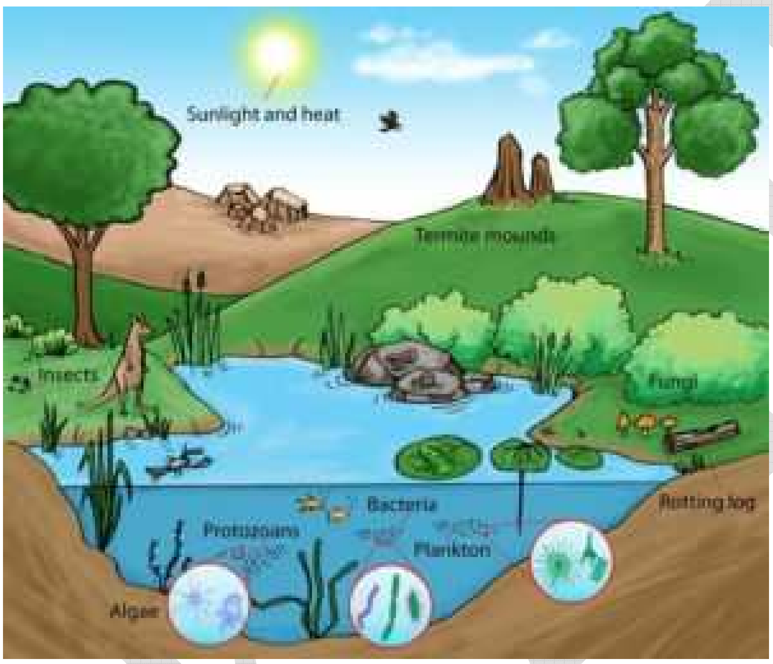
Micro and Macro Nutrients Involved in Nutrient Cycling

Forest Leaves

Nutrient Cycling in Forest Ecosystems

In forest environments, the nutrient cycle involves animals, plants, fungi and bacteria living above- and below-ground (the soil is alive!), as well as mineral components of soil, dead leaves and wood, and water from rain and snowfall. Trees and other plants take up mineral and non-mineral nutrients from the soil through their roots. These nutrients are stored in the leaves, flowers and other parts of plants. The nutrients are either transferred to animals when animals eat the plants or they are transferred back into the soil. For instance, when plants and animals die, arthropods, earthworms, fungi and bacteria in the soil break them down. Arthropods are insects such as mites. Arthropods and earthworms grind up the decaying material and they mix this material with the soil. Fungi can break apart some of the more complex compounds and break them down into smaller components. All of these organisms ultimately consume and respire much of the material back into carbon dioxide gas, which is why it disappears over time.

Concept of an Ecosystem



Living organisms cannot live isolated from their non-living environment because the latter provides materials and energy for the survival of the former i.e. there is an interaction between a biotic community and its environment to produce a stable system; a natural self-sufficient unit which is known as an ecosystem.

An ecosystem, therefore includes all of the living things (plants, animals and organisms) in a given area, interacting with each other, and also with their non-living environments (weather, earth, sun, soil, climate, atmosphere). A pond, lake, desert, grassland, meadow, forest etc. are common examples of ecosystems. Ecosystems are the foundations of the Biosphere and they determine the health of the entire earth system.

This very complex, but wonderful interaction of living things and their environment, has been the foundations of energy flow and recycling of carbon and nitrogen

Anytime a 'stranger' (living thing(s) or an external factor such as rise in temperature) is introduced to an ecosystem, it can be disastrous to that ecosystem. This is because the new organism (or factor) can distort the natural balance of the interaction and potentially harm or destroy the ecosystem.

Usually, biotic members of an ecosystem, together with their abiotic factors depend on each other. This means the absence of one member or one abiotic factor can affect all parties of the ecosystem.

Structure and Function of an Ecosystem

Each ecosystem has two main components:

(1) Abiotic

(2) Biotic

(1) Abiotic Components:

The abiotic components of an ecosystem are all of the nonliving elements. They include the water, the air, the temperature and the rocks and minerals that make up the soil. Abiotic components of an ecosystem might include how much rain falls on it, whether it is fresh water or salt water, how much sun it gets or how often it freezes and thaws.

Abiotic components are mainly of two types:

(a) Climatic Factors:

Which include rain, temperature, light, wind, humidity etc.

(b) Edaphic Factors:

Which include soil, pH, topography minerals etc.?

The functions of important factors in abiotic components are given below:

Soils are much more complex than simple sediments. They contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic matter, and living organisms. Soils provide nutrients, water, a home, and a structural growing medium for organisms. The vegetation found growing on top of a soil is closely linked to this component of an ecosystem through nutrient cycling.

The atmosphere provides organisms found within ecosystems with carbon dioxide for photosynthesis and oxygen for respiration. The processes of evaporation, transpiration and precipitation cycle water between the atmosphere and the Earth's surface.

Solar radiation is used in ecosystems to heat the atmosphere and to evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis. Photosynthesis provides the energy for plant growth and metabolism and the organic food for other forms of life.

Most living tissue is composed of a very high percentage of water, up to and even exceeding 90%. The protoplasm of a very few cells can survive if their water content drops below 10%, and most are killed if it is less than 30-50%.

Water is the medium by which mineral nutrients enter and are trans-located in plants. It is also necessary for the maintenance of leaf turgidity and is required for photosynthetic chemical reactions. Plants and animals receive their water from the Earth's surface and soil. The original source of this water is precipitation from the atmosphere.

(2) Biotic Components:

The living organisms including plants, animals and micro-organisms (Bacteria and Fungi) that are present in an ecosystem form the biotic components. The biotic components of the ecosystem both live on and interact with the abiotic components.

On the basis of their role in the ecosystem the biotic components can be classified into three main groups:

(A) Producers

(B) Consumers

(C) Decomposers or Reducers.

(A) Producers:

1. Producers are the living organisms in the ecosystem that take in energy from sunlight and use it to transform carbon dioxide and oxygen into sugars.
2. Plants, algae and photosynthetic bacteria are all examples of producers. As the green plants manufacture their own food they are known as Autotrophs (i.e. auto = self, trophos = feeder). Producers form the base of the food web and are generally the largest group in the ecosystem by weight, or biomass.
3. They also act as an interface with the abiotic components of the ecosystem during nutrient cycles as they incorporate inorganic carbon and nitrogen from the atmosphere.
4. The chemical energy stored by the producers is utilized partly by the producers for their own growth and survival and the remaining is stored in the plant parts for their future use.

(B) Consumers:

1. Consumers are living organisms in the ecosystem that get their energy from consuming other organisms. Conceptually, consumers are further subdivided by what they eat.

2. Herbivores eat producers, carnivores eat other animals and omnivores eat both. Along with producers and decomposers, consumers are part of what is known as food chains and webs, where energy and nutrient transfer can be mapped out.
3. Consumers can only harvest about 10 percent of the energy contained in what they eat, so there tends to be less biomass at each stage as you move up the food chain.

The consumers are of four types, namely:

(a) Primary Consumers or First-Order Consumers or Herbivores:

These are the animals which feed on plants or the producers. They are called herbivores. Examples are rabbit, deer, goat, cattle etc.

(b) Secondary Consumers or Second Order Consumers or Primary Carnivores:

The animals which feed on the herbivores are called the primary carnivores. Examples are cats, foxes, snakes etc.

(c) Tertiary Consumers or Third Order Consumers:

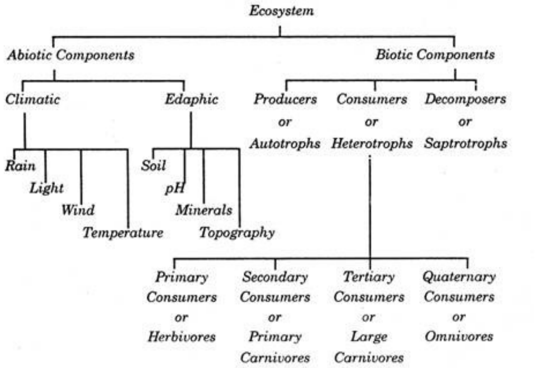
These are the large carnivores which feed on the secondary consumers. Example are Wolves.

(d) Quaternary Consumers or Fourth Order Consumers or Omnivores:

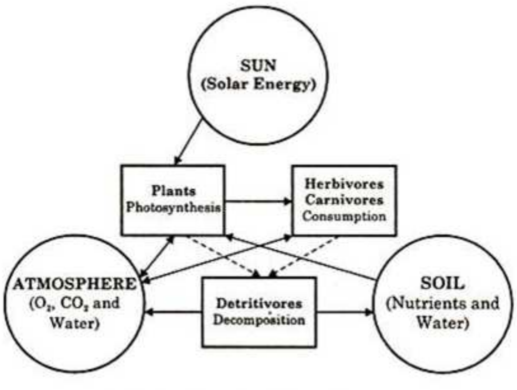
These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.

(C) Decomposers or Reducers:

1. Decomposers are the living component of the ecosystem that breaks down waste material and dead organisms. Examples of decomposers include earthworms, dung beetles and many species of fungi and bacteria.
2. The decomposers are known as Saprotrophs (i.e., sapros = rotten, trophos = feeder).
3. They perform a vital recycling function, returning nutrients incorporated into dead organisms to the soil where plants can take them up again.
4. In this process, they also harvest the last of the sunlight energy initially absorbed by producers. Decomposers represent the final step in many of the cyclical ecosystem processes.



Schematic Representation of the Structure of an Ecosystem.



Relationship within an Ecosystem.

Major Types of Terrestrial Ecosystems?

The concept of ecosystem includes the abiotic (or non-living) and biotic (or living) portions of an area as well as the interactions between the two. Matter and energy flow between the abiotic and biotic components of the ecosystem. Abiotic factors influencing an ecosystem include temperature, precipitation, elevation and soil type. Scientists divide ecosystems into terrestrial and non-terrestrial. Ecosystems may be further classified by their geographical region and dominant plant type. Aquatic, marine and wetlands constitute the non-terrestrial ecosystems, while the five major terrestrial ecosystems are desert, forest, grassland, taiga and tundra.

Desert Ecosystems

The amount of rainfall is the primary abiotic determining factor of a desert ecosystem. They receive less than 25 centimeters (about 10 inches) of rain per year. Large fluctuations between day and night temperature characterize deserts. The soils contain high mineral content with little organic matter. The vegetation ranges from nonexistent to including large numbers of highly adapted plants. The Sonora Desert ecosystem contains a variety of succulents or cactus as well as trees and shrubs. They have adapted their leaf structures to prevent water loss. For instance, the Creosote shrub has a thick layer covering its leaves to prevent water loss due to transpiration.

Forest Ecosystems

About one third of the Earth's land is covered in forest. The primary plant in this ecosystem is trees. Forest ecosystems are subdivided by the type of tree they contain and the amount of precipitation they receive. Some examples of forests are are temperate deciduous, temperate rainforest, tropical rainforest, tropical dry forest and northern coniferous forests. Tropical dry forests have wet and dry seasons, while tropical rain forests have rain year-round. Both of these forests suffer from human pressure, such as trees being cleared to make room for farms. Because of the copious amounts of rain and favorable temperatures, rainforests have high biodiversity.

Taiga Ecosystems

Another type of forest ecosystem is the taiga, also known as northern coniferous forest or boreal forest. It covers a large range of land stretching around the northern hemisphere. It is lacking in biodiversity, having only a few species. Taiga ecosystems are characterized by short growing seasons, cold temperatures, and poor soil. They have long summer days, and very short winter days. Animals found in the taiga include lynx, moose, wolves, bears and burrowing rodents.

Grassland Ecosystems

Temperate grasslands include prairies and steppes. They have seasonal changes, but don't get enough rainfall to support large forests. Savannas are tropical grasslands. Savannas have seasonal precipitation differences, but temperatures remain constant. Grasslands around the world have been converted to farms, decreasing the amount of biodiversity in these areas. The prominent animals in grassland ecosystems are grazers such as gazelle and antelope.

Tundra

Two types of tundra exist: Arctic and alpine. The Arctic tundra is located in the Arctic Circle, north of the boreal forests. Alpine tundras occur on mountain tops. Both types experience cold temperatures throughout the year. Because the temperatures are so cold, only the top layer of soil thaws during the summer; the rest of it remains frozen year round, a condition known as permafrost. Plants in the tundra are primarily lichens, shrubs, and brush. Tundras do not have trees. Most animals that live in the tundra migrate south or down the mountain for the winter.

Various Land Biomes?

Planet Earth is a world filled with endless, scintillating places. It also harbors a glittering array of many plant and animal species. These plant and animal species live in completely diverse environments. These diverse environments are commonly known as biomes. Biomes differ in climate, precipitation, location, and plants and animals. **There are two major categories of biomes; Aquatic and land (terrestrial) biomes**.

Aquatic biomes occur under water bodies. The water body can be fresh water or salt water. Aquatic biomes are further divided into freshwater biomes and marine biomes. Freshwater biomes include lakes, rivers, streams, and ponds. Marine biomes include oceans, coral reefs, and estuaries.

Land Biomes or terrestrial biomes form on dry land. They are very distinct in regard to climate, plant and animal life. Many land biomes exist in the world today, including tundra biome, desert biome, forest biome, and grassland biome.

Let's have a look at various types of land biomes:

Tundra Biome

The tundra biome is a collection of habitats with different plant and animal species of various characteristics and adaptations. This biome is situated in proximity to the North Pole in the Arctic Circle. It's regarded as the coldest biome in the world. Tundra biome is typically extremely cold, with temperatures plummeting as low as -34 degrees Celsius. This biome experiences only two months of summer, with average temperatures still extremely cold between 3 degrees Celsius to 12 degrees Celsius. Although tundra biome experiences freezing temperatures, plants and animals still live here.

Desert Biome

The desert biome is a collection of ecosystems that form as a result of the extremely low levels of rainfall it receives each year. Desert biomes attribute to approximately 20% of the surface of the earth. Four main types of deserts exist in this biome, including hot and dry deserts, semi-arid deserts, coastal deserts and cold deserts.

The desert climate is extremely hot and dry. Annual average precipitation is 25 cm. Spring and summer experience the least rain in the desert biome. Desert biomes temperatures vary considerably. Temperatures are lower than the ordinary; it gets hotter during spring and summer and cools down a little bit in fall. Despite the scant rainfall experienced in desert biomes, a wide range of animals and plants live here.

Plants in the desert have developed special adaptations to survive here. They shed leaves to prevent moisture loss; some are thorny to protect themselves from herbivores. Succulent plants like cactus store a lot of water for later use. Others have deep roots to reach water tables.

Animals also have developed unique traits to survive the harsh temperatures in the desert biome. They stay in shadows of plants to avoid direct heat from the sun. Some burrow into the ground to escape the intense heat. Other animals remain inactive during the day when temperatures are extremely high, and become active at night when temperatures drop. A few animals have developed salt glands, which mean they will secret salt without loss of water. Animals like camels store fat in humps, instead of the body. The fat storage in the hump means the camel can go for days without food and water.

Forest Biome

A Forest biome is a collection of habitats where trees are in bountiful supply. Forest biomes are divided into 5 major categories depending upon the kind of trees growing there. These kinds of forest biomes include Tropical forest biome, temperate forest biome, and taiga (boreal forest biome).

Tropical Forest biomes experience average annual temperatures of approximately 50 degrees Fahrenheit. Average annual precipitation is 30 to 60 inches per year. They are situated on the eastern half of U.S., Europe, Canada, parts of Russia, Japan and China. This biome does not have a lot of plant life, but are dense with trees containing shocking amount of flowers. Animals living here must adjust to the cold winters and hot summers to survive.

Temperate forest biomes are located in eastern North America, northeastern Asia, western and central Europe. Temperatures in temperate forest biomes vary considerably from -30 degrees Celsius to 30 degrees Celsius. The average annual precipitation is 75 to 150 cm, which is distributed all year round. Trees in temperate forest biome are characterized by broad leaves that are lost each year. Typical tree species include oak, hemlock, hickory, maple, cottonwood, beech, basswood, willow, and elm. Animals are represented by different bird species, squirrels, skunks, rabbits, bobcat, fox, wolf, mountain lion, deer and black bear.

Taiga (Boreal Forest) Biome

Taiga is the largest terrestrial biome. It's located between 50 and 60 degrees north latitudes. Taiga biome is also located in the expansive belt of Eurasia and North America, with two-thirds occurring in Siberia and the rest in Alaska, Canada, and Scandinavia. Temperatures are extremely low, with precipitation occurring in the form of snow (40-100cm yearly). Plants in taiga biome mainly consist of cold-resistant evergreen conifers, featuring needle-like leaves, such as spruce, fir, and spine. Animal species here include fox, chipmunks, hawks, bats, weasel, moose, bear, wolf, screws, hares, and deer.

Grassland Biome

Grassland biomes are characterized by large, rolling terrains of wide-ranging grass species. Large shrubs and trees are scarce in this biome. Grassland biomes attribute to approximately one-quarter of the earth's land surface. They are considered to be between a forest and a desert regarding rainfall. Grassland biomes don't experience a lot of rainfall to support the growth of numerous trees like the forest biome, but they have lots of grass, which means they receive more rain than desert. Two main types of grassland biomes exist in the world; savanna grasslands and temperate grasslands.

Savanna grassland biome has wet and dry climate. Seasons vary considerably in savanna biome. The dry season comes in winter. All the rain is experienced in summer. The savanna biome experiences a temperature range of 68 to 86 degrees Fahrenheit (25-30 degree Celsius). Winter temperatures range from 78 to 86 degrees Fahrenheit (25 to 30 degrees Celsius. The average annual precipitation in the savanna biome is 10 to 30 inches (100 to 150 cm).

The vast sections of the savanna are covered by different species of grass including star grass, lemon grass, Bermuda grass and Rhodes grass. Trees are also scattered in this biome. Examples of trees growing in the savanna include baobab tree, acacia, and jackal berry tree. Plants have developed adaptations to get by in the dry season and drought of the savanna. Some plant species store water and energy in their trunk, roots, and bulbs. Others have deep roots that are able to reach water tables.

Temperate grassland biomes are situated in colder climate regions and generally receive less precipitation than savanna. Temperatures in the temperate grasslands differ with seasons. Temperatures can drop to below zero degrees Fahrenheit in winter. Summer temperatures, on the other hand, can go up to 90 degrees Fahrenheit. Temperate grassland biomes are situated north of the Tropic of Cancer about 23.5 degrees North, and south of the Tropic of Capricorn about 23.5 degrees South.

Grasses predominate in temperate grassland biomes. Large shrubs and trees are scarce due to occasional fires, seasonal drought, and grazing by large mammals. Tree species such as oaks, cottonwoods, and willows thrive in river valleys, including species of flowers, which grow among them.

Temperate grassland biomes support a low diversity of wildlife. However, there is an abundance of wildlife here. Examples of animals living in temperate grassland biomes include bison, pronghorn, pocket gophers, prairie dogs, coyotes, wolves, badgers, swift foxes, black-footed ferrets, Hawks, owls, quails, sparrows, grouses, meadowlarks.

The soil in temperate grassland is rich in nutrients. The nutrients come from the growth and decomposition of grass roots. The rooted roots also hold the soil intact and prevent running water from stealing the soil.

Marine Freshwater Biome

The world’s aquatic biomes cover three quarters of the earth’s surface, comprising two main categories: the marine regions and the freshwater regions. Fresh water has an extremely low concentration of salt, generally below one percent. Marine regions have higher concentrations of salt. Marine biomes – for the most part oceans – account for about 72 percent of the earth’s surface, according to National Geographic Society.

Land Features Around Freshwater Biomes

Freshwater biomes include rivers, streams, ponds, lakes and wetlands, such as marshes, alongside river estuaries. Ponds and lakes are essentially basins filled with water. The depression caused by flowing water of rivers and streams is called a channel, and the bends along the water's path are called meanders. Common land features along rivers that have overflowed their banks in the past are floodplains on which river sediment builds up to form natural levees.

Land Features Under the Ocean

Marine regions include oceans, coral reefs and estuaries. The ocean meets the land in the "intertidal zone." In the ocean, or rather under it, are continental shelves, abyssal plains (at the deepest points under the ocean), rises, ridges, basin-shaped estuaries and trenches. Coral reefs are not land in the same sense as other forms, but rather the secretions of living creatures called coral that build an extraordinary ecosystem that is habitat to more species.

Land Features Where the Oceans Meet the Shore

Where oceans meet the land in the intertidal zones, common landforms are beaches, headlands, spits (created by waves striking the beach diagonally, forming ridges of sand and other sediment carried by the waves), lagoons, sand islands, rocky islets or cliffs. A sea cliff slopes down from above ground to under water, and erodes at different rates depending on the types of rock and velocity of wave movement. Some sea cliffs can be eroded to the point of separating into discrete parts to become sea arches or sea stacks.

Marine and Freshwater Biomes Combine in Estuaries

Estuaries are a combination of two aquatic biomes where the fresh water in rivers or wetlands meets and mixes with the salt water of the sea. This water is called brackish. Many (but not all) bays, lagoons, harbors and sounds may be estuaries. For example, San Francisco Bay and New York Harbor are both estuaries. All estuaries are partially enclosed by natural land barriers -- including barrier islands and peninsulas -- that protect them from the waves and wild storms of the sea.

Estuarine ecosystems

Introduction

Estuaries, or transitional waters, represent the transition between freshwater and marine environments and are influenced by both aquatic realms. Salinity levels are indicative of the position within the mixing zones of an estuary. The upper limit of an estuary is referred to as its head, while the lower limit is called the mouth of the estuary. Between the freshwater head and the saline mouth of the estuary lie a number of zones marked by intermediate salinity values, each with distinct characteristics pertaining to light penetration and type of substratum, thus hosting different communities of organisms.

Estuary division	Substratum	Salinity range	Zone	Organism type
river	gravels	<0.05	limnetic	freshwater
head	becoming finer	0.5 - 5.0	oligohaline	oligohaline, freshwater migrants
upper reaches	mud, currents minimal	5.0 - 18.0	mesohaline	true estuarine, limit of non-transient migrants
middle reaches	mud, some sand	18.0 - 25.0	polyhaline	estuarine, euryhaline
lower reaches	sand/mud depending on tidal currents	25.0 - 30.0	polyhaline	estuarine, euryhaline, marine migrants
mouth	clean sand/rock	30.0 - 35.0	euhaline	stenohaline, all marine

Division of transitional waters (Carricker, 1967[1]; McLusky, 1989[2])

The challenges of estuarine ecosystems

Estuaries are peculiar yet challenging ecosystems. The main challenge and at the same time the most important feature governing species diversity of transitional waters is the **variable salinity regime**. Salt dissolved in water dehydrates living organisms by exerting what is called osmotic pressure on the cell walls. Organisms living in the sea are equipped with buffering mechanisms allowing them to retain their body fluids in the presence of salt. In most cases this mechanism is adjusted to a particular salinity and yields a distinction between freshwater and marine species. Most aquatic organisms fall into one of these categories. In turn very few species can withstand variable salinity, which has implications for the biodiversity of estuaries.

Turbid waters of the Shannon Estuary

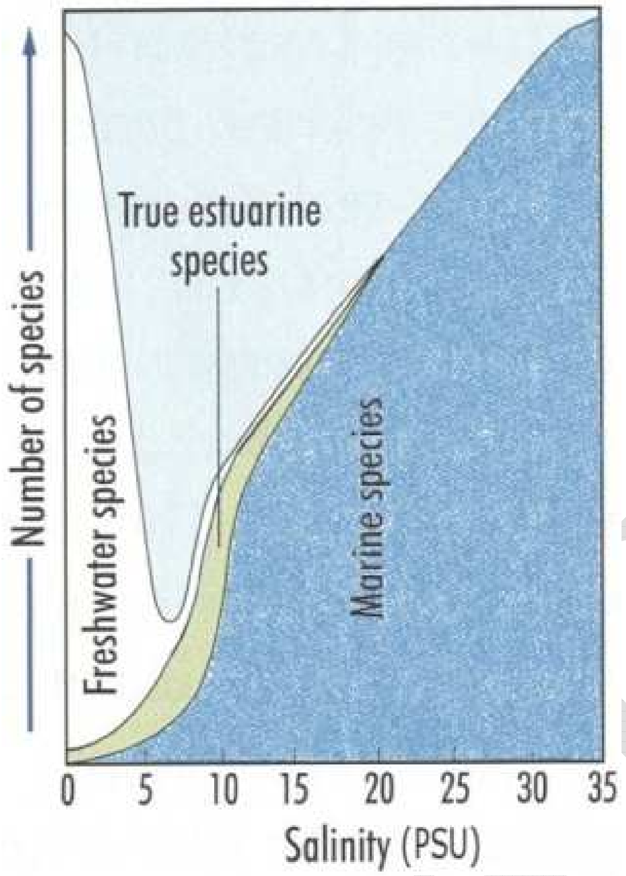
Lowland reaches of rivers are characterised by high levels of suspended solids, such as silt, clay and organic detritus, inducing high turbidity. In the fresh water – sea water transition zone these particles become effectively 'trapped' due to flocculation and converging suspended sediment fluxes [3][4] (see also Dynamics of mud transport). These convergences result in pronounced estuarine turbidity maxima (ETM).

Turbidity limits the depth of the photic zone (light penetration zone), thus limiting the photosynthesis and primary production. Much of the primary production in estuaries occurs on the seaward side of the ETM (Swart, 2007[5]). Macrophyte vegetation and benthic algae are often limited to the periodically exposed (intertidal) part of the estuary, while the growth of phytoplankton is restricted to a thin uppermost layer of the water column (Cloern, 1997[6].) As a result, estuaries are **heterotrophic systems**, where more energy is consumed than produced. Most estuarine species are detritivores, meeting their energy intake requirements from organic matter contained either in the sediment (deposit feeders), in suspension (filter feeders) or both. Benthic invertebrates play a major role in energy transfer and circulation in estuaries (Wilson & Parkes, 1998[7]).

Particulate matter eventually settles out and the substratum of estuarine mid reaches tends to be composed of fine fractions, typically creating **extensive sand and mudflats**. These conditions hinder organisms with an affinity for hard substratum but constitute important habitats for a range of burrowing invertebrate species, of which bivalve molluscs and polychaete worms are usually dominant in terms of numbers and biomass. These in turn provide a rich feeding opportunity for a range of higher consumers.

Industrialised and urbanised river catchments and estuaries receive anthropogenic input from various sources (both point sources and diffuse sources) and often carry a range of contaminants. Sheltered, low-energy areas such as intertidal mudflats in enclosed bays or estuaries are most susceptible to these pollutants due to slow dispersion. The finer substrata in these areas act as a **sink for contaminants** making estuarine benthic fauna susceptible to pollution (Kausch & Michaelis, 1996[8]).

Biodiversity of estuarine ecosystems



Species richness in estuaries follows a long established pattern along the salinity gradient described by Remane (1934[9])

Truly **estuarine species** are those that complete their whole life cycle within the transitional waters. Species permanently dwelling there are mostly hardy, stress-tolerant species able to handle salinity shifts and high suspended solid levels. Not many species can perform well under such conditions. Estuarine ecosystems are thus typically characterised by relatively low species diversity comparing to freshwater or full salinity conditions. Freshwater species are becoming less abundant with increasing salinity and are gradually replaced by marine organisms moving down the estuary with some truly estuarine species found at intermediate salinities. This pattern is reflected by the overall species richness, where the least diverse fauna is found at salinity levels of between 5 and 18 PSU.

Apart from the permanent dwellers, estuaries are host to a number of **visitors**. Some of them have to travel through estuaries on their migratory route, being either anadromous (spawn in freshwater and feed and grow at sea) or catadromous (spawn at sea and feed and grow in freshwater). The absence of many of the marine predators and rich particulate food supply offer attractive spawning and nursery grounds for many species that normally live under full salinity conditions. Even though estuarine ecosystems are usually species-poor, they maintain a high productive throughput of invertebrate fauna. This productivity provides rich feeding opportunities for a range of higher consumers. Some marine predators are well equipped to cope with reduced salinity and frequently enter estuaries in search of food. Ebb tide makes estuarine beds available to terrestrial predators, of which birds take the greatest share. Estuarine sand and mudflats that are periodically exposed to air support high densities of a diverse bird fauna. This value of estuaries has been long recognized and many estuarine sand and mudflats have been designated as Special Protection Areas (SPA) under the EU Birds Directive (79/409/EEC).

Threats

Estuarine ecosystems are usually dominated by stress-tolerant organism, able to withstand a relatively wide range of environmental factors. However, they to face some threats from anthropogenic activities.

- Estuaries are preferred locations for human settlement due to their high productivity and availability of natural connections between maritime and inland waterways. Residential, recreational and industrial developments (such as marinas, harbours or ports) are usually located right at the waterfront with supporting structures such as embankments impacting on the upper shore communities. Estuaries are often challenged by **land development**; land reclamation is particularly detrimental in this respect as it results in a permanent loss of habitat.

Highly polluted and channeled section of the Liffey Estuary.

- Rivers discharging into their estuaries carry various constituents depending on the landuse of the drainage area (catchment). This means that various contaminants introduced at any point in the catchment ultimately end up in the estuary. Although estuarine organisms are typically hardy, these **pollutants and excess nutrients** impede their overall performance (including growth and reproduction). Pollution from densely populated or heavily industralised catchments has detrimental effects on life in estuaries. See: Eutrophication in coastal environments, Coastal pollution and impacts.

- Climate change impacts of concern for estuaries are the overall temperature rise and elevation of the sea level. The first one is likely to induce latitudinal migration with more warm-water species being increasingly established and possibly outcompeting the native species in a long run. Sea level rise would result in a shift of the salinity zonation landwards (see also Effects of global climate change on European marine biodiversity). However, coastal areas, including estuaries, are usually heavily populated and developed. In such developed areas the vertical shift of salinity zonation can be hindered by flood defence structures and river and shore embankments resulting in estuarine squeeze.

Terrestrial Biomes

There are eight major terrestrial biomes: tropical rainforests, savannas, subtropical deserts, chaparral, temperate grasslands, temperate forests, boreal forests, and Arctic tundra. **Biomes** are large-scale environments that are distinguished by characteristic temperature ranges and amounts of precipitation. These two variables affect the types of vegetation and animal life that can exist in those areas. Because each biome is defined by climate, the same biome can occur in geographically distinct areas with similar climates (Figures 1 and 2).

Tropical rainforests are found in equatorial regions (Figure 1) are the most biodiverse terrestrial biome. This biodiversity is under extraordinary threat primarily through logging and deforestation for agriculture. Tropical rainforests have also been described as nature's pharmacy because of the potential for new drugs that is largely hidden in the chemicals produced by the huge diversity of plants, animals, and other organisms. The vegetation is characterized by plants with spreading roots and broad leaves that fall off throughout the year, unlike the trees of deciduous forests that lose their leaves in one season.

The temperature and sunlight profiles of tropical rainforests are stable in comparison to other terrestrial biomes, with average temperatures ranging from 20^{o}C to 34^{o}C (68^{o}F to 93^{o}F). Month-to-month temperatures are relatively constant in tropical rainforests, in contrast to forests farther from the equator. This lack of temperature seasonality leads to year-round plant growth rather than just seasonal growth. In contrast to other ecosystems, a consistent daily amount of sunlight (11–12 hours per day year-round) provides more solar radiation and therefore more opportunity for primary productivity.

The annual rainfall in tropical rainforests ranges from 125 to 660 cm (50–200 in) with considerable seasonal variation. Tropical rainforests have wet months in which there can be more than 30 cm (11–12 in) of precipitation, as well as dry months in which there are fewer than 10 cm (3.5 in) of rainfall. However, the driest month of a tropical rainforest can still exceed the *annual* rainfall of some other biomes, such as deserts.Tropical rainforests have high net primary productivity because the annual temperatures and precipitation values support rapid plant growth. However, the high amounts of rainfall leaches nutrients from the soils of these forests.

Tropical rainforests are characterized by vertical layering of vegetation and the formation of distinct habitats for animals within each layer. On the forest floor is a sparse layer of plants and decaying plant matter. Above that is an understory of short, shrubby foliage. A layer of trees rises above this understory and is topped by a closed upper canopy—the uppermost overhead layer of branches and leaves. Some additional trees emerge through this closed upper canopy. These layers provide diverse and complex habitats for the variety of plants, animals, and other organisms. Many species of animals use the variety of plants and the complex structure of the tropical wet forests for food and shelter. Some organisms live several meters above ground, rarely descending to the forest floor.

Savannas are grasslands with scattered trees and are found in Africa, South America, and northern Australia (Figure 4 below). Savannas are hot, tropical areas with temperatures averaging from 24°C –29°C (75°F –84°F) and an annual rainfall of 51–127 cm (20–50 in). Savannas have an extensive dry season and consequent fires. As a result, there are relatively few trees scattered in the grasses and forbs (herbaceous flowering plants) that dominate the savanna. Because fire is an important source of disturbance in this biome, plants have evolved well-developed root systems that allow them to quickly re-sprout after a fire.

Subtropical deserts exist between 15° and 30° north and south latitude and are centered on the Tropic of Cancer and the Tropic of Capricorn (Figure 6 below). Deserts are frequently located on the downwind or lee side of mountain ranges, which create a rain shadow after prevailing winds drop their water content on the mountains. This is typical of the North American deserts, such as the Mohave and Sonoran deserts. Deserts in other regions, such as the Sahara Desert in northern Africa or the Namib Desert in southwestern Africa are dry because of the high-pressure, dry air descending at those latitudes. Subtropical deserts are very dry; evaporation typically exceeds precipitation. Subtropical hot deserts can have daytime soil surface temperatures above 60°C (140°F) and nighttime temperatures approaching 0°C (32°F). Subtropical deserts are characterized by low annual precipitation of fewer than 30 cm (12 in) with little monthly variation and lack of predictability in rainfall. Some years may receive tiny amounts of rainfall, while others receive more. In some cases, the annual rainfall can be as low as 2 cm (0.8 in) in subtropical deserts located in central Australia ("the Outback") and northern Africa.

The low species diversity of this biome is closely related to its low and unpredictable precipitation. Despite the relatively low diversity, desert species exhibit fascinating adaptations to the harshness of their environment. Very dry deserts lack perennial vegetation that lives from one year to the next; instead, many plants are annuals that grow quickly and reproduce when rainfall does occur, then they die. Perennial plants in deserts are characterized by adaptations that conserve water: deep roots, reduced foliage, and water-storing stems (Figure 6 below). Seed plants in the desert produce seeds that can lie dormant for extended periods between rains. Most animal life in subtropical deserts has adapted to a nocturnal life, spending the hot daytime hours beneath the ground. The Namib Desert is the oldest on the planet, and has probably been dry for more than 55 million years. It supports a number of endemic species (species found only there) because of this great age. For example, the unusual gymnosperm *Welwitschia mirabilis* is the only extant species of an entire order of plants. There are also five species of reptiles considered endemic to the Namib.

In addition to subtropical deserts there are **cold deserts** that experience freezing temperatures during the winter and any precipitation is in the form of snowfall. The largest of these deserts are the Gobi Desert in northern China and southern Mongolia, the Taklimakan Desert in western China, the Turkestan Desert, and the Great Basin Desert of the United States.

The **chaparral** is also called scrub forest and is found in California, along the Mediterranean Sea, and along the southern coast of Australia (Figure 7 below). The annual rainfall in this biome ranges from 65 cm to 75 cm (25.6–29.5 in) and the majority of the rain falls in the winter. Summers are very dry and many chaparral plants are dormant during the summertime. The chaparral vegetation is dominated by shrubs and is adapted to periodic fires, with some plants producing seeds that germinate only after a hot fire. The ashes left behind after a fire are rich in nutrients like nitrogen and fertilize the soil, promoting plant regrowth. Fire is a natural part of the maintenance of this biome.

Temperate grasslands are found throughout central North America, where they are also known as prairies, and in Eurasia, where they are known as steppes (Figure 8 below). Temperate grasslands have pronounced annual fluctuations in temperature with hot summers and cold winters. The annual temperature variation produces specific growing seasons for plants. Plant growth is possible when temperatures are warm enough to sustain plant growth, which occurs in the spring, summer, and fall.

Annual precipitation ranges from 25.4 cm to 88.9 cm (10–35 in). Temperate grasslands have few trees except for those found growing along rivers or streams. The dominant vegetation tends to consist of grasses. The treeless condition is maintained by low precipitation, frequent fires, and grazing. The vegetation is very dense and the soils are fertile because the subsurface of the soil is packed with the roots and rhizomes (underground stems) of these grasses. The roots and rhizomes act to anchor plants into the ground and replenish the organic material (humus) in the soil when they die and decay.

Fires, which are a natural disturbance in temperate grasslands, can be ignited by lightning strikes. It also appears that the lightning-caused fire regime in North American grasslands was enhanced by intentional burning by humans. When fire is suppressed in temperate grasslands, the vegetation eventually converts to scrub and dense forests. Often, the restoration or management of temperate grasslands requires the use of controlled burns to suppress the growth of trees and maintain the grasses.

Temperate forests are the most common biome in eastern North America, Western Europe, Eastern Asia, Chile, and New Zealand (Figure 9 below). This biome is found throughout mid-latitude regions. Temperatures range between –30^oC and 30^oC (–22^oF to 86^oF) and drop to below freezing on an annual basis. These temperatures mean that temperate forests have defined growing seasons during the spring, summer, and early fall. Precipitation is relatively constant throughout the year and ranges between 75 cm and 150 cm (29.5–59 in).

Deciduous trees are the dominant plant in this biome with fewer evergreen conifers. Deciduous trees lose their leaves each fall and remain leafless in the winter. Thus, little photosynthesis occurs during the dormant winter period. Each spring, new leaves appear as temperature increases. Because of the dormant period, the net primary productivity of temperate forests is less than that of tropical rainforests. In addition, temperate forests show far less diversity of tree species than tropical rainforest biomes.

The trees of the temperate forests leaf out and shade much of the ground. However, more sunlight reaches the ground in this biome than in tropical rainforests because trees in temperate forests do not grow as tall as the trees in tropical rainforests. The soils of the temperate forests are rich in inorganic and organic nutrients compared to tropical rainforests. This is because of the thick layer of leaf litter on forest floors and reduced leaching of nutrients by rainfall. As this leaf litter decays, nutrients are returned to the soil. The leaf litter also protects soil from erosion, insulates the ground, and provides habitats for invertebrates and their predators.

The **boreal forest,** also known as **taiga** or **coniferous forest**, is found roughly between $50^o$and 60^o north latitude across most of Canada, Alaska, Russia, and northern Europe (Figure 10 below). Boreal forests are also found above a certain elevation (and below high elevations where trees cannot grow) in mountain ranges throughout the Northern Hemisphere. This biome has cold, dry winters and short, cool, wet summers. The annual precipitation is from 40 cm to 100 cm (15.7–39 in) and usually takes the form of snow; relatively little evaporation occurs because of the cool temperatures.

The long and cold winters in the boreal forest have led to the predominance of cold-tolerant cone-bearing plants. These are evergreen coniferous trees like pines, spruce, and fir, which retain their needle-shaped leaves year-round. Evergreen trees can photosynthesize earlier in the spring than deciduous trees because less energy from the Sun is required to warm a needle-like leaf than a broad leaf. Evergreen trees grow faster than deciduous trees in the boreal forest. In addition, soils in boreal forest regions tend to be acidic with little available nitrogen. Leaves are a nitrogen-rich structure and deciduous trees must produce a new set of these nitrogen-rich structures each year. Therefore, coniferous trees that retain nitrogen-rich needles in a nitrogen limiting environment may have had a competitive advantage over the broad-leafed deciduous trees.

The net primary productivity of boreal forests is lower than that of temperate forests and tropical wet forests. The aboveground biomass of boreal forests is high because these slow-growing tree species are long-lived and accumulate standing biomass over time. Species diversity is less than that seen in temperate forests and tropical rainforests. Boreal forests lack the layered forest structure seen in tropical rainforests or, to a lesser degree, temperate forests. The structure of a boreal forest is often only a tree layer and a ground layer. When conifer needles are dropped, they decompose more slowly than broad leaves; therefore, fewer nutrients are returned to the soil to fuel plant growth.

The Arctic **tundra** lies north of the subarctic boreal forests and is located throughout the Arctic regions of the Northern Hemisphere. Tundra also exists at elevations above the tree line on mountains. The average winter temperature is –34°C (–29.2°F) and the average summer temperature is 3°C–12°C (37°F –52°F). Plants in the Arctic tundra have a short growing season of approximately 50–60 days. However, during this time, there are almost 24 hours of daylight and plant growth is rapid. The annual precipitation of the Arctic tundra is low (15–25 cm or 6–10 in) with little annual variation in precipitation. And, as in the boreal forests, there is little evaporation because of the cold temperatures.

Plants in the Arctic tundra are generally low to the ground and include low shrubs, grasses, lichens, and small flowering plants (Figure 11 below). There is little species diversity, low net primary productivity, and low above-ground biomass. The soils of the Arctic tundra may remain in a perennially frozen state referred to as permafrost. The permafrost makes it impossible for roots to penetrate far into the soil and slows the decay of organic matter, which inhibits the release of nutrients from organic matter. The melting of the permafrost in the brief summer provides water for a burst of productivity while temperatures and long days permit it. During the growing season, the ground of the Arctic tundra can be completely covered with plants or lichens.

Biogeographic Regions of India

India is a megadiverse country. With only 2.4 per cent of the total land area of the world, the known biological diversity of India contributes 8 per cent to the known global biological diversity. In terms of Biogeography, India has been divided into 10 biogeographic zones as shown in the below table:

India has been devided into **ten recognizable biogeographic zones** as follows:

Biogeographic Region	%*
Andaman & Nicobar Island	0.3
Coastal region	2.5
North East Region	5.2
Gangetic Plains	10.8
Deccan Plateau	42
Western Ghats	4
Semi Arid Region	16.6
Indian Desert Zone	6.6
Himalayan Zone	6.4
Transhimalayan Region	5.6
Total	100
*Of total geographic area	

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Trans-Himalayan Region

It constitutes 5.6 per cent of the total geographical area, includes the high altitude, cold and arid mountain areas of Ladakh, Jammu & Kashmir, North Sikkim, Lahaul and Spiti areas of Himachal Pradesh. This zone has sparse alpine steppe vegetation that harbours several endemic species and is a favourable habitat for the *biggest populations of wild sheep and goat in the world* and other rare fauna that *includes **Snow Leopard** and the migratory Blacknecked Crane (Grus nigricollis).* The cold dry desert of this zone represents an extremely fragile ecosystem.

Himalayan Zone

It constitutes 6.4 per cent of the total geographical area includes some of the highest peaks in the world. The Himalayan zone makes India one of the richest areas in terms of habitats and species.

The alpine and sub-alpine forests, grassy meadows and moist mixed deciduous forests provide diverse habitat for endangered species of bovids such as Bharal (*Pseudois nayaur*), Ibex (*Capra ibex*), Markhor (*Capra falconeri*), Himalayan Tahr (*Hemitragus jemlabicus*), and Takin (*Budoreas taxicolor*). Other rare and endangered species restricted to this zone include Hangul (*Cervus eldi eldi*) and Musk Deer (*Moschus moschiferus*) .

Indian Desert Zone

Indian Desert Zone, constituting 6.6 per cent of the total geographical area, includes the Thar and the Kutch deserts and has large expanses of grassland that supports several endangered species of mammals such as Wolf (*Canis lupus*), Caracal (*Felis caracal*), Desert Cat (*Felis libyca*) and birds of conservation interest viz., Houbara Bustard (*Chamydotis undulate*) and the Great Indian Bustard (*Ardeotis nigriceps*).

Semi Arid Region

Semi-arid Region, constituting 16.6 per cent of the total geographical area, is a transition zone between the desert and the dense forests of Western Ghats.

Peninsular India has two large regions, which are climatically semi-arid. *This semi-arid region also has several artificial and natural lakes and marshy lands.*

The *dominant grass and palatable shrub layer in this zone supports the highest wildlife biomass*. The cervid species of **Sambar** (*Cervus unicolor*) and **Chital** (*Axis axis*) are restricted to the better wooded hills and moister valley areas respectively. The Lion (*Leo persica*), an endangered carnivore species (restricted to a small area in Gujarat), Caracal (Felis caracal),Jackal (Canis aureus) and Wolf (Canis lupus) are some of the endangered species that are characteristic of this region.

Western Ghats

Constitutes 4.0 per cent of the total geographical area. It is one of the major tropical evergreen forest regions in India and represents one of the two biodiversity 'hot spots'. Western Ghats are home to viable populations of most of the vertebrate species found in peninsular India, besides an endemic faunal element of its own.

Significant species endemic to this region include **Nilgiri Langur** *(Presbytis jobni),* **Lion Tailed Macaque** *(Macaca silenus),* **Grizzled Giant Squirrel** *(Ratufa macroura),* **Malabar Civet** *(Viverricula megaspila),* **Nilgiri Tahr** *(Hemitragus bylocrius)* **and Malabar Grey Hornbill** *(Ocycerous griseus)*. The Travancore Tortoise *(Indotestudo forstem)* and Cane turtle *(Heosemys silvatica)* are two endangered taxa restricted to a small area in central Western Ghats.

Deccan Plateau

Deccan Plateu is India's largest biogeographic region making 42 per cent of the total geographical area. It's a semi-arid region that falls in the rain shadow area of the Western Ghats. This bio-geographic zone of peninsular India is by far the most extensive zone, covering India's finest forests, particularly in the States of Madhya Pradesh, Maharashtra and Odisha.

Majority of the forests are deciduous in nature but there are regions of greater biological diversity in the hill ranges. The zone comprising of deciduous forests, thorn forests and degraded scrubland support diverse wildlife species.

Species found in this region are **Chital** *(Axis axis),* **Sambar** *(Cervus unicolor),* **Nilgai** *(Boselapbus tragocamelus)* **and Chousingha** *(Tetracerus quadricornis)*, **Barking deer** (Muntiacus muntjak) and Gaur (Antilope cervicapra), Elephant (Elephas maximus) in Bihar-Orissa and Karnataka-Tamil Nadu belts, Wild Buffalo (Bubalus bubalis) in a small area at the junction of Orissa, Madhya Pradesh and Maharashtra and the hard ground Swamp Deer (Cervus duvauceli), now restricted to a single locality in Madhya Pradesh.

Gangetic Plain

Gangetoc plain constitutes around 10.8 per cent of the total geographical area. The Gangetic plain is topographically homogenous for hundreds of kilometers. The characterstic fauna of this region include Rhino (Rhinoceros unicornis), Elephant (Elephas maximus), Buffalo (Bubalus bubalis), Swamp Deer (Cervus duvauceli), Hog-Deer (Axis porcinus) and Hispid Hare (Carprolagus bispidus).

North East Region

North East Region constitutes 5.2 per cent of the total geographical area. This region represents the transition zone between the Indian, Indo-Malayan and Indo-Chinese bio-geographical regions as well as being a meeting point of the Himalayan mountains and peninsular India. The North-East is thus the biogeographical 'gateway' for much of India's fauna and flora and also a biodiversity hotspot (Eastern Himalaya). Many of the species contributing to this biological diversity are either restricted to the region itself, or to the smaller localized areas of the Khasi Hills.

Coastal Region

Coastal region constitutes 2.5 per cent of the total geographical area with sandy beaches, mangroves, mud flats, coral reefs and marine angiosperm pastures make them the wealth and health zones of India. The coastline from Gujarat to Sunderbans is estimated to be 5,423 km long. Atotal of 25 islets constitute the Lakshadweep, which are of coral origin, and have a typical reef lagoon system, rich in biodiversity. However, the densely populated Lakshadweep islands virtually have no natural vegetation.

Andaman and Nicobar Islands

This constitutes 0.3 per cent of the total geographical area are one of the three tropical moist evergreen forests zones in India. *The islands house an array of flora and fauna not found elsewhere.* These islands are centres of high endemism and contain some of India's finest evergreen forests and support a wide diversity of corals. In India, *endemic island biodiversity is found only in the Andaman and Nicobar Islands.* Some of the endemic fauna of Andaman & Nicobar islands include *Narcondam hornbill*, South Andaman krait etc.

What Is Applied Ecology?

Picture going on vacation to Yellowstone National Park in Wyoming. The natural beauty of the park is stunning, with steaming hot geysers, herds of bison and even the occasional wolf. You know the government protects this land, but who manages it?

Who studies the animals and makes sure this ecosystem stays in balance? Who helped fence off this land as a national park in the first place? The answer is applied ecologists.

Applied ecologists are scientists in a subfield of ecology. They apply principles in ecology, genetics, biology, and biotechnology to conserve our ecosystems, protect unique species, and study how humans impact our environment. Today, we're going to look at some important jobs they do, such as conservation biology, restoration ecology, and studying climate change.

Conservation Biology

Picture a tropical rainforest. Orangutans raise their offspring high in the trees, away from the prying eyes of the jaguar. Smaller animals dot the forest floor, such as the beautiful, but poisonous, blue dart frog. Apart from their habitat, what do all these species have in common?

Unfortunately, the are all **endangered species**, or species that are in danger of going extinct. **Conservation biologists** apply ecological studies to protect these species. They study the reproduction, migration, behavior, and genetics of species in hopes of restoring their populations with proper management.

Conservation biologists also focus on how human interactions with the environment and organisms cause problems. Unfortunately, human poaching, deforestation, and pollution are often key causes. Conservation biologists usually focus their efforts around **keystone species**, or species that are essential for an ecosystem. These important species control the population of other species in the ecosystem, preventing them from overpopulating and disrupting **homeostasis**, or a balance in the ecosystem.

For example, tigers are an endangered species, as well as a top predator that acts as a keystone species in their Asian habitat. Scientists have focused their conservation efforts on strengthening policies against poaching in countries with native tigers, protecting their habitat from logging, and monitoring tiger migration and population numbers.

Restoration Ecology

In order for any species to live, they have to have a home. Unfortunately, humans have been destroying natural ecosystems for thousands of years. Humans cut down trees, create farmland where there were once forests, pollute marine and terrestrial environments alike, and fragment animal habitats to build roads, cities, oil pipelines and more.

Once an environment has been disrupted by human interaction, **restoration ecologists** come to the rescue. The job of restoration ecologists is to restore, or build back up, environments that have been damaged by human activity. Restoration ecologists want to find a balance between culture and human interactions with nature and meeting the ecological needs of an environment. Their goal is to balance humans and the ecosystem so they can exist in harmony.

For example, in Yosemite National Park, several restoration efforts have been successfully completed while still allowing visitors to access the park. The Lukens Meadow Ecological Restoration Project was completed in 2008, restoring a wet meadow in the park to its natural **biodiversity**, or variety of species.

Restoration ecologists first surveyed what natural plants should be in the area, and salvaged any that were struggling near trail junctions. They removed rutted trails and filled in gaps with mulch and reseeded these areas, allowing natural plants to grow back as well. Trails traversing the meadow were redirected to other existing trails to prevent foot traffic in the meadow, helping to restore it to its former levels of biodiversity.

UNIT-III

SYLLABUS

Unit – III

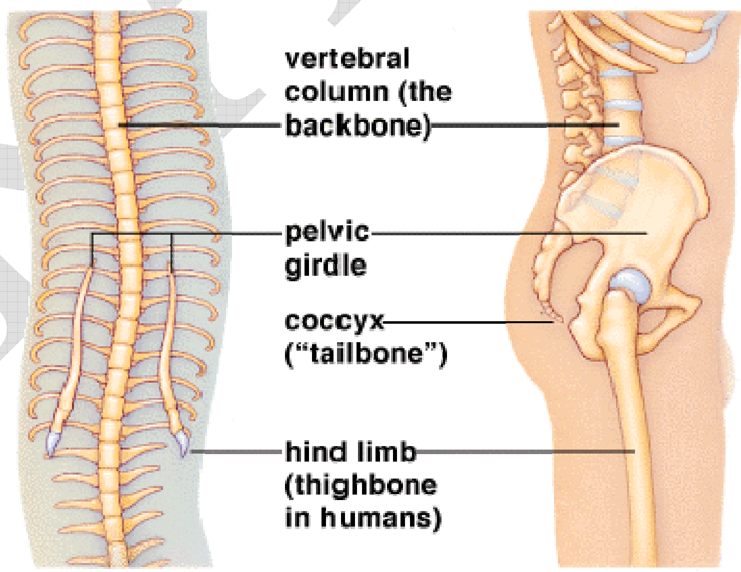
Evolutionary Biology: Emergence,Lamarck; Darwin–concepts, Mendelism; Origin of cells and unicellular evolution: Concept of Oparin and Haldane; The first cell; Evolution of prokaryotes, eukaryotic, unicellular eukaryotes. Origins of unicellular and multi cellular organisms; plants and animals; Molecular Evolution: Concepts, tools.

Early Concepts of Evolution: Jean Baptiste Lamarck

Emergence of Evolutionary Thought

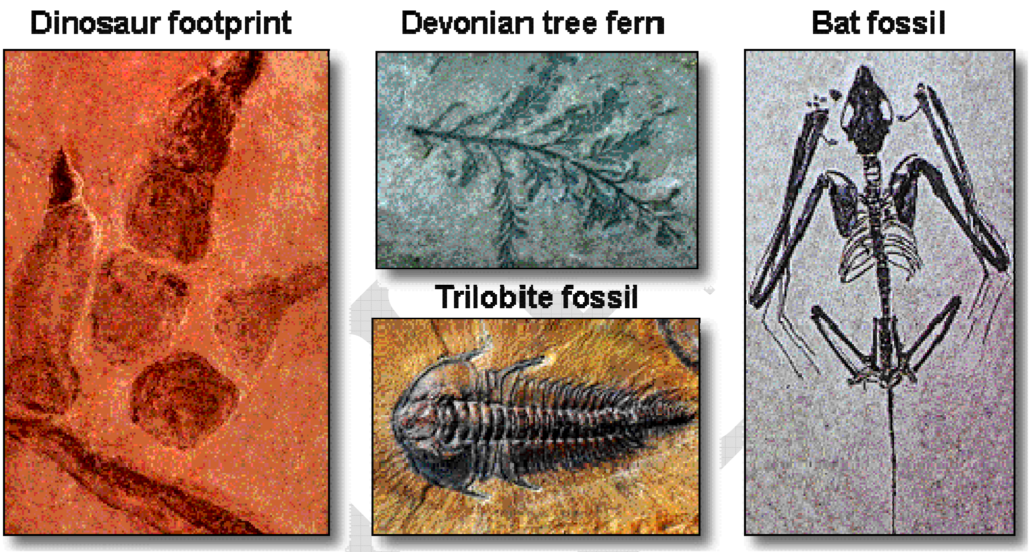
All cultures throughout history have come to contemplate "the big picture": where we came from and where are we going. Belief systems of all types have evolved to explain the unexplainable, but one unique system has recently accumulated an unprecedented paradigm of theories that stand up to rigorous logic and experimental testing. Science will never replace other religions, but the ground it is covering is often seen as an unholy encroachment to time honored traditions.

I. Early Beliefs, Confounding Discoveries
   A. The Great Chain of Being
      1. The Greeks began a systematics of classification that led to a formal *dendrogram* (dirt to angels!).
   B. Questions from Biogeography
      1. Technological developments led to further and faster travel. Naturalists observed incredible diversity of life in their travels. How could such variety, which was *endemic* in many areas, have spread to corners of the earth without a trace?
   C. Questions from Comparative Anatomy
      1. The variation of *homologous* and *analogous* structures puzzled anatomists. Some said they were variations from the moment of creation, but what about vestigial structures (pelvic girdle in snakes, tailbones in humans)?



D. Questions About Fossils

1. Studies of sedimentary beds revealed that deposits had been laid down slowly, one above the other.
    a. The layers held recognizable remains or impressions of organisms�fossils. The arrangement of the layers suggested that different organisms had lived at different times.



2. De Buffon�s explanation: Perhaps species originated in more than one place, and perhaps species became modified over time�evolution!

II. A Flurry of New Theories
  A. Squeezing New Evidence Into Old Beliefs
    1. Georges Cuvier believed in an original creation of all species.

       He further suggested that the abrupt changes in the fossil record in different rock strata reflected the concept of *catastrophism.*

        a. After each catastrophe, fewer species remained.
        b. The survivors were not new species; it was just that their ancestors� fossils had not been found.
    2. Lamarck formulated a theory of *inheritance of acquired characteristics* which the idea that simple forms had changed into more complex ones by a built-in drive for perfection up the Chain of Being. For instance, a giraffe stretching its neck to reach higher branches would result in longer necks in the offspring.
  B. Voyage of the *Beagle*
    1. As a child (early 1800s), Darwin was curious about nature, but in college he first pursued premedicine and finally received a degree in theology
    2. Darwin, age 20, sailed around the world as the ship�s naturalist.

a. He was reading Lyell�s *Principles of Geology,* which proposed a theory of uniformity�the notion of a gradual, lengthy molding of the earth�s geologic structure.
b. Thus, the earth was not thousands, but possibly millions of years old � enough time for evolution.

III. Darwin�s Theory Takes Form

A. Old Bones and Armadillos
  1. In Argentina, Darwin had observed extinct *glyptodonts* that bore suspicious resemblance to living armadillos; Darwin wondered if the present species had evolved from the extinct one.

B. A Key Insight�Variation in Traits
  1. Thomas Malthus had suggested that as a population outgrows its resources, its members must compete for what is available; some will not make it.
  2. Darwin felt that if some normally variant members of a population bore traits that increased their survival, then nature would select those same individuals to survive, reproduce, and possibly change future populations� traits.
     a. On the Galapagos Islands, the dozen or so species of finches all varied from one another to some extent but resembled the mainland finches to some degree also; perhaps they had descended from common ancestors.
     b. Darwin reasoned that a population is evolving when its heritable traits are changing through successive generations.
  3. In 1858, Darwin received a paper from Alfred Wallace, who had developed the same theory of natural selection independently of Darwin. Wallace had been travelling throughout present day Indonesia.
  4. Darwin and Wallace presented a joint paper but Darwin published (alone) his ideas in book form in 1859.
  5. The book was entitled: <u>On the Origin of Species or the Preservation of Favoured Races in the Struggle for Survival</u>.
  6. "Origin" went through several revisions, each omitting critically shortsighted elaborations.

C. Darwin saw evolution of one kind into another as happening gradually, in small increments, over hundreds or thousands of generations.

D. It is crucial to note that Darwin had no knowledge of either Mendelian or molecular genetics to support or guide his theory. Some say that this is direct evidence of the weakness of evolutionary theory, but Darwinists have considered this the greatest strength.

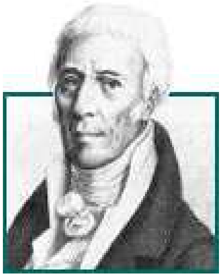
E. Today, we have expanded and modified the theory to include recent evidence: *The Modern Synthesis*.

F. "Evolution" is now separated into two semantic divisions: *microevolution* (change within a species) and *macroevolution* (change from one species to another). This seems to have been done to divide religious opposition. Now another division "human evolution" seeks to again divide the shrinking religious opposition from what seems undeniable by even the most uniformed.

G. The possibility of transitional forms was illustrated when, in 1861, fossil evidence of *Archaeopteryx* was unearthed.

1. This animal appears to be a transitional form between reptiles and birds. Like birds, it was covered with feathers; but like reptiles, it had teeth and a long, bony tail.

Early Concepts of Evolution: Jean Baptiste Lamarck



Darwin was not the first naturalist to propose that species changed over time into new species—that life, as we would say now, evolves. In the eighteenth century, Buffon and other naturalists began to introduce the idea that life might not have been fixed since creation. By the end of the 1700s, paleontologists had swelled the fossil collections of Europe, offering a picture of the past at odds with an unchanging natural world. And in 1801, a French naturalist named Jean Baptiste Pierre Antoine de Monet, Chevalier de Lamarck took a great conceptual step and proposed a full-blown theory of evolution.

Lamarck started his scientific career as a botanist, but in 1793 he became one of the founding professors of the Musee National d'Histoire Naturelle as an expert on invertebrates. His work on classifying worms, spiders, molluscs, and other boneless creatures was far ahead of his time.

Change through use and disuse

Lamarck was struck by the similarities of many of the animals he studied, and was impressed too by the burgeoning fossil record. It led him to argue that life was not fixed. When environments changed, organisms had to change their behavior to survive. If they began to use an organ more than they had in the past, it would increase in its lifetime. If a giraffe stretched its neck for leaves, for example, a "nervous fluid" would flow into its neck and make it longer. Its offspring would inherit the longer neck, and continued stretching would make it longer still over several generations. Meanwhile organs that organisms stopped using would shrink.

Lamarck believed that the long necks of giraffes evolved as generations of giraffes reached for ever higher leaves.

Organisms driven to greater complexity

This sort of evolution, for which Lamarck is most famous today, was only one of two mechanisms he proposed. As organisms adapted to their surroundings, nature also drove them inexorably upward from simple forms to increasingly complex ones. Like Buffon, Lamarck believed that life had begun through spontaneous generation. But he claimed that new primitive life forms sprang up throughout the history of life; today's microbes were simply "the new kids on the block."

Evolution by natural processes

Lamarck was proposing that life took on its current form through natural processes, not through miraculous interventions. For British naturalists in particular, steeped as they were in natural theology, this was appalling. They believed that nature was a reflection of God's benevolent design. To them, it seemed Lamarck was claiming that it was the result of blind primal forces. Rejected by some on religious grounds and shunned by scientists like Cuvier for lack of deductive rigor in his arguments, Lamarck died in 1829 in poverty and obscurity.

But the notion of evolution did not die with him. The French naturalist Geoffroy St. Hilaire would champion another version of evolutionary change in the 1820s, and the British writer Robert Chambers would author a best-selling argument for evolution in 1844: *Vestiges of a Natural Creation*. And in 1859, Charles Darwin would publish the *Origin of Species*. Lamarck, St. Hilaire, Chambers, and Darwin all had radically different ideas about how evolution operates, but only Darwin's still have scientific currency today.

Lamarck	Darwin
Use and disuse	Variation
Transmission of acquired characteristics	Inheritance
Increasing complexity	Differential survival
No extinction	Extinction

Different from Darwin

Darwin relied on much the same evidence for evolution that Lamarck did (such as vestigial structures and artificial selection through breeding), but made completely different arguments from Lamarck. Darwin did not accept an arrow of complexity driving through the history of life. He argued that complexity evolved simply as a result of life adapting to its local conditions from one generation to the next, much as modern biologists see this process. But of course, Darwin's ideas weren't entirely modern either. For example, he tried on and eventually rejected several different ideas about heredity (including the inheritance of acquired characteristics, as championed by Lamarck) and never came to any satisfying conclusion about how traits were passed from parent to offspring.

Lamarckian inheritance is an idea that today is known mainly from textbooks, where it is used to as a historical contrast for our modern understanding of genetic inheritance, which began with the rediscovery of Mendel's work in the late 1800s. Despite all he got wrong, Lamarck can be credited with envisioning evolutionary change for the first time.

Darwin's Theory Of Evolution

Darwin's Theory Of Evolution - The Premise

Darwin's Theory of Evolution is the widely held notion that all life is related and has descended from a common ancestor: the birds and the bananas, the fishes and the flowers -- all related. Darwin's general theory presumes the development of life from non-life and stresses a purely naturalistic (undirected) "descent with modification". That is, complex creatures evolve from more simplistic ancestors naturally over time. In a nutshell, as random genetic mutations occur within an organism's genetic code, the beneficial mutations are preserved because they aid survival -- a process known as "natural selection." These beneficial mutations are passed on to the next generation. Over time, beneficial mutations accumulate and the result is an entirely different organism (not just a variation of the original, but an entirely different creature).

Darwin's Theory of Evolution - Natural Selection

While Darwin's Theory of Evolution is a relatively young archetype, the evolutionary worldview itself is as old as antiquity. Ancient Greek philosophers such as Anaximander postulated the development of life from non-life and the evolutionary descent of man from animal. Charles Darwin simply brought something new to the old philosophy -- a plausible mechanism called "natural selection." Natural selection acts to preserve and accumulate minor advantageous genetic mutations. Suppose a member of a species developed a functional advantage (it grew wings and learned to fly). Its offspring would inherit that advantage and pass it on to their offspring. The inferior (disadvantaged) members of the same species would gradually die out, leaving only the superior (advantaged) members of the species. Natural selection is the preservation of a functional advantage that enables a species to compete better in the wild. Natural selection is the naturalistic equivalent to domestic breeding. Over the centuries, human breeders have produced dramatic changes in domestic animal populations by selecting individuals to breed. Breeders eliminate undesirable traits gradually over time. Similarly, natural selection eliminates inferior species gradually over time.

Darwin's Theory of Evolution - Slowly But Surely...
Darwin's Theory of Evolution is a slow gradual process. Darwin wrote, "…Natural selection acts only by taking advantage of slight successive variations; she can never take a great and sudden leap, but must advance by short and sure, though slow steps." [1] Thus, Darwin conceded that, "If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down." [2] Such a complex organ would be known as an "irreducibly complex system". An irreducibly complex system is one composed of multiple parts, all of which are necessary for the system to function. If even one part is missing, the entire system will fail to function. Every individual part is integral. [3] Thus, such a system could not have evolved slowly, piece by piece. The common mousetrap is an everyday non-biological example of irreducible complexity. It is composed of five basic parts: a catch (to hold the bait), a powerful spring, a thin rod called "the hammer," a holding bar to secure the hammer in place, and a platform to mount the trap. If any one of these parts is missing, the mechanism will not work. Each individual part is integral. The mousetrap is irreducibly complex. [4]

Darwin's Theory of Evolution - A Theory In Crisis
Darwin's Theory of Evolution is a theory in crisis in light of the tremendous advances we've made in molecular biology, biochemistry and genetics over the past fifty years. We now know that there are in fact tens of thousands of irreducibly complex systems on the cellular level. Specified complexity pervades the microscopic biological world. Molecular biologist Michael Denton wrote, "Although the tiniest bacterial cells are incredibly small, weighing less than 10^{-12} grams, each is in effect a veritable micro-miniaturized factory containing thousands of exquisitely designed pieces of intricate molecular machinery, made up altogether of one hundred thousand million atoms, far more complicated than any machinery built by man and absolutely without parallel in the non-living world." [5]

And we don't need a microscope to observe irreducible complexity. The eye, the ear and the heart are all examples of irreducible complexity, though they were not recognized as such in Darwin's day. Nevertheless, Darwin confessed, "To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree." [6]

Medical Definition of Mendelism

Mendelism: The principles of genetics, specifically of single-gene traits, based on the work of Gregor Mendel (1822-84), a Moravian monk and biologist who established the laws that are the foundation of classical genetics.

Mendel lived in an Augustinian monastery where teaching and research were emphasized and where he was given the freedom to pursue scientific studies in the diverse fields that interested him: mathematics, botany, physics, and meteorology. His meticulous controlled experiments with breeding peas in the monastery garden led him to conclude that the heritable units (now called genes) were not blends of parental traits but rather were separate physical entities passed individually from one generation to the next.

The report in 1865 of Mendel's discoveries went unnoticed for some years. Charles Darwin never read the copy of Mendel's paper he received The only scientist who did acknowledge it (a German botanist named Nageli) managed to misinterpret it. Finally in 1900 (16 years after his death), Mendel's paper was rediscovered independently by three different scientists. With the rediscovery of Mendel's work, he came to be recognized as the father of the new science of genetics.

Mendelian inheritance is the manner in which genes and traits are passed from parents to their children. The modes of Mendelian inheritance are autosomal dominant, autosomal recessive, X-linked dominant and X-linked recessive.

Origin of Cells

The appearance of the first cells marked the origin of life on Earth. However, before cells could form, the organic molecules must have united with one another to form more complex molecules called *polymers*. Examples of polymers are polysaccharides and proteins.

In the 1950s, Sidney Fox placed amino acids in primitive Earth conditions and showed that amino acids would unite to form polymers called **proteinoids.** The proteinoids were apparently able to act as enzymes and catalyze organic reactions.

More recent evidence indicates that RNA molecules have the ability to direct the synthesis of new RNA molecules as well as DNA molecules. Because DNA provides the genetic code for protein synthesis, it is conceivable that DNA may have formed in the primitive Earth environment as a consequence of RNA activity. Then DNA activity could have led to protein synthesis (see Chapter 10).

For a cell to come into being, some sort of enclosing membrane is required to hold together the organic materials of the cytoplasm. A generation ago, scientists believed that membranous droplets formed spontaneously. These membranous droplets, called **protocells,** were presumed to be the first cells. Modern scientists believe, however, that protocells do not carry any genetic information and lack the internal organization of cells. Thus the protocell perspective is not widely accepted. Several groups of scientists are currently investigating the synthesis of polypeptides and short nucleic acids on the surface of clay. The origin of the first cells remains a mystery.

The Origin and Evolution of Cells

Cells are divided into two main classes, initially defined by whether they contain a nucleus. Prokaryotic cells (bacteria) lack a nuclear envelope; eukaryotic cells have a nucleus in which the genetic material is separated from the cytoplasm. Prokaryotic cells are generally smaller and simpler than eukaryotic cells; in addition to the absence of a nucleus, their genomes are less complex and they do not contain cytoplasmic organelles or a cytoskeleton (Table 1.1). In spite of these differences, the same basic molecular mechanisms govern the lives of both prokaryotes and eukaryotes, indicating that all present-day cells are descended from a single primordial ancestor. How did this first cell develop? And how did the complexity and diversity exhibited by present-day cells evolve?

Characteristic	Prokaryote
Nucleus	Absent
Diameter of a typical cell	≈ 1 μm
Cytoskeleton	Absent
Cytoplasmic organelles	Absent
DNA content (base pairs)	1×10^6 to 5×10^6
Chromosomes	Single circular DNA molecu

Table 1.1

Prokaryotic and Eukaryotic Cells.

Go to:

The First Cell

It appears that life first emerged at least 3.8 billion years ago, approximately 750 million years after Earth was formed (Figure 1.1). How life originated and how the first cell came into being are matters of speculation, since these events cannot be reproduced in the laboratory. Nonetheless, several types of experiments provide important evidence bearing on some steps of the process.

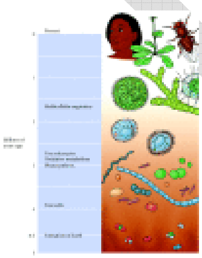


Figure 1.1

Time scale of evolution. The scale indicates the approximate times at which some of the major events in the evolution of cells are thought to have occurred.

It was first suggested in the 1920s that simple organic molecules could form and spontaneously polymerize into macromolecules under the conditions thought to exist in primitive Earth's atmosphere. At the time life arose, the atmosphere of Earth is thought to have contained little or no free oxygen, instead consisting principally of CO_2 and N_2 in addition to smaller amounts of gases such as H_2, H_2S, and CO. Such an atmosphere provides reducing conditions in which organic molecules, given a source of energy such as sunlight or electrical discharge, can form spontaneously. The spontaneous formation of organic molecules was first demonstrated experimentally in the 1950s, when Stanley Miller (then a graduate student) showed that the discharge of electric sparks into a mixture of H_2, CH_4, and NH_3, in the presence of water, led to the formation of a variety of organic molecules, including several amino acids (Figure 1.2). Although Miller's experiments did not precisely reproduce the conditions of primitive Earth, they clearly demonstrated the plausibility of the spontaneous synthesis of organic molecules, providing the basic materials from which the first living organisms arose.

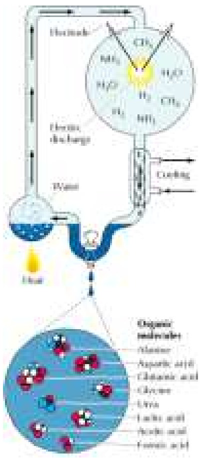


Figure 1.2

Spontaneous formation of organic molecules. Water vapor was refluxed through an atmosphere consisting of CH_4, NH_3, and H_2, into which electric sparks were discharged. Analysis of the reaction products revealed the formation of a variety of organic molecules, (more...)

The next step in evolution was the formation of macromolecules. The monomeric building blocks of macromolecules have been demonstrated to polymerize spontaneously under plausible prebiotic conditions. Heating dry mixtures of amino acids, for example, results in their polymerization to form polypeptides. But the critical characteristic of the macromolecule from which life evolved must have been the ability to replicate itself. Only a macromolecule capable of directing the synthesis of new copies of itself would have been capable of reproduction and further evolution.

Of the two major classes of informational macromolecules in present-day cells (nucleic acids and proteins), only the nucleic acids are capable of directing their own self-replication. Nucleic acids can serve as templates for their own synthesis as a result of specific base pairing between complementary nucleotides (Figure 1.3). A critical step in understanding molecular evolution was thus reached in the early 1980s, when it was discovered in the laboratories of Sid Altman and Tom Cech that RNA is capable of catalyzing a number of chemical reactions, including the polymerization of nucleotides. RNA is thus uniquely able both to serve as a template for and to catalyze its own replication. Consequently, RNA is generally believed to have been the initial genetic system, and an early stage of chemical evolution is thought to have been based on self-replicating RNA molecules—a period of evolution known as the **RNA world**. Ordered interactions between RNA and amino acids then evolved into the present-day genetic code, and DNA eventually replaced RNA as the genetic material.

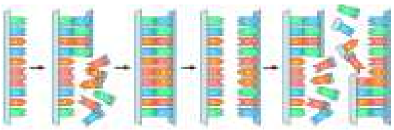


Figure 1.3

Self-replication of RNA. Complementary pairing between nucleotides (adenine [A] with uracil [U] and guanine [G] with cytosine [C]) allows one strand of RNA to serve as a template for the synthesis of a new strand with the complementary sequence.

The first cell is presumed to have arisen by the enclosure of self-replicating RNA in a membrane composed of phospholipids (Figure 1.4). As discussed in detail in the next chapter, phospholipids are the basic components of all present-day biological membranes, including the plasma membranes of both prokaryotic and eukaryotic cells. The key characteristic of the phospholipids that form membranes is that they are amphipathic molecules, meaning that one portion of the molecule is soluble in water and another portion is not. Phospholipids have long, water-insoluble (hydrophobic) hydrocarbon chains joined to water-soluble (hydrophilic) head groups that contain phosphate. When placed in water, phospholipids spontaneously aggregate into a bilayer with their phosphate-containing head groups on the outside in contact with water and their hydrocarbon tails in the interior in contact with each other. Such a phospholipid bilayer forms a stable barrier between two aqueous compartments—for example, separating the interior of the cell from its external environment.

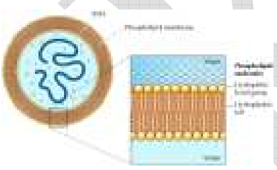


Figure 1.4

Enclosure of self-replicating RNA in a phospholipid membrane. The first cell is thought to have arisen by the enclosure of self-replicating RNA and associated molecules in a membrane composed of phospholipids. Each phospholipid molecule has two long hydrophobic (more...)

The enclosure of self-replicating RNA and associated molecules in a phospholipid membrane would thus have maintained them as a unit, capable of self-reproduction and further evolution. RNA-directed protein synthesis may already have evolved by this time, in which case the first cell would have consisted of self-replicating RNA and its encoded proteins.

Go to:

The Evolution of Metabolism

Because cells originated in a sea of organic molecules, they were able to obtain food and energy directly from their environment. But such a situation is self-limiting, so cells needed to evolve their own mechanisms for generating energy and synthesizing the molecules necessary for their replication. The generation and controlled utilization of metabolic energy is central to all cell activities, and the principal pathways of energy metabolism (discussed in detail in Chapter 2) are highly conserved in present-day cells. All cells use **adenosine 5′-triphosphate** (ATP) as their source of metabolic energy to drive the synthesis of cell constituents and carry out other energy-requiring activities, such as movement (e.g., muscle contraction). The mechanisms used by cells for the generation of ATP are thought to have evolved in three stages, corresponding to the evolution of glycolysis, photosynthesis, and oxidative metabolism (Figure 1.5). The development of these metabolic pathways changed Earth's atmosphere, thereby altering the course of further evolution.

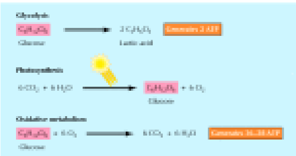


Figure 1.5

Generation of metabolic energy. Glycolysis is the anaerobic breakdown of glucose to lactic acid. Photosynthesis utilizes energy from sunlight to drive the synthesis of glucose from CO_2 and H_2O, with the release of O_2 as a by-product. The O_2 released by (more...)

In the initially anaerobic atmosphere of Earth, the first energy-generating reactions presumably involved the breakdown of organic molecules in the absence of oxygen. These reactions are likely to have been a form of present-day glycolysis—the anaerobic breakdown of glucose to lactic acid, with the net energy gain of two molecules of ATP. In addition to using ATP as their source of intracellular chemical energy, all present-day cells carry out glycolysis, consistent with the notion that these reactions arose very early in evolution.

Glycolysis provided a mechanism by which the energy in preformed organic molecules (e.g., glucose) could be converted to ATP, which could then be used as a source of energy to drive other metabolic reactions. The development of photosynthesis is generally thought to have been the next major evolutionary step, which allowed the cell to harness energy from sunlight and provided independence from the utilization of preformed organic molecules. The first photosynthetic bacteria, which evolved more than 3 billion years ago, probably utilized H_2S to convert CO_2 to organic molecules—a pathway of photosynthesis still used by some bacteria. The use of H_2O as a donor of electrons and hydrogen for the conversion of CO_2 to organic compounds evolved later and had the important consequence of changing Earth's atmosphere. The use of H_2O in photosynthetic reactions produces the by-product free O_2; this mechanism is thought to have been responsible for making O_2 abundant in Earth's atmosphere.

The release of O_2 as a consequence of photosynthesis changed the environment in which cells evolved and is commonly thought to have led to the development of **oxidative metabolism**. Alternatively, oxidative metabolism may have evolved before photosynthesis, with the increase in atmospheric O_2 then providing a strong selective advantage for organisms capable of using O_2 in energy-producing reactions. In either case, O_2 is a highly reactive molecule, and oxidative metabolism, utilizing this reactivity, has provided a mechanism for generating energy from organic molecules that is much more efficient than anaerobic glycolysis. For example, the complete oxidative breakdown of glucose to CO_2 and H_2O yields energy equivalent to that of 36 to 38 molecules of ATP, in contrast to the 2 ATP molecules formed by anaerobic glycolysis. With few exceptions, present-day cells use oxidative reactions as their principal source of energy.

Go to:

Present-Day Prokaryotes

Present-day prokaryotes, which include all the various types of bacteria, are divided into two groups—the archaebacteria and the eubacteria—which diverged early in evolution. Some archaebacteria live in extreme environments, which are unusual today but may have been prevalent in primitive Earth. For example, thermoacidophiles live in hot sulfur springs with temperatures as high as 80°C and pH values as low as 2. The eubacteria include the common forms of present-day bacteria—a large group of organisms that live in a wide range of environments, including soil, water, and other organisms (e.g., human pathogens).

Most bacterial cells are spherical, rod-shaped, or spiral, with diameters of 1 to 10 μm. Their DNA contents range from about 0.6 million to 5 million base pairs, an amount sufficient to encode about 5000 different proteins. The largest and most complex prokaryotes are the cyanobacteria, bacteria in which photosynthesis evolved.

The structure of a typical prokaryotic cell is illustrated by ***Escherichia coli*** (E. coli), a common inhabitant of the human intestinal tract (Figure 1.6). The cell is rod-shaped, about 1 μm in diameter and about 2 μm long. Like most other prokaryotes, *E. coli* is surrounded by a rigid cell wall composed of polysaccharides and peptides. Within the cell wall is the plasma membrane, which is a bilayer of phospholipids and associated proteins. Whereas the cell wall is porous and readily penetrated by a variety of molecules, the plasma membrane provides the functional separation between the inside of the cell and its external environment. The DNA of *E. coli* is a single circular molecule in the nucleoid, which, in contrast to the nucleus of eukaryotes, is not surrounded by a membrane separating it from the cytoplasm. The cytoplasm contains approximately 30,000 ribosomes (the sites of protein synthesis), which account for its granular appearance.

Figure 1.6

Electron micrograph of *E. coli*. The cell is surrounded by a cell wall, within which is the plasma membrane. DNA is located in the nucleoid. (Menge and Wurtz/Biozentrum, University of Basel/Science Photo Library/Photo Researchers, Inc.)

Go to:

Eukaryotic Cells

Like prokaryotic cells, all eukaryotic cells are surrounded by plasma membranes and contain ribosomes. However, eukaryotic cells are much more complex and contain a nucleus, a variety of cytoplasmic organelles, and a cytoskeleton (Figure 1.7). The largest and most prominent organelle of eukaryotic cells is the nucleus, with a diameter of approximately 5 μm. The nucleus contains the genetic information of the cell, which in eukaryotes is organized as linear rather than circular DNA molecules. The nucleus is the site of DNA replication and of RNA synthesis; the translation of RNA into proteins takes place on ribosomes in the cytoplasm.

Figure 1.7

Structures of animal and plant cells. Both animal and plant cells are surrounded by a plasma membrane and contain a nucleus, a cytoskeleton, and many cytoplasmic organelles in common. Plant cells are also surrounded by a cell wall and contain chloroplasts (more...)

In addition to a nucleus, eukaryotic cells contain a variety of membrane-enclosed organelles within their cytoplasm. These organelles provide compartments in which different metabolic activities are localized. Eukaryotic cells are generally much larger than prokaryotic cells, frequently having a cell volume at least a thousandfold greater. The compartmentalization provided by cytoplasmic organelles is what allows eukaryotic cells to function efficiently. Two of these organelles, mitochondria and chloroplasts, play critical roles in energy metabolism. Mitochondria, which are found in almost all eukaryotic cells, are the sites of oxidative metabolism and are thus responsible for generating most of the ATP derived from the breakdown of organic molecules. Chloroplasts are the sites of photosynthesis and are found only in the cells of plants and green algae. Lysosomes and peroxisomes also provide specialized metabolic compartments for the digestion of macromolecules and for various oxidative reactions, respectively. In addition, most plant cells contain large vacuoles that perform a variety of functions, including the digestion of macromolecules and the storage of both waste products and nutrients.

Because of the size and complexity of eukaryotic cells, the transport of proteins to their correct destinations within the cell is a formidable task. Two cytoplasmic organelles, the endoplasmic reticulum and the Golgi apparatus, are specifically devoted to the sorting and transport of proteins destined for secretion, incorporation into the plasma membrane, and incorporation into lysosomes. The endoplasmic reticulum is an extensive network of intracellular membranes, extending from the nuclear membrane throughout the cytoplasm. It functions not only in the processing and transport of proteins, but also in the synthesis of lipids. From the endoplasmic reticulum, proteins are transported within small membrane vesicles to the Golgi apparatus, where they are further processed and sorted for transport to their final destinations. In addition to this role in protein transport, the Golgi apparatus serves as a site of lipid synthesis and (in plant cells) as the site of synthesis of some of the polysaccharides that compose the cell wall.

Eukaryotic cells have another level of internal organization: the cytoskeleton, a network of protein filaments extending throughout the cytoplasm. The cytoskeleton provides the structural framework of the cell, determining cell shape and the general organization of the cytoplasm. In addition, the cytoskeleton is responsible for the movements of entire cells (e.g., the contraction of muscle cells) and for the intracellular transport and positioning of organelles and other structures, including the movements of chromosomes during cell division.

The eukaryotes developed at least 2.7 billion years ago, following some 1 to 1.5 billion years of prokaryotic evolution. Studies of their DNA sequences indicate that the archaebacteria and eubacteria are as different from each other as either is from present-day eukaryotes. Therefore, a very early event in evolution appears to have been the divergence of three lines of descent from a common ancestor, giving rise to present-day archaebacteria, eubacteria, and eukaryotes. Interestingly, many archaebacterial genes are more similar to those of eukaryotes than to those of eubacteria, indicating that the archaebacteria and eukaryotes share a common line of evolutionary descent and are more closely related to each other than either is to the eubacteria (Figure 1.8).

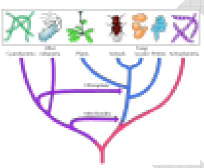


Figure 1.8

Evolution of cells. Present-day cells evolved from a common prokaryotic ancestor along three lines of descent, giving rise to archaebacteria, eubacteria, and eukaryotes. Mitochondria and chloroplasts originated from the endosymbiotic association of aerobic (more...)

A critical step in the evolution of eukaryotic cells was the acquisition of membrane-enclosed subcellular organelles, allowing the development of the complexity characteristic of these cells. The organelles are thought to have been acquired as a result of the association of prokaryotic cells with the ancestor of eukaryotes.

The hypothesis that eukaryotic cells evolved from a symbiotic association of prokaryotes—endosymbiosis—is particularly well supported by studies of mitochondria and chloroplasts, which are thought to have evolved from bacteria living in large cells. Both mitochondria and chloroplasts are similar to bacteria in size, and like bacteria, they reproduce by dividing in two. Most important, both mitochondria and chloroplasts contain their own DNA, which encodes some of their components. The mitochondrial and chloroplast DNAs are replicated each time the organelle divides, and the genes they encode are transcribed within the organelle and translated on organelle ribosomes. Mitochondria and chloroplasts thus contain their own genetic systems, which are distinct from the nuclear genome of the cell. Furthermore, the ribosomes and ribosomal RNAs of these organelles are more closely related to those of bacteria than to those encoded by the nuclear genomes of eukaryotes.

An endosymbiotic origin for these organelles is now generally accepted, with mitochondria thought to have evolved from aerobic bacteria and chloroplasts from photosynthetic bacteria, such as the cyanobacteria. The acquisition of aerobic bacteria would have provided an anaerobic cell with the ability to carry out oxidative metabolism. The acquisition of photosynthetic bacteria would have provided the nutritional independence afforded by the ability to perform photosynthesis. Thus, these endosymbiotic associations were highly advantageous to their partners and were selected for in the course of evolution. Through time, most of the genes originally present in these bacteria apparently became incorporated into the nuclear genome of the cell, so only a few components of mitochondria and chloroplasts are still encoded by the organelle genomes.

Go to:

The Development of Multicellular Organisms

Many eukaryotes are unicellular organisms that, like bacteria, consist of only single cells capable of self-replication. The simplest eukaryotes are the yeasts. Yeasts are more complex than bacteria, but much smaller and simpler than the cells of animals or plants. For example, the commonly studied yeast ***Saccharomyces cerevisiae*** is about 6 μm in diameter and contains 12 million base pairs of DNA (Figure 1.9). Other unicellular eukaryotes, however, are far more complex cells, some containing as much DNA as human cells have (Table 1.2). They include organisms specialized to perform a variety of tasks, including photosynthesis, movement, and the capture and ingestion of other organisms as food. *Amoeba proteus*, for example, is a large, complex cell. Its volume is more than 100,000 times that of *E. coli,* and its length can exceed 1 mm when the cell is fully extended (Figure 1.10). Amoebas are highly mobile organisms that use cytoplasmic extensions, called **pseudopodia**, to move and to engulf other organisms, including bacteria and yeasts, as food. Other unicellular eukaryotes (the green algae) contain chloroplasts and are able to carry out photosynthesis.

Figure 1.9

Scanning electron micrograph of *Saccharomyces cerevisiae*. Artificial color has been added to the micrograph. (Andrew Syed/Science Photo Library/ Photo Researchers, Inc.)

Table 1.2 DNA Content of Cells

Organism	Haploid DNA co
Bacteria	
Mycoplasma	
E. coli	
Unicellular eukaryotes	
Saccharomyces cerevisiae (yeast)	
Dictyostelium discoideum	
Euglena	
Plants	

Table 1.2

DNA Content of Cells.

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Figure 1.10

Light micrograph of *Amoeba proteus*. (M. I. Walker/Photo Researchers, Inc.)

Multicellular organisms evolved from unicellular eukaryotes at least 1.7 billion years ago. Some unicellular eukaryotes form multicellular aggregates that appear to represent an evolutionary transition from single cells to multicellular organisms. For instance, the cells of many algae (e.g., the green alga *Volvox*) associate with each other to form multicellular colonies (Figure 1.11), which are thought to have been the evolutionary precursors of present-day plants. Increasing cell specialization then led to the transition from colonial aggregates to truly multicellular organisms. Continuing cell specialization and division of labor among the cells of an organism have led to the complexity and diversity observed in the many types of cells that make up present-day plants and animals, including human beings.

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Figure 1.11

Colonial green algae. Individual cells of *Volvox* form colonies consisting of hollow balls in which hundreds or thousands of cells are embedded in a gelatinous matrix. (Cabisco/Visuals Unlimited.)

Plants are composed of fewer cell types than are animals, but each different kind of plant cell is specialized to perform specific tasks required by the organism as a whole (Figure 1.12). The cells of plants are organized into three main tissue systems: ground tissue, dermal tissue, and vascular tissue. The ground tissue contains parenchyma cells, which carry out most of the metabolic reactions of the plant, including photosynthesis. Ground tissue also contains two specialized cell types (**collenchyma cells** and sclerenchyma cells) that are characterized by thick cell walls and provide structural support to the plant. Dermal tissue covers the surface of the plant and is composed of epidermal cells, which form a protective coat and allow the absorption of nutrients. Finally, several types of elongated cells form the vascular system (the xylem and phloem), which is responsible for the transport of water and nutrients throughout the plant.

Figure 1.12

Light micrographs of representative plant cells. (A) Parenchyma cells, which are responsible for photosynthesis and other metabolic reactions. (B) Collenchyma cells, which are specialized for support and have thickened cell walls. (C) Epidermal cells (more...)

The cells found in animals are considerably more diverse than those of plants. The human body, for example, is composed of more than 200 different kinds of cells, which are generally considered to be components of five main types of tissues: epithelial tissue, connective tissue, blood, nervous tissue, and muscle (Figure 1.13). Epithelial cells form sheets that cover the surface of the body and line the internal organs. There are many different types of epithelial cells, each specialized for a specific function, including protection (the skin), absorption (e.g., the cells lining the small intestine), and secretion (e.g., cells of the salivary gland). Connective tissues include bone, cartilage, and adipose tissue, each of which is formed by different types of cells (osteoblasts, chondrocytes, and adipocytes, respectively). The loose connective tissue that underlies epithelial layers and fills the spaces between organs and tissues in the body is formed by another cell type, the fibroblast. Blood contains several different types of cells, which function in oxygen transport (red blood cells, or erythrocytes), inflammatory reactions (**granulocytes**, **monocytes**, and macrophages), and the immune response (lymphocytes). Nervous tissue is composed of nerve cells, or neurons, which are highly specialized to transmit signals throughout the body. Various types of sensory cells, such as cells of the eye and ear, are further specialized to receive external signals from the environment. Finally, several different types of muscle cells are responsible for the production of force and movement.

Figure 1.13

Light micrographs of representative animal cells. (A) Epithelial cells of the mouth (a thick, multilayered sheet), bile duct, and intestine. (B) Fibroblasts are connective tissue cells characterized by their elongated spindle shape. (C) Erythrocytes, (more...)

The evolution of animals clearly involved the development of considerable diversity and specialization at the cellular level. Understanding the mechanisms that control the growth and differentiation of such a complex array of specialized cells, starting from a single fertilized egg, is one of the major challenges facing contemporary cell and molecular biology.

Origin Of Life: Twentieth Century Landmarks

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The Oparin-Haldane Hypothesis

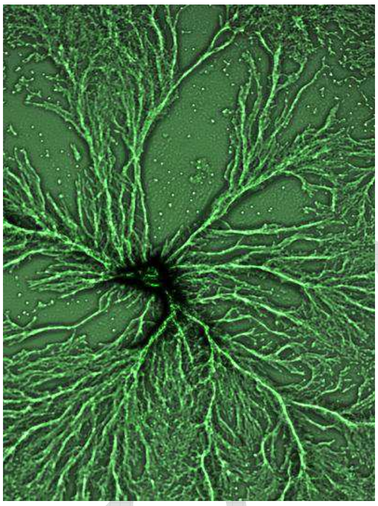
In the early decades of the 20th century, Aleksandr Oparin (in 1924), and John Haldane (in 1929, before Oparin's first book was translated into English), independently suggested that if the primitive atmosphere was reducing (as opposed to oxygen-rich), and if there was an appropriate supply of energy, such as lightning or ultraviolet light, then a wide range of organic compounds might be synthesised.

Oparin suggested that the organic compounds could have undergone a series of reactions leading to more and more complex molecules. He proposed that the molecules formed colloid aggregates, or 'coacervates', in an aqueous environment. The coacervates were able to absorb and assimilate organic compounds from the environment in a way reminiscent of metabolism. They would have taken part in evolutionary processes, eventually leading to the first lifeforms.

Haldane's ideas about the origin of life were very similar to Oparin's. Haldane proposed that the primordial sea served as a vast chemical laboratory powered by solar energy. The atmosphere was oxygen free, and the combination of carbon dioxide, ammonia and ultraviolet radiation gave rise to a host of organic compounds. The sea became a 'hot dilute soup' containing large populations of organic monomers and polymers. Haldane envisaged that groups of monomers and polymers aquired lipid membranes, and that further developments eventually led to the first living cells.

Haldane coined the term 'prebiotic soup', and this became a powerful symbol of the Oparin-Haldane view of the origin of life.

Multicellular Life Evolve?



Cells of Dictyostelium purpureum, a common soil microbe, streaming to form a multicellular fruiting body. Credit: Natasha Mehdiabadi/Rice University

Scientists are discovering ways in which single cells might have evolved traits that entrenched them into group behavior, paving the way for multicellular life. These discoveries could shed light on how complex extraterrestrial life might evolve on alien worlds.

Researchers detailed these findings in the Oct. 24 issue of the journal *Science*.

The first known single-celled organisms appeared on Earth about 3.5 billion years ago, roughly a billion years after Earth formed. More complex forms of life took longer to evolve, with the first multicellular animals not appearing until about 600 million years ago.

The evolution of multicellular life from simpler, unicellular microbes was a pivotal moment in the history of biology on Earth and has drastically reshaped the planet's ecology. However, one mystery about multicellular organisms is why cells did not return back to single-celled life.

"Unicellularity is clearly successful — unicellular organisms are much more abundant than multicellular organisms, and have been around for at least an additional 2 billion years," said lead study author Eric Libby, a mathematical biologist at the Santa Fe Institute in New Mexico. "So what is the advantage to being multicellular and staying that way?"

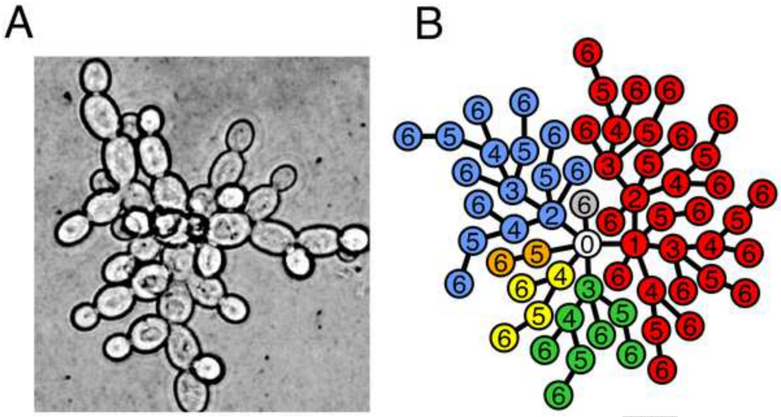
The answer to this question is usually cooperation, as cells benefitted more from working together than they would from living alone. However, in scenarios of cooperation, there are constantly tempting opportunities "for cells to shirk their duties — that is, cheat," Libby said.

When social amoeba Dictyostelium discoideum starves, it forms a multicellular body. Credit: Scott Solomon

"As an example, consider an ant colony where only the queen is laying eggs and the workers, who cannot reproduce, must sacrifice themselves for the colony," Libby said. "What prevents the ant worker from leaving the colony and forming a new colony? Well, obviously the ant worker cannot reproduce, so it cannot start its own colony. But if it got a mutation that enabled it to do that, then this would be a real problem for the colony. This kind of struggle is prevalent in the evolution of multicellularity because the first multicellular organisms were only a mutation away from being strictly unicellular."

Experiments have shown that a group of microbes that secretes useful molecules that all members of the group can benefit from can grow faster than groups that do not. But within that group, freeloaders that do not expend resources or energy to secrete these molecules grow fastest of all. Another example of cells that grow in a way that harms other members of their groups are cancer cells, which are a potential problem for all multicellular organisms.

Indeed, many primitive multicellular organisms probably experienced both unicellular and multicellular states, providing opportunities to forego a group lifestyle. For example, the bacterium *Pseudomonas fluorescens* rapidly evolves to generate multicellular mats on surfaces to gain better access to oxygen. However, once a mat has formed, unicellular cheats have an incentive to not produce the glue responsible for mat formation, ultimately leading to the mat's destruction.



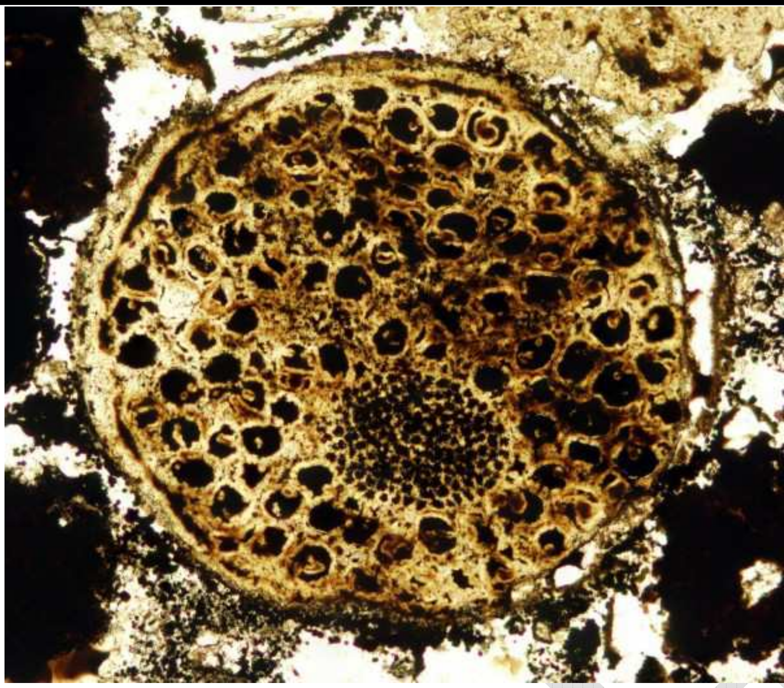
Groups of yeast cells. If key cells die a programmed death, these groups can separate. Credit: E. Libby et al., PLOS Computational Biology

To solve the mystery of how multicellular life persisted, scientists are suggesting what they call "ratcheting mechanisms." Ratchets are devices that permit motion in just one direction. By analogy, ratcheting mechanisms are traits that provide benefits in a group context but are detrimental to loners, ultimately preventing a reversion to a single-celled state, said Libby and study co-author William Ratcliff at the Georgia Institute of Technology in Atlanta.

In general, the more a trait makes cells in a group mutually reliant, the more it serves as a ratchet. For instance, groups of cells may divide labor so that some cells grow one vital molecule while other cells grow a different essential compound, so these cells do better together than apart, an idea supported by recent experiments with bacteria.

Ratcheting can also explain the symbiosis between ancient microbes that led to symbionts living inside cells, such as the mitochondria and chloroplasts that respectively help their hosts make use of oxygen and sunlight. The single-celled organisms known as *Paramecia* do poorly when experimentally derived of photosynthetic symbionts, and in turn symbionts typically lose genes that are required for life outside their hosts.

These ratcheting mechanisms can lead to seemingly nonsensical results. For instance, apoptosis, or programmed cell death, is a process by which a cell essentially undergoes suicide. However, experiments show that higher rates of apoptosis can actually have benefits. In large clusters of yeast cells, apoptotic cells act like weak links whose death allows small clumps of yeast cells to break free and go on to spread elsewhere where they might have more room and nutrients to grow.



A fossil of a 600 million-year-old multicellular organism displays unexpected evidence of complexity. Credit: Virginia Tech

"This advantage does not work for single cells, which meant that any cell that abandoned the group would suffer a disadvantage," Libby said. "This work shows that a cell living in a group can experience a fundamentally different environment than a cell living on its own. The environment can be so different that traits disastrous for a solitary organism, like increased rates of death, can become advantageous for cells in a group."

When it comes to what these findings mean in the search for alien life, Libby said this research suggests that extraterrestrial behavior might appear odd until one better understands that an organism may be a member of a group.

"Organisms in communities can adopt behaviors that would appear bizarre or counterintuitive without proper consideration of their communal context," Libby said. "It is essentially a reminder that a puzzle piece is a puzzle until you know how it fits into a larger context."

Libby and his colleagues plan to identify other ratcheting mechanisms.

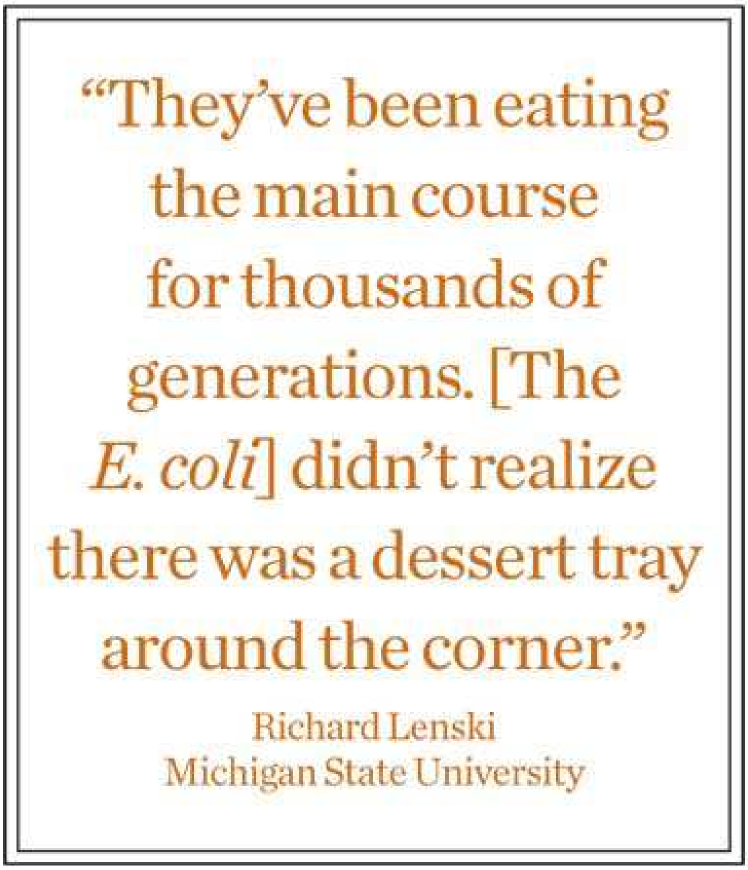
"We also have some experiments in the works to calculate the stability provided by some possible ratcheting traits," Libby said.

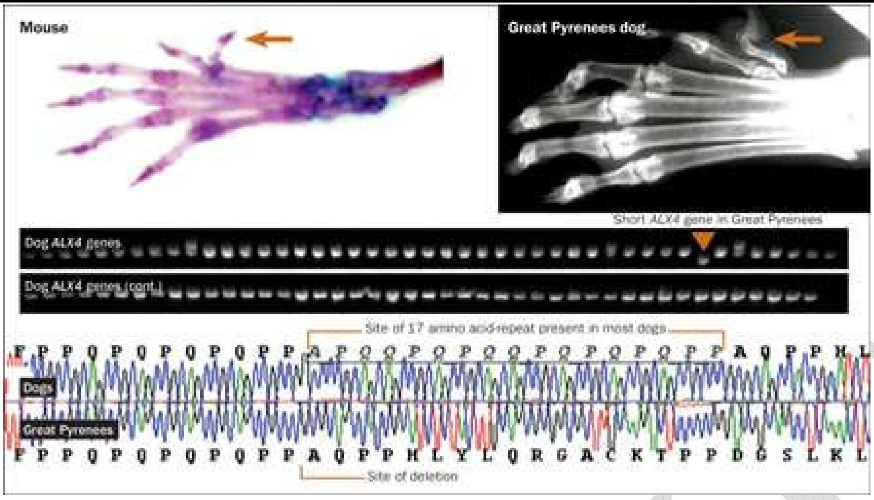
Molecular Evolution

Charles Darwin didn't know about genes and DNA. In fact, hardly anyone noticed when Gregor Mendel, a monk whose pea experiments eventually led to modern genetics, published his findings in an obscure journal a few years after Darwin's On the Origin of Species appeared in 1859. It would take nearly a century more before James Watson and Francis Crick deciphered the structure of DNA, the molecule that contains the manual for building an organism. Yet Darwin was still able to describe a mechanism — natural selection — for how evolution shapes life on Earth. That's like describing how a car works without knowing about the existence of internal combustion engines.

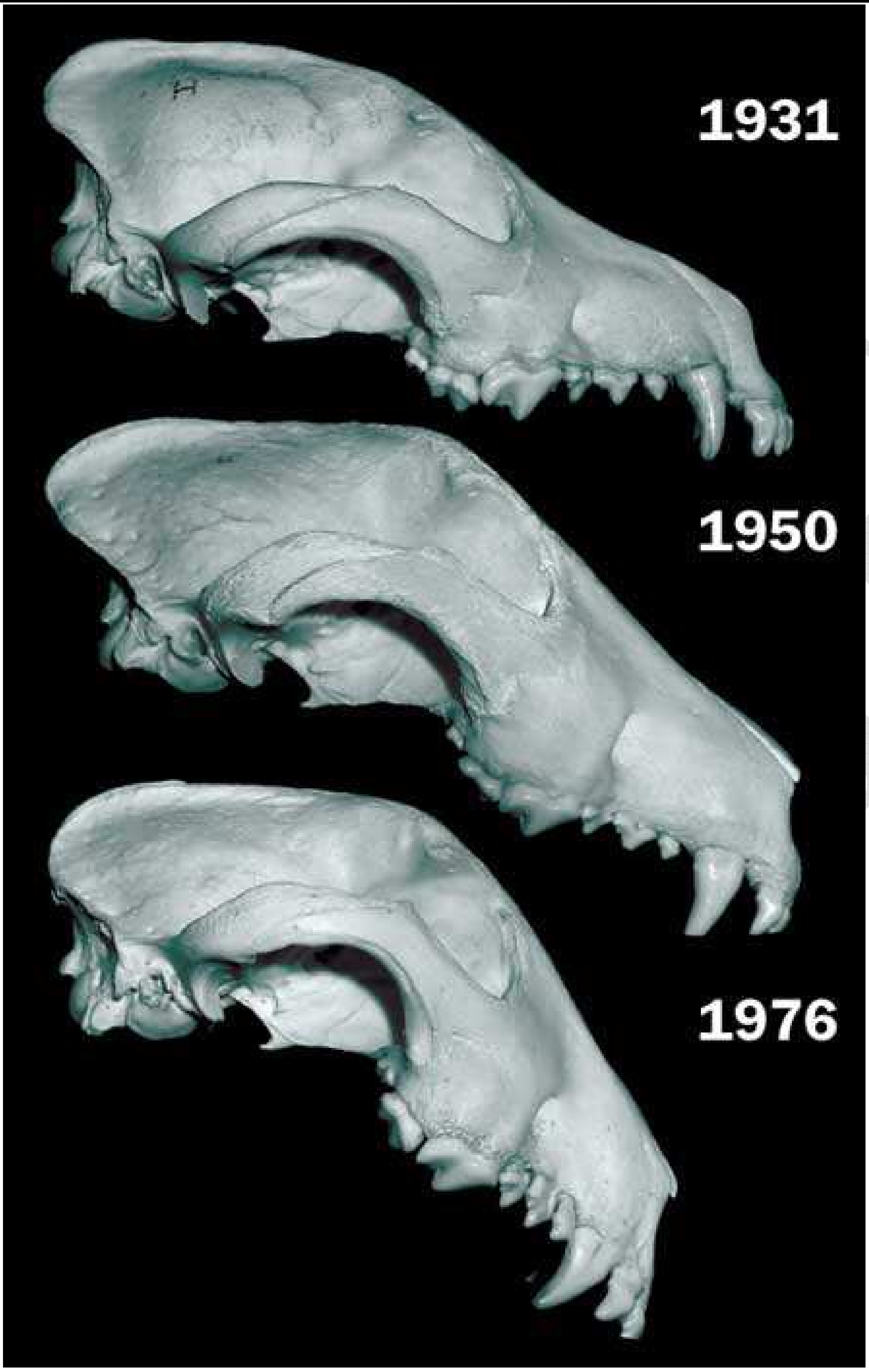
TOWERS OF BACTERIA Zachary Blount sits in front of a tower of petri dishes. Blount used the assembled dishes to test trillions of bacteria to see which had evolved the ability to eat a chemical called citrate.
Brian Baer/Michigan State University

E. COLI SAMPLES These 12 flasks contain separate populations of E. coli, all evolved from a single ancestor. Only the bacteria in flask A-3 evolved the ability to eat citrate.
Neerja Hajela and Brian Baer/Michigan State University

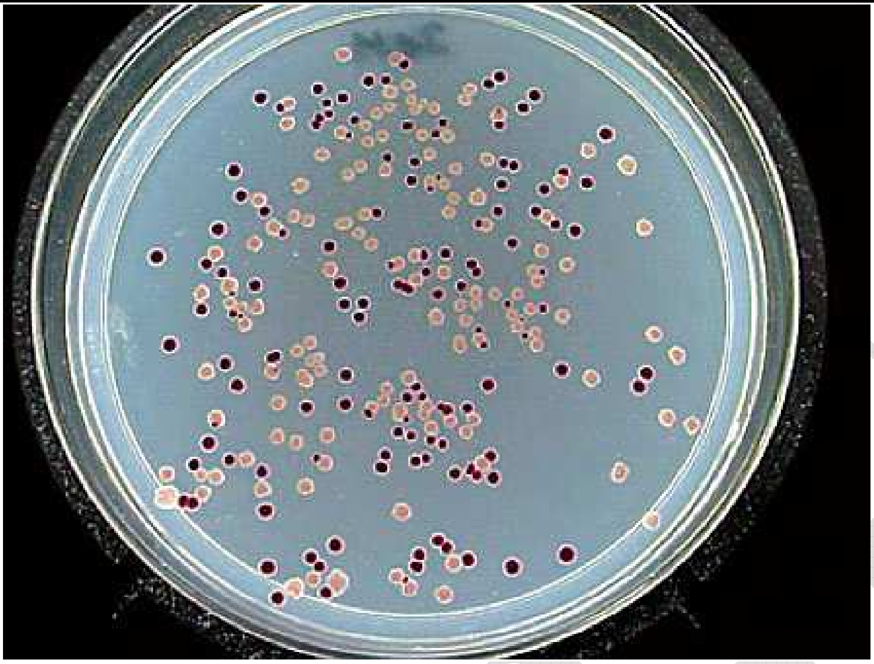




RECIPE FOR AN EXTRA TOE | Mice with a defect in the gene ALX4 grow extra toes on their back feet (top left). Back feet with extra digits are a hallmark of the Great Pyrenees dog breed (top right). Scientists have associated the extra toe with a deletion of repeated amino acids in the breed's ALX4 protein. In tests of 89 dog breeds, researchers found that the ALX4 gene was shorter only in Great Pyrenees dogs with an extra toe (gels, middle, compare ALX4 from 89 breeds; arrow shows Pyrenees' short version). The short gene results in the loss of a 17 amino-acid repeat (highlighted in the amino acid sequence from other dog breeds) from the ALX4 protein in Great Pyrenees (site of deletion marked on sequence, bottom).
Fondon/University of Texas at Arlington



RECENT EVIDENCE Evidence of recent evolution isn't limited to microbes. Skulls show the evolution of flatter faces in purebred bull terriers that has been linked to changes in a single protein.
John Fondon III / University of Texas at Arlington



COLORING BACTERIA To study evolution, researchers use color to distinguish ancestral E. coli from later generations in experiments gauging relative fitness (in this case, how well the bacteria use glucose).
Neerja Hajela/Michigan State University

But while Darwin achieved his insights without molecular help, biologists today are intimately familiar with the molecules responsible for the diverse array of plants, animals and other organisms that populate the planet. The study of genes has revealed evolution as essentially a high-stakes poker game in which organisms draw randomly from a deck of genetic choices. At stake is the chance to pass along genes to the next generation. Sometimes the hand is good enough to get ahead in the game, but some hands are losers, perhaps to the extent of extinction. By studying the winners, scientists are learning how the forces of evolution work on DNA, the biochemical repository of an organism's entire natural history. DNA records the mutations that helped some animals to survive ice ages while others perished, the nips and tucks that make animals more attractive to mates, the big leaps that allowed plants to become domestic crops — they're all there, written out in a simple alphabet of four letters.

Each organism has its own book of life, but it's not a just-so story. The genomes of living things are constantly undergoing editing and revision. And each individual has its own edition of its species's book, shaped by natural selection and the other, perhaps less-appreciated forces of genetic mutation, recombination and drift.

In recent years, the U.S. National Institutes of Health and private companies have sponsored programs to build a library of species' books, with projects to decode the genomes of humans, chimpanzees, bonobos, dogs, cats, cows, duck-billed platypuses, opossums, orangutans, bacteria, fungi, corn, wheat, bees, fruit flies, worms and a menagerie of other creatures large and small. Comparing the genetic records from these genomes will help researchers piece together a history of how Earth's current life evolved. But that work has barely begun, and many questions remain to be answered.

Scientists, for example, still don't know how cells evolved, including how former bacteria came to live inside cells as mitochondria and chloroplasts. (Mitochondria are tiny power plants that supply cells with energy, and chloroplasts are the organelles in plant cells that carry out photosynthesis.) Another mystery is how the complex structure of genes in eukaryotic organisms — in which the genetic material is encased in a nucleus — evolved. Researchers also debate how the shapes and forms of organisms came to look as they do. One of the biggest unanswered questions is whether life on Earth was destined to evolve the way it has.

Limits on evolution

At some time in your life you've probably asked yourself if, given a chance to do it all again, you would do it the same way.

Scientists have been asking the same question about evolution, but they've been getting different answers.

Play a poker game, rewind it to the beginning, start again and see what happens. Would the game play out the same every time? Stephen Jay Gould, the late evolutionary biologist, didn't think so. If you replay the game, the shuffled cards will turn up a little different each time, and the order in which the cards are drawn can have profound consequences for the outcome. Replaying the "tape of life" from some point in the past would produce very different life-forms than the ones we have today, Gould thought.

Other scientists disagree. Organisms are dealt a finite number of genes and so must choose from a limited menu of evolutionary options, narrowing the directions the organisms can go in a particular environment. "The evolutionary routes are many, but the destinations are limited," says Simon Conway Morris, a paleontologist at the University of Cambridge in England. As a result, disparate organisms often end up independently developing the same sorts of structures to solve a particular problem. Take eyes. Although the details of how eyes work vary between species, the basic structures are similar.

But since it's impossible to turn back time (no matter how easy Superman makes it look) and replay all of evolution again, scientists have devised other ways of investigating the issue.

Richard Lenski, an evolutionary biologist at Michigan State University in East Lansing, is among the scientists hitting the rewind button on evolution. Meter-high letters taped to the windows of his lab spell out the lab's motto: EVOLVE. In the center of the "O," the face of Charles Darwin peers out toward the football stadium.

Inside the lab, a dozen glass flasks containing what looks like clear liquid swirl in a temperature-controlled incubator. Although the naked eye can't see them, millions of E. coli bacteria grow in the flasks, doing what the window exhorts. Lenski started the cultures in 1988, intending to follow the course of natural selection for several hundred generations. Now, 20 years later, the cultures are still growing and have produced more than 45,000 generations of bacteria each.

Lenski inoculated each of the 12 flasks with bacteria from the same ancestor, so they all started out with the same genetic deck of cards. Only one gene differed among the bacteria at the beginning — six flasks contain a marker gene that makes the bacteria red when grown on certain media while bacteria in the other six grow white. The marker gene doesn't affect the strains' fitness — the term biologists use to describe the capacity of an organism to compete against others to pass on its genes — but it does help researchers distinguish between two lineages of the bacteria during competition experiments.

Each flask contains media with only the minimum requirements for survival — some glucose (a sugar that bacteria use for food) and a few other nutrients. The bacteria replicate, or divide, six or seven times daily, creating a new generation with each round. Each division shuffles the cards and produces genetic changes and mutations, some of which may help or hurt the bacteria's ability to compete for glucose and win the evolutionary poker game. The next day, a dilution is done, with 10 percent of the culture within a flask transferred to a new flask, and a new hand is played. (Every 500 generations or so, the remaining 90 percent is frozen and stored for later experiments.) The dilution acts as a population bottleneck, randomly selecting a subset of the bacteria (and so a subset of accumulated genetic changes) to continue the experiment.

These 12 flasks "represent the stripped-down bare essentials of evolution," says Zachary Blount, a graduate student in Lenski's lab. The environment never changes. No new genes enter the system from migrating microorganisms. And the scientists take no action to affect the course of evolution within the flasks. Only the intrinsic, core processes of evolution influence the outcome, Blount says.

Lenski and his colleagues have watched the game play out, occasionally analyzing DNA to peer over the players' shoulders and find out what cards they hold. On the surface, the populations in the 12 flasks seem to have traveled similar paths — all have grown larger and become more efficient at using glucose than their ancestors. And many of the strains have accumulated mutations in the same genes. Notably, though, no one strain has developed exactly the same genetic changes as another.

Randomness is an important part of the evolutionary equation, as the experiment illustrates. During the first 2,000 generations, all of the 12 populations rapidly increased in size and fitness. But then cell size changes and reproductive and glucose efficiency gains began to slow down, hitting the evolutionary equivalent of a dieter's plateau.

After 10,000 generations, it became apparent that not all the flasks were on the same trajectory. Though the cells in all the flasks became larger, each population differed in the maximum size the cells reached. The populations also differed in how much fitter they were than their ancestors, when the researchers grew them in direct competition. The "experiment demonstrates the crucial role of chance events (historical accidents) in adaptive evolution," Lenski and his colleague Michael Travisano wrote in a 1994 paper.

The experiment has progressed, and several of the flasks now contain mutater strains, bacteria that have defects in their DNA replication system. Such defects make mistakes more likely to happen every time those bacterial strains copy their DNA to divide. Sometimes a mistake can have lethal consequences, damaging a gene crucial for survival. But other times coloring a bit outside the lines creates opportunity for advancement.

Even within a given flask, some bacteria take slightly different paths. One flask now contains two separate strains — one that evolved to make large colonies when grown on petri dishes, and one that makes small colonies. The large- and small-colony strains have coexisted for more than 12,000 generations. The large-colony producers are much better at using glucose so they grow quickly, but they make by-products that the small-colony producers can eat. Each of the populations, both large and small, have improved their ability to use glucose over the generations. By at least one measure, the two populations could constitute separate species, Lenski and his colleagues proposed in 2005 in the Journal of Molecular Evolution.

Still, it seems that Conway Morris was basically right: Though the details were different, replaying evolution in a dozen flasks produced very similar outcomes in each. But then something completely unexpected happened.

After about 31,500 generations, glucose-eating bacteria in one of the flasks suddenly developed the ability to eat a chemical called citrate, something no other E. coli do, the researchers reported last June in the Proceedings of the National Academy of Sciences (SN Online: 6/2/08).

"They've been eating the main course for thousands of generations," Lenski says. "They didn't realize that there was a dessert tray around the corner."

The switch was clearly a radical change of destination for the bacteria. The inability to eat citrate is a biochemical hallmark of the E. coli species, so by some definitions, the citrate eaters in that flask are no longer E. coli, but a different species.

But a single change did not a citrate eater make. The researchers found that the bacteria went through a series of steps before evolving the ability to use citrate. One initial mutation happened at least 11,000 generations before the citrate eaters appeared. Lenski and his crew don't yet know which specific DNA changes led to citrate use, but the researchers have enough evidence to say that the ability to use citrate is dependent, or contingent, upon those earlier changes. And even the bacteria that have undergone those initial changes are still not guaranteed to find the dessert cart. Blount tested 40 trillion bacteria from earlier generations to see if any could evolve the ability to eat citrate. Fewer than one in a trillion could.

The profound difference between the citrate eaters and the other 11 strains, as well as the dependence of the citrate change on earlier mutations, seems to suggest that Gould was also right: Replaying evolution will result in some surprise endings. "The long-term evolution experiment with E. coli provides some of the best evidence for both Conway
Morris and Gould that one could ever hope to see," Lenski says. "Conway Morris 'wins' based on the number of changes that fit his pattern, but Gould might prevail if weighted by the

profundity of change. Both perspectives are important contributions, and they are not mutually exclusive."

Now the researchers are watching to see if citrate-eating bacteria will evolve in other flasks, and if citrate eaters will eventually reject glucose and feast only on citrate. Such a transformation would probably herald the birth of a new species. "It would be amazing," says Blount. "It would be like teenagers who no longer like to eat pizza — they prefer broccoli."

When the game changes

While Lenski's experiment takes place in a constant environment, natural evolution must cope with a messier reality. In Steven Finkel's lab at the University of Southern California in Los Angeles, a long-term experiment is showing how evolution plays out in a closed and ever-changing environment, more like the real world. This allows Finkel to focus on how evolution and environment are interwoven.

Finkel didn't start out to test evolution in changing environments. The experiment was prompted by a graduate student's casual remark that E. coli will live a long time. Finkel asked, "How long?"

"A long time," the student responded.

"So we set up some experiments to see how long they would live, and they just would never die," Finkel says. The immortal bacterial cultures are teaching scientists a few things about how organisms change their environments and adapt to changes wrought by outside forces.

Some of the cultures in Finkel's laboratory have been growing for more than five years. The bacteria started out with the same genetic background, or so the researchers like to tell themselves. In reality, each flask started with a single bacterial colony, containing perhaps 50 billion individuals. Given that DNA replication systems aren't perfect, one in every 10,000 cells probably carries a typo in at least one letter of its instruction manual. Such DNA typos are known as point mutations.

Finkel and his colleagues placed the bacteria in a rich broth full of sugars and many other nutrients and then just let them grow. After a short initial lag, the bacteria began growing like gangbusters, a phenomenon known to microbiologists as "log phase" because the bacteria increase their numbers logarithmically. Once the nutrients start to run out, the bacteria stop growing so quickly and settle into a senescent state. After a few days, millions of bacteria die, spilling their guts into the surrounding media and providing food for survivors.

It's the postapocalyptic survivors that interest Finkel. As 99 percent of their comrades die off, the surviving bacteria feed on the carcasses of the dead and on metabolic by-products of other survivors. Thus the bacteria change the environment in which they live. It doesn't take long for the cultures in each flask to go their own ways. Within a month, the bacteria in the various flasks convert the light honey color of the broth into a spectrum ranging from light amber to dark amber, Finkel says. And his nose tells him the cultures are different as well. Microscope examinations reveal that the originally rod-shaped bacteria take on a wide variety of shapes; in one flask, some of the cells never cut the apron strings during cell division, forming long strands resembling linked sausages.

Yet as different as the bacterial populations appear, they also have something in common. All of the cells that have gone through the valley of death and come out the other side are tougher than naive bacteria. And the older the cells get, the more competitive they are, so that 20-day–old cells will drive 10-day–old cells to extinction, and 30-day–old cells beat 20-day–olds. Finkel calls that phenomenon “growth advantage in stationary phase,” or GASP.

On the surface it appears that the number of surviving cells stays constant. But underneath, different mutants rise and fall in number, like waves crashing on the beach, Finkel showed in a 2006 review published in Nature Reviews Microbiology.

The ability for older cells to compete better has been traced to mutations in four genes. Three of the genes allow the bacteria to feast more readily on certain amino acids. One of the genes encodes a key protein, RpoS, needed to turn on stress-response genes. The protein gives the green light to turn on genes under certain conditions. When cells are under stress — for bacteria, stress means high salt, low or high temperatures, broth that is too acidic or alkaline, or other environmental extremes — RpoS turns on genes that help the bacteria cope. But the protein is not necessary when cells aren’t under stress. In fact, it takes resources away from the cells’ main “go” signal, RpoD, a protein critical to normal function. Inactivating or handicapping RpoS makes more resources available for other genes.

Many of the GASP cells contain changes in rpoS, the gene for RpoS, but they don’t all have the same change, Finkel and colleagues reported in 2003. Nearly all of the changes reduce activity of RpoS to 1 percent or less of its normal activity but don’t abolish it entirely. Low levels of RpoS are a fixture in bacterial populations that have GASP.

But just because a mutation serves an organism well under some conditions doesn’t mean it’s always beneficial. Thomas Ferenci, a microbiologist at the University of Sydney in Australia, reviewed what happens to rpoS mutants under a variety of environmental conditions in the May 2008 Heredity. Depending on a cell’s genetic background, an rpoS mutation might give the strain a big boost in fitness or make an undetectable difference. And even if the mutations are beneficial under most conditions, the changes hold the bacteria back when the environment changes. If salt concentrations go up, the temperature drops, bacteria lack oxygen or encounter a toxin, then rpoS mutants, less able to cope with certain types of stress, don’t become established members of the community as quickly as they do under other conditions.

Natural selection works for rpoS mutants in some environments and against them in other conditions. “Selection is a deterministic force pushing relentlessly in one direction,” says Michael Lynch, an evolutionary biologist at Indiana University in Bloomington. That direction is toward ever-greater adaptation for the environment in which a population finds itself. But most environments are in a constant state of flux and, as Darwin was careful to point out in his introduction to the Origin of Species, selection isn’t the only evolutionary force at work.

Sex, chance and genes

Random genetic drift is an evolutionary force to be reckoned with too. And, as with selection, molecular biologists are helping to reveal its workings.

Drift by any other name would be known as chance. The number of individuals that carry a specific genetic variation within a population — what scientists call the frequency of a gene variant — can change at random, bobbing along like driftwood on the ocean. The indiscriminate nature of drift doesn't always work to organisms' betterment.

"Drift doesn't care about fitness," Lynch says.

Drift can haphazardly make a detrimental gene prominent in a population, or accidentally eliminate beneficial mutations — especially in small populations. Imagine two versions, or alleles, of a gene as the head and tail of a coin. Every time an organism reproduces, the coin is tossed to see which allele will be passed to the offspring. In a large population, coins will flip many times and the number of heads and tails will be roughly equal. But in a small population, runs of heads or tails can skew the outcome in favor of one or the other allele, maybe even eliminating one version altogether.

That's a simple example of what drift can do, but Lynch thinks it also accounts for some complex traits, such as the complicated structure of genes in eukaryotic organisms — including multicellular beings like people and plants and unicellular life such as yeasts.

Drift causes noise in the evolutionary process, says Lynch. But there is yet another force that mixes things up — genetic recombination. Recombination is an essential element of sexual reproduction. In general, each parent contributes a single copy of each chromosome to its offspring. Before mom and dad divvy up the genetic goodies to hand down to the children, the two copies of each chromosome are lined up and matched like pairs of socks. When the two chromosomes are zipped together, they swap chunks of DNA, giving each egg or sperm a different combination of the parents' genes.

Genes follow each other along a chromosome like freight cars on a train follow the lead engine, unless recombination happens. So if one gene develops a lethal mutation it may doom the other genes on the chromosome, like a train car that gets unbalanced and derails the train. Similarly, a beneficial mutation might get trapped on a slow train to nowhere if not for recombination shuffling the mutated gene's position on the chromosome. Or a particularly good mutation may create such a powerful engine that natural selection can't resist taking along whatever's attached — like an engine dragging a decrepit train.

Low rates of recombination enhance the effect of drift because "beneficial alleles could get trapped in bad backgrounds," Lynch says. Natural selection would derail some trains, taking "good" genes along with the bad. "That's simply because you are a victim of the surrounding genetic material," he says.

Recombination allows the cars to uncouple and switch around, creating faster, more efficient trains. Once removed from a bad neighborhood and pasted in a beneficial or neutral stretch of chromosome, an allele's attributes can shine, and natural selection can act on the allele without any worries about the company it keeps. In this way, the process helps to increase the efficiency of natural selection, Lynch says.

Researchers are still debating the details of how selection works together with mutation, recombination and drift to shape genes and help organisms adapt to their environments, producing the abundance of species around today.

"We're peeling back the onion of the evolutionary process," says Sean Carroll, a developmental and evolutionary biologist at the University of Wisconsin–Madison. "The question is no longer 'does adaptation happen?' but 'how does it happen?' "

Evolutionary tweaks

In the past few years, scientists have learned that genes work together in vast networks to regulate every process in the body. Of special interest to many evolutionary biologists are transcription factors, proteins that are important for controlling the timing and placement of gene activity during development (and later). Each transcription factor may govern multiple genes, even hundreds of genes.

"We're into scores of direct targets," Carroll says. "More than we imagined. More than we even have an explanation for."

Implications of such vast gene regulatory networks are clear for Carroll. Altering the structure of a transcription factor to better regulate one gene could have effects on hundreds of other genes. Tinkering with a transcription factor doesn't just alter the shape of a fin, add a horn or move a spine. No. These molecules are so important and work in so many different parts of an organism that changing the transcription factor itself is likely to affect nearly everything about the living thing. Most of the time, such far-reaching changes are bad, even lethal. Carroll and others have been working to understand how body shapes and coloring morph in animals. If changing transcription factors could be catastrophic, organisms must make molecular tweaks elsewhere to create a new look.

Carroll is a leading proponent of an idea called the cis-regulatory theory. (Cis refers to a region adjacent to the gene or on the same chromosome.) The theory holds that altering the control region of a gene to change some feature of an animal or plant would produce fewer side effects than tinkering with the proteins that direct construction of the features. So an organism can change one part of its body without affecting the rest simply by adding a few more switches and buttons to its control panel (or taking some away), or by rewiring a switch to work at a different time or govern development in a new location.

Fish called three-spined sticklebacks have provided some of the most direct evidence that the cis-regulatory theory could be correct. The fish live in saltwater but swim into rivers to spawn. That habit led to isolation of many of the fish in inland freshwater lakes at the end of the last ice age.

Over the past 10,000 years the fish have adapted to their new homes, says David Kingsley, an evolutionary biologist at Stanford University.

In the ocean, sticklebacks wear armor and sport pelvic spines that protect them from sliding down the throats of predators. Fish stranded in freshwater lakes found themselves without the fishy predators they knew in the ocean, but some encountered deadly insects, such as dragonflies.

Dragonflies grab the sticklebacks by their pelvic spines and eat the fish sideways, so the feature that once offered protection became a liability. Over time, some populations of fish have shed their armor and their pelvic spines.

Kingsley and his colleagues discovered that a protein called PITX1 is responsible for building the pelvic spines. The protein is made in the hind limbs of many different animals, including humans. A group of researchers from Washington University in St. Louis showed that a mutation in PITX1 in humans caused clubfoot in members of a family. The team published the research in the Nov. 7 American Journal of Human Genetics. The protein also controls development of the pituitary gland and facial development. Defects in PITX1 can lead to cleft palate.

But when Kingsley and his colleagues examined the gene encoding PITX1 in stickleback fish with and without spines, the researchers found no differences. That led them to believe that the defect must lie in the control panel for PITX1 and not in the gene itself. But the scientists had no direct evidence that changes in the control panel were responsible for the missing spines.

Recently, Kingsley's group did discover that some of the stickleback species that have lost spines also lost a portion of the control panel that turns PITX1 on in the pelvis. Restoring the lost switch also restored spines, Kingsley told science journalists gathered in Palo Alto, Calif., in October at a conference sponsored by the Council for the Advancement of Science Writing.

"That's an 'i' that has needed to be dotted," says John "Trey" Fondon III, an evolutionary biologist at the University of Texas at Arlington. "We've had some really great circumstantial evidence for cis-regulatory evolution, but the data have been lacking. It's been a little, what we call, 'empirically challenged.'"

Fish aren't the only animals providing evidence for how evolution works in genes. Fondon and others have turned to man's best friend to figure out how genes influence body shape and size, behavior and other traits. Dogs come in an astounding number of variations, with the smallest dogs, Chihuahuas, weighing under six pounds and the largest breeds weighing more than 100 pounds.

A group of scientists from the National Institutes of Health and collaborators traced body size in dogs to a variation of the insulin-like growth factor gene (IGF1). Within the gene itself, researchers found no differences between large dogs and small dogs. But dog breeds that weigh less than 20 pounds had a common change in the IGF1 control panel, altering how much of the protein is produced, the researchers reported in 2007.

Kingsley cites the IGF1 finding as further evidence that changes in control regions can account for surprisingly large differences in body shapes and sizes. But Fondon says he isn't ready to swallow the "cis-regulatory Kool-Aid" just yet.

In contrast to the cis-regulatory theory, Fondon and his colleagues have found evidence that tampering with transcription factors can change specific features without having disastrous consequences for the whole organism. The team focused on repeats of amino acids within proteins. Proteins work a bit like Swiss Army knives with various tools tied together in a single package. The repeated amino acids are often found between the stretches of amino acids that form each of the tools. Fondon reasoned that slightly altering the number of repeated amino acids, each of which are encoded by repeated three-letter DNA sequences, might subtly change the function of the protein, creating a variant that could be put to an evolutionary test.

But Fondon realized that hypothesis also had its weak point: Repeats in DNA tend to mutate at high rates. The machinery that replicates DNA loses its place when reading the same letters over and over and over again. Sometimes it slips up and skips a repeat or adds an extra. High mutation rates can be dangerous because of a higher chance of catastrophic error. In some families, extra DNA triplet repeats in the gene for the huntingtin protein can lead to Huntington's disease. Often the number of repeats grows with each generation, causing people to develop the disease at younger and younger ages.

"I thought selection wouldn't tolerate this kind of crap in our genes," Fondon says.

But when he created a computer program to find genes in dogs that contain such repeats, he found a surprising number. "The top half of the list was a who's who of development," he says. This list includes genes that control bone development and the homeobox genes, which encode transcription factors that direct construction of an animal's body, distinguishing head from tail and back from front, and guiding the positions of limbs and appendages. These genes are found in almost every type of animal on Earth, from sponges to people. Even fungi and plants have some forms of homeobox genes.

Expanding and contracting the number of amino acid repeats in certain homeobox genes seems to give dog breeds some of their distinguishing characteristics.

"If what the protein does is a verb, a repeat is an adverb," says Fondon. The repeats don't change what the protein does; they just make it happen more quickly, slowly or frequently.

For instance, in Great Pyrenees, deletion of a repeat in the ALX4 gene leads to the formation of an extra toe on the back feet, a hallmark characteristic of the breed. Mice with defects in ALX4 also grew extra digits on their back feet.

A protein called RUNX2 governs genes that help control facial development in dogs. Fondon and his colleagues found that changing numbers of repeats within RUNX2 are associated with ongoing exaggeration of certain face traits. Scientists have documented such changes in the bull terrier's RUNX2 protein between 1931 and today. Modern bull terriers have fewer repeats of a certain amino acid sequence than members of the breed did in 1931. That doesn't sound like a big change, but could be one factor contributing to the flatter faces seen in today's bull terriers.

Carroll doesn't deny that mutations happen in transcription factors too, but he thinks such mutations probably affect genes that play a more limited role in development. Regulatory changes are more likely in genes that govern development of many different parts of the body, he says.

But others don't think it has to be all regulatory mutations or all protein changes that create novel traits in animals. Vincent Lynch, an evolutionary biologist at Yale University, and his colleagues discovered that both types of changes were needed for pregnancy to evolve in mammals.

Control issues

When most female mammals get pregnant, the embryo attaches to the wall of the uterus. Normally something burrowing into the body causes the immune system to take up arms and oust the intruder, but that would make pregnancy impossible. So placental mammals turn up production of prolactin, a protein that calms the immune system and does other jobs that allow an embryo to develop safely.

Yale's Lynch and his colleagues discovered that the evolution of pregnancy probably happened in several steps. The first step was that a jumping gene, called a transposon, hopped into the control panel of the prolactin gene. The transposon brought with it a switch operated by the homeobox protein HOXA11. Over time, HOXA11 developed changes that allowed it to work with other proteins to more precisely control prolactin production, Lynch and his colleagues reported in the Sept. 30 Proceedings of the National Academy of Sciences. Only HOXA11 from mammals turns on prolactin, the researchers showed. HOXA11 from chickens, platypuses and opossums (all animals without a placenta) failed to turn on production of the pregnancy-associated protein.

Such complementary changes to proteins and their genetic control panels help evolve a toolkit that organisms can use for every occasion, Lynch says.

"A hammer in a toolbox can be a ball-peen hammer. It can be a hammer that pulls nails. It can be a mallet, but it's still a hammer. It evolves to its own context," he says.

Animals, plants, bacteria, archaea, fungi and all organisms on Earth evolve to their own contexts as well. Scientists are now beginning to learn how tweaks and major changes on the molecular level enable adaptation to environments. The picture is painted in DNA, but it's far from a completed masterpiece. Changing environments coupled with the forces of natural selection, mutation, recombination and drift are continually reworking the painting. Only time will tell how the landscape will morph — and its inhabitants with it.

Two marks

1. Write about the biotic environment.
2. Write about Habitat.
3. What is Population Ecology?
4. Write short note on r and K selection.
5. Write short note on concept of metapopulations.
6. Write short note on Community Ecology.
7. What are Ecological Succession?
8. Write about the Ecosystem structure.
9. Define mineral cycling.
10. Write in detail about the function of some Indian ecosystems.
11. What are aquatic ecosystems?
12. Write short note on Biogeography.
13. Write short note on Emergence.
14. Write the Darwin–concepts.
15. Discuss on Convergent evolution.
16. Give two examples for Social communication.
17. What are behavioral changes?
18. Discuss on the role of cytoplasmic determinants.
19. What is Gametogenesis?
20. What are early development?
21. Write the fertilization.
22. Define the Morphogenesis.
23. What are organogenesis?
24. Write about Cell aggregation.
25. Define the term differentiation.

Six Marks

1. Write briefly on Population Ecology.
2. Describe the life history strategies.
3. Explain in detail about the concept of metapopulations.
4. Describe the Community Ecology.
5. Describe about Ecological Succession.
6. Explain in detail on the Indian case studies on conservation/management strategy.
7. Write in detail on structure and function of some Indian ecosystems.
8. Elaborate on the Major terrestrial biomes.
9. Describe about the biogeographical zones of India
10. Explain the Conservation Biology?
11. Write about the Origin of cells and unicellular evolution.
12. Explain about the Concept of Oparin and Haldane.
13. Write in detail on Evolution of prokaryotes, eukaryotic, unicellular eukaryotes.
14. Write about the Origins of unicellular and multi cellular organisms.
15. Give a detailed study on Molecular Evolution.

16. Write about Development of behavior
17. Describe in detail about the Behavior and Evolution
18. Explain the detail process of Social communication.
19. Explain in detail about the genomic equivalence and the cytoplasmic determinants.
20. Write about the mutants and transgenics in analysis of development.
21. Elaborate on Morphogenesis and organogenesis in animals.
22. Explain in detail about Cell aggregation and differentiation
23. Explain about environmental regulation of normal development.
24. Elaborate on Morphogenesis and organogenesis in plants.

Questions	Opt 1	Opt 2	Opt 3	Opt 4	Answer
Unit I					
The term environment literally means……	The surroundings	The structures	The system	The climate	The surroundings
The Primary consumer are also called as	herbivores	carnivores	omnivores	detrivores	herbivores
Valuable, practical services that help to	ecosystem service	biological control	the green house	biosphere	ecosystem service
The surrounding physical and biological	nature	ecology	forest	environment	environment
The organic matter produced by the	light energy	cellular process	energy flow	primary	primary
___________ is diffused into the ground	Rain water	Ocean	River water	sea	Rain water
Solar energy stored in material such as	fossil fuels	biomass	geothermal energy	natural gas	biomass
Decomposers are otherwise called as	detritivores	primary	organic matter	secondary	detritivores
Light energy is transformed into chemical	photosynthesis	respiration	recycling	productivity	photosynthesis
All food chains starts with ___________	environment	organisms	photosynthesis	fungi	photosynthesis
In grazer food chain the living plants are	destroy	consume	decay	grown	consume
A pond, serves as a good example for a	fresh	brackish	marine	se	fresh
The type of ecosystem with the highest	tropical rain forest	temperate	desert	tundr	tropical rain forest
In an aquatic ecosystem, the tropic level	nekton	zooplankton	phytoplankton	benthos	zooplankton
The most serious pollutant to rubber tyres is	CO_2	CO	O_3	NO_2	O_3
All species on earth together with their	lithosphere	hydrosphere	atmosphere	biosphere	biosphere
_________ is the study that deals with the	Etiology	Ecology	Botany	Biology	Ecology
Organisms that feed upon other living	producers	consumers	pests	decomposers	consumers
A food web is __________	like a food chain	a set of	the set of prey	the tropic	a set of
The first tropic level refers to __________	all herbivores	all green plants	sunlight	all animals	all green plants
A biomass pyramid is important because it	how energy flows	the number of	the biomass of all	the number of	the number of
Fungi is/are __________	single-celled	Phototrophic	eukaryotes single-	heterotrophic	heterotrophic

Basidiospores are considered to be a major	airborne allergens	water borne	animal faeces	bioweapon	airborne allergens
Man and biosphere programme is affiliated	UNESCO	IUCN	WWF	WIPO	UNESCO
Trichodermaharzianum has proved a useful	reclamation of	bioremediation of	biological control	gene transfer	bioremediation of
Ozone depletion in the stratosphere will	increased	forest tires	global warming	hole	hole
The relationship between living and non living things are called ….	Biodiversity	Ecosystem	Acid rain	Water	Ecosystem
Most harmful environmental pollutants are	natural nutrients in	human organic	non-biodegradable	waste animal	non-biodegradable
There would be no life in the oceans	decomposers,	zooplankton,	phytoplankton,	zooplankton,	phytoplankton,
The ozone at ground level is primarily from	fossil fuel	CFCs	oxygen	methane	fossil fuel
The major biodiversity hotspot in Tamil Nadu is ….	western Ghats	saputhara	kollihills	all the above	western Ghats
__________ is the totality of genes, species	Habit	Habitat	Biodiversity	Food chain	Biodiversity
A food chain starts with a………………	consumers	scavengers	producer	decomposer	producer
The main source of water in India	rain water	ground water	surface water	sea water	rain water
The unit of ecosystem is………	Kelvin	Biosphere	Calories	Animals	Biosphere
The process of light energy converted to	reduction	oxidation	photosynthesis	All the above	photosynthesis
The food chain stats with dead matters are	grazing food	detritus food chain	Parasitic chain	none of the	detritus food chain
The reducer are also called …..	plants	decomposer	animals	parasites	decomposer
_______is one of the following is the non-	Water	Oxygen	Sunlight	Coal	Coal
________ soil is the best for plant growth	Sandy soil	Clay	Gravel	Loamy Soil	Loamy Soil
_____________ of stratosphere provides	Nitrogen	Hydrogen	Ozone	Argon	Ozone
Both power and manure are provided by	thermal	nuclear	biogas	hydroelectri	biogas
The resources that are derived from bio-	renewable	non-renewable	environmental	natural	renewable
The dramatic increase in agricultural	biotechnical	bioeconomic	green house effect	green	green revolution
A form of energy or matter that is essential	resources	natural resource	environment	forest	resources
Oil spills are a source of pollution	water	land and water	land and air	air and noise	land and water

Air is composed of gases, water vapours	rainfall	snowfall	dust particles	light	dust particles
_________ is a water borne disease	Small Pox	Meningitis	diarrhoea	Cholera	Cholera
The first 'Green revolution' in	1960s	1970s	1980s	1990s	1960s
Flora is the _______ life occurring in a	plant	animal	human	microbial	plant
Water used for paper mills should not	magnesium	sodium	iron	chlorine	iron
Fuel cells are………………	Carbon cell	Hydrogen battery	Nuclear cell	Chromium cell	Hydrogen battery
Which is the renewable energy source?	natural gas furnace	cows	coal burning	gas grill	cows
Air is composed of gases, water vapours	rainfall	snowfall	dust particles	light	dust particles
________ cycle is not a gaseous	Nitrogen	Carbon	Sulphur	Phosphorus	Phosphorus
Carbon dioxide is called green-house gas	transparent to	transparent to	used in green-	transparent to	transparent to
The species rich ecosystem	Marine ecosystem	Terrestrial	Special Ecosystem	Extra terrestrial	Marine ecosystem
The most fundamental level of biodiversity	Genetic diversity	Species diversity	Population	Diversity	Genetic diversity
The lowest species diversity in the tropical	Eastern Atlantic	Eastern Pacific	Western Atlantic	Indo-Pacific	Eastern Atlantic
Physically India is divided into…….	Four region	Seven region	Five region	Two region	Four region
Unit I I					
Some species play ecological roles that are	primary species	Keystone species	Climax species	Decomposers	Keystone species
People love, live, a phenomenon called…	Spirituality	Meditation	Peace	Biophilia	Biophilia
Three important issues of biodiversity……	Commodity,	Genus, species	Community,	Flora, Fauna	Commodity,
Total identifies species on theearth………	1.5 million	5-30 million	3 million	10 million	1.5 million
Two biodiversityhotspots in India…………	Gangetic and	Western Ghats	Peninsular and	J&K and	Western Ghats and
Total biodiversity hotspots in the world…	25	2	15	50	25
Levels of biodiversity include all but one…	Genetics	Species	Population	Ecosystem	Population
The type of diversity including all the	Species diversity	Genetic diversity	Ecosystem	Population	Species diversity
A taxon with restricted geographical	Rare	Vulnerable	Extinct	Endemic	Endemic

Conservation of biodiversity outside the	Ex-situ	In-situ	Conservation	In-vivo	Ex-situ
Biosphere reserve has following zone	Core zone	Command zone	Buffer zone	Spherical zone	Spherical zone
In which of the following boundaries are	Biosphere reserve	Sanctuary	National parks	Colony parks	Sanctuary
The knowledge of which of the following	Habitat of wildlife	Behaviour of	Food habit of	Name of	Name of wildlife
In ________ type of wildlife management	Closed season	Open wildlife	Custodial	Limited entry	Closed season
The tigers are found in which of the	Thar desert	Neelgiri biosphere	Namdhapa	Sunderbans	Sunderbans
How many biosphere reserves are present in	41	34	14	17	14
Biodiversity of which organism is more in	Reptilia	Amphibian	Aves	Mammals	Amphibian
Which one of the following is not used for	Field gene banks	Seed banks	Shifting cultivation	Botanical	Shifting cultivation
Which one is odd for species diversity ?	alpha diversity	gamma diversity	beta diversity	lamnda	lamnda diversity
Species diversity is responsible for which	process of	speciation	For alternative	For stability	For stability and
How many botanical gardens are registered	1500	80,000	800	900	800
Which of the following represent maximum	Algae	Lichens	Fungi	Mosses and	Fungi
Prolonged liberal irrigation of agricultural	Aridity	Metal toxicity	Salinity	Acidity	Salinity
The greatest problem of water conservation	Precipitation	Runoff water	Groundwater	Evaporation	Runoff water
Maximum nutritional diversity is found in	Monera	Plantae	Fungi	Animalia	Monera
Which regions are included in Biodiversity	Sanctuary	National park	Garden	Only Hotspot	Sanctuary
For which animal sunderbans is declared as	Lion	Rhino	Tiger	Wild ass	Tiger
Which organisation is active for	WWF	WCU	a and b both	EE	a and b both
Which animal is remnant gene pool in the	Flamingo	Painted Frog	Wild ass	Spring tailed	Wild ass
Which is true for wild life conservation ?	Hunting of prey	ex-situ	In-situ	ex-situ	ex-situ
At which place animals and plants are most	Botanical gardens	National Park	Zoos	Sanctuary	National Park
What is called the area which is remain	Buffer	Transition zone	Developed zone	Peripherial	Buffer
Where Mangroves forest found ?	Dry region	Coastal region	Open area	tropical region	Coastal region

Where is the genes of rare plants species to	Gene bank	Gene Library	Herberium	Open area	Gene bank
In India different types of mangoes species	species diversity	Genetic diversity	Induced mutation	Breeding	Genetic diversity
Which number is correct for Indentfied	1.1 to 1.1 million	0.5 to 1.0 million	2.5 to 3.0 million	1.7 to 1.8	1.7 to 1.8 million
What is important of gene diversity ?	Maintenance of	speciation	Research of genetic	Maintenance	speciation
Which is the modern concept of	Biosphere reserve	sanctuary	National park	Protected	Biosphere reserve
Which of the following is not an air	Smoke	Carbon Dioxide	Nitrogen Gas	Sulphur	Nitrogen Gas
A fossil fuel is best described as_______	a flammable solid	a fuel that	fossilised rock that	a flammable	a flammable
The process of extraction,	embodied energy	kinetic energy	potential energy	Enbedded	embodied energy.
___________depends on energy mainly	rural transport	Urban transport	Metro transport	Semiurban	Urban transport
As ________and __________spreads due	deforestation and	afforestation and	deforestation and	desertification	deforestation and
Urban residential and commercial facilities	25%	35%	45%	65%	35%
______________is defined as de-	Sustainable	Economic	Social development	Environment	Sustainable
_______supplies water to plants near its	Drip irrigation	Well irrigation	Tube irrigation	Submersible	Drip irrigation
The management of a single unit of land	Watershed	Rainwater	Land recreation	Drainage	Watershed
Changes in climate may affect the	vector species	vetebral species	fungi species	bacterial	vector species
The _______ plant is grown on the doorstep	tulsi	moneyplant	green leaves	olive	tulsi
Certain species of trees have been protected	fruit or flowers	flowers or trees	trees or fruits	trees or plants	fruit or flowers
The ___________ is protected for its fruit	banyan tree	coconut tree	mango tree	peach tree	mango tree
The __________is protected by tribal	Mohua tree	Madhuca indica	mango tree	Mohua and	Mohua and
About ______ of the solar energy reaching	85%	75%	65%	95%	75%
The _______ affects plant and animal life in	fossil fuel	oil refining	acid rain	acidic raining	acid rain
Wasteland can be classified into	2	3	4	5	2
NGO stands for ___________	non-governmental	non govern	not good	non	non-governmental
The Government has formulated Water Act	1975	1974	1973	1972	1974

The main objectives of the Water Act are to	prevention	control	protect and	prevention and	prevention and
The Forest Conservation Act was passed in	1982	1980	1981	1985	1980
India's first Forest Policy was enunciated in	1951	1952	1953	1954	1952

Unit III

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
Archaebacteria?	a)Actinomycetes	b)Pseudomonas	c)Rickettisae	d)Methanogens	d)Methanogens
Formation of most amino acids as well as adenine andother nucleic acid bases from inorganic molecules was experimentally shown by	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
Which of the following statement cannot be support the endosymbiotic theory for the orgin of mitochondria?	a)Mitochondria DNA has a circular genome	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	c)mitochondrial genes code for enzymes of oxidative respiration	d)mitochondria l ribosomes are 70s	c)mitochondrial genes code for enzymes of oxidative respiration
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
Which of the following process offers the greatest opportunities for accelerating the evolution of new useful proteins?	a)exon shuffling	b)intron excisions	c)transposons insertions	d)DNA amplification	a)exon shuffling
The correct chronological sequences of geological times is	a) Devonian, Carboniferous, Cretaceous, Eocene	b) Eocene, Devonian, Carboniferous, Cretaceous	c) Devonian, Carboniferous, Eocene ,Cretaceous	Carboniferous, Devonian, Cretaceous, Eocene	a) Devonian, Carboniferous, Cretaceous, Eocene

The extant bacterial group that is most closely related to the ancestor from which mitochondria evolved is	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	Photoautotrophs	c) Chemoheterotrophs
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
The animals of cold countries have relavely shorter and poorly developed ears, eyes, hairs and other phenotypic characters. This is known by which law?	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

First experiment regarding 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	polymerisation and	d) polymerisation and aggregation
Miller and Urey performed an experiment to prove origin of life. They look for gases NH and H along with?	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 of the following was not present in the primitive atmosphere of the earth?	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
Finding of Miller's experiment on origin of life has provided evidence for the	a) theory of special creation	b) theory of biogenesis	c) theory of abiogenesis	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	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
The evolution of a species is 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
According to Neo- Darwinism, 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
Quick change in phenotypes in 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	isolation	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	acquired characters	c) Descent with change	d) continuity of fermplasm	b) Inheritance of acquired characters
Which one is used for knowing 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
Balancing selection is concerned with successful reproduction of	a) Homozygous recessives	b) homozygous indivduals	c) heterozygous individuals	d) all of the above	c) heterozygous individuals
During which geological period did the earth become oxygen rich?	a) Orosirian period	b) Ediacaran period	c) Devonian period	d) Ordovician period	a) Orosirian period
The first green plants and fungi 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
known as	a) Holocene	b) Miocene	c) Pleistocene	d) Pliocene	a) Holocene
The rise of human civiliza#on is the main characteris#cs of.............	a) Holocene	b) Pleistocene	c) Pliocene	d) miocene	a) Holocene
Which geological period in the 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
As per the latest radiometric 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

During which period in the age 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	b) lower Jurassic	c) mid cretaceous	carboniferous	c) mid cretaceous
During evolu#on the first mul#cellular organism appeared during	a) 1 billion years ago	b) 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
Which of the following statement cannot be support the endosymbiotic theory for the orgin of mitochondria?	a)Mitochondria DNA has a circular genome	b)mitochondrial ribosomes are inactivated by the antibiotic chloramphenicol	c)mitochondrial genes code for enzymes of oxidative respiration	d)mitochondrial ribosomes are 70s	c)mitochondrial genes code for enzymes of oxidative respiration
Mutation may be described as	a) Continuous genetic variation	b) Phenotypic change	c) Discontinuous genetic variation	to hybridisation	c) Discontinuous genetic variation
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
Unit IV					
Which of the following is the male gamete	Egg	Sperm	Primary Oocyte	above	Sperm
Normal mammalian gametes are:	Haploid	Monoploid	Tetraploid	Both A & B	Both Haploid and Monoploid
The male sex organs and female sex organs are collectively called:	Ovaries	Govarestes	Testes	Gonads	Gonads
Which of the following describes the process of DNA-->DNA	Transcription	Translation	Replication	All of the above	Replication
The yolky side of an egg is called its:	Animal side	Vegetal side	Vegetable side	Vegan side	Vegetal side
gamete maturation from already haploid gametes:	Spermatogenesis	Spermiogenesis	Spermatoformicon	All of the above	Spermatogenesis
Oocytes that are discarded in the process of Oogenesis:	Antigens	Epitopes	Non-polar bodies	Polar bodies	Polar bodies

The correct order of the stages of early development is:	Fertilization-->Gametogenesis-->Blastulation-->Gastrulation	Gametogenesis-->Fertilization-->Blastulation-->Gastrulation	Fertilization-->Gametogenesis-->Gastrulation-->Blastulation	-->Fertilization-->Gastrulation-->Blastulation	Gametogenesis-->Fertilization-->Blastulation-->Gastrulation
developing during oogenesis in Drosophila are called:	Chorionomeres	Cytochannels	Gap Junctions	Ring canals	Ring canals
with a considerable amount of extra cellular matrix called:	Mezzanine	Monoploid	Mesenchyme	Stepintyme	Mesenchyme
The imaginal discs of drosophila include separate groups of 40 cells that will form:	Gonads	Eyes	Legs	All of the above	All of the above
Pigment granules in amphibian eggs are located in the cortex on the _____ pole:	Animal	Vegetable	Mineral	Vegetal	Animal
intimately related to the Spemann Organizer?	Dorsal lip	Blastopore	Ventral lip	Blastocoelum	Dorsal lip
The cells in an amphibian blastula are equivenlant until the beginning of the:	early blastula stage	mid blastula stage	late blastula stage	post-modern blastula stage	late blastula stage
regulation of which of the following processes?	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 endodermal germ layer derivative	Kidneys	Heart	Pancreas	Muscle	pancreas
The first blood and vascular tissue of amniotes forms initially:	As extraembryonic blood island formation near the yolk sac	By the process of angiogenesis	As embryonic blood islands near the yolk sac	As a maternal mesoderm coming from the placenta	As extraembryonic blood island formation near the yolk sac
Which animal served as a useful model organism in addition to chickens in the investigation of limb development	Grouse	Quail	Peacocks	Snakes	Quail
The anterior-most region of the endodermal tube that gives rise to the thymus, salivary glands, and oral plate is the:	Stomach region	Cloacal region	Pharyngeal region	Pancreal reagion	Pharyngeal region

Which of the following is the hormone that slows the metamorphic rate in insects?	Ecdyson	Thyroxin	Juvenile Hormone	Pax 6	Juvenile Hormone
The normal function of the promoter is to	Bind the small subunit of the ribosome	Serve as an origin of replication	Serve as an acceptor for transfer RNA	Serve as a binding site for RNA	Serve as a binding site for RNA polymerase
Protein molecules are polymers of-----	DNA moelcule	Amino acid molecules	Fatty acid molecules	Sucrose moelcules	Amino acid molecules
The peptide bond is -----	A covalent joing simple sugars together to form a polypeptide	A covalent bond joining nucleotides together to form a	A hydrogen bond joing nucleotides together to form polypoetide	A covalent bond joining aminoacid together to	A covalent bond joining aminoacid together to form a polypeptide
In prokaryotes, the ribosomal binding site on mRNA is called	Hogness sequence	Shine-Dalgarno sequence	Pribnow Sequence	TATA box	Shine-Dalgarno sequence
During translation, the role of enzyme peptidyl transferase is	transfer of phosphate group	amino acid activation	peptide bond formation between adjacent amino	binding of ribosome subunits to	peptide bond formation between adjacent amino
Polysomes are	Aggregation of ribosomes	aggregation of lysosomes	mRNA molecules to which many ribosomes are attached	a strech of tRNA assemblies	mRNA molecules to which many ribosomes are attached
Translation is the	Synthesis of DNA from a mRNA template	Synthesis of protein from a mRNA template	Synthesis of RNA from a mRNA template	Synthesis of RNA from a DNA template	Synthesis of protein from a mRNA template
During translation, proteins are synthesized	by ribosomes using the information on DNA	by lysosome using the information on DNA	by ribosomes using the information on mRNA	by ribosomes using the information on rRNA	by ribosomes using the information on mRNA
The enzyme involved in amino acid activation is	ATP synthetase	aminoacyl tRNA synthetase	aminoacyl mRNA synthetase	aminoacyl rRNA	aminoacyl tRNA synthetase
Which of the following RNA molecules serves as an adaptor molecule during	rRNA	mRNA	tRNA	tRNA and mRNA	tRNA

In eukaryotes, translation is inititated by binding of ribosomes to the	Pribnow box	Hogness box	5' CAP	poly A tail	5' CAP
Which is the energy rich molecule required for initiation of translation	ATP synthetase	GTP	CTP	AMP	GTP
Which of the following best explains the sequence of central dogma	DNA makes RNA makes Proteins	RNA makes DNAmakes Proteins	DNA makes proteins makes RNA	Protein makes DNA makes RNA	DNA makes RNA makes Proteins
Many primary transcripts of noncoding RNAs must be -------in order to be	translated	polyadenylated	processed	replicated	processed
RNA polymerase used for the transcription of genes require a -------template	rRNA	DNA	RNA	mRNA	DNA
Which of the following statements is not true?	Transcription but not translation is regulated in bacteria	Bacterial non coding RNAs mus t be processed by cleavage to form functional molecules	The regulation of the transcription initiation complex is a key feature of gene expression control in	Linking of exons must precede translation in eukaryotes	Transcription but not translation is regulated in bacteria
Regarding RNA polymerase in E.Coli which of the following describes the difference between the holo enyzyme and the core enzyme?	The holoenzyme is used to synthesize mRNA, while the core enzyme synthesizes noncoding RNAs	The holoenzyme consists of five subunits including σ, while the core enzyme lacks σ	The core enzyme and not the holoenzyme is required for the initation of RNA synthesis	The holoenzyme binds to DNA upstream of the promoter while the core enzyme binds to	The holoenzyme consists of five subunits including σ, while the core enzyme lacks σ
RNA polymerase II transcribes all of the following except genes specifying	rRNAs	proteins	snRNAs	miRNAs	rRNAs
The recognition sequence to whiich RNA polymerase binds at the initiation of transcription is found-----	downstream of the promoter target sequence	b)upstream of the gene to be transcribed	withinthe first intron	downstream of the transcription	upstream of the gene to be transcribed

Which of the following best describes a promoter?	An element that promotes termination of transcription	A regualatory protein that accelerates mRNA turnover	A specific target sequence to which RNA polymeraase binds	An extracellular environmental inducer that controls gene	A specific target sequence to which RNA polymeraase binds
Some eukaryotic promoters contain an element positioned around nucleotide +1	the TATA box	the pribnow box	an initiator (Inr) sequence	an inverted repeat	an initiator Inr sequence
"Null" genes are characterized by their-----	transcription by RNA polymerase I and II	possession of neither TATA box nor an Inr	Invariable start position of transcription	inability to be transcribed	possession of neither TATA box nor an Inr sequence
The conversion of a clsoed rpomoter complex to an open promoter complex in bacteria requires------	the activity of alternative promoters	hydrogen bond breakage of base pairs around the initiation site	a G-C rich sequence around to +1 site	strong interaction between the core enzyme	hydrogen bond breakage of base pairs around the initiation site
An improtant difference between the initiation of prokarytoic and eukaryotic transcription of protein coding genes is that--------	only prokaryotic genes use upstream sequence	only eukaryotic RNA polymerase possess a σ subunit	eukaryotic promoters indirectly recognize core promoter	d)only prokaryotes cells alter the rate of	eukaryotic promoters indirectly recognize core promoter
Each time a ribonucleotide is added to the elongating RNA molecule during transcription a-----is released	deoxy ribonucleotide	sugar-base component	c)pyrophosphate	phosphate	pyrophosphate
The 5'end of mRNAs made by RNA polymerase II possess a distinct cap structure depicted in short-hand notation	7-MeGppNpN	7-MeGpppNpN	pppN-7MeGppppNpN	pppNpN	7-MeGpppNpN
The formation of hairpin loops at the 3' end of prokaryotic RNAs during transcription results in------	stabilization of DNA:RNA pairing promoting further elongation of the transcript	activation of poly (polymerase	a reduction in base pairing between the template strand and the RNA transcript	Rho-dependent activation of transcription	a reduction in base pairing between the template strand and the RNA transcript

Which of the following statements regarding the poly (tail of eukaryotic RNA is incorrect?	The poly (tail is located at the 3, end	The poly (tract is transcribed from the DNA template	poly (tails are found on transcripts made by RNA polyemrase II	Tissue specific gene expression patterns soemtimes correlate with laternative	The poly (tract is transcribed from the DNA template
Translation occurs in the	nucleus	cytoplasm	nucleolus	lysosome	cytopalsm
What is the main function of tRNA in relation to protein synthesis?	inhibits protein synthesis	proof reading	identifies amino acids and transport them to ribosomes	promoter binding	identifies amino acids and transport them to ribosomes
Which site of tRNA molecule hydrogen bonds to a mRNA molecule?	codon	anticodon	5, ends of the tRNA molecule	3' ends of the tRNA	anticodon
In the context of prokaryotic gene expression, which of the following is the msot appropriate definition of an operator?	A cluster of genes that are rqgulated by a single promoter	A DNA-binding protein that regulates gene expression	A non-coding regulatory DNA sequence that is bound by RNA polymerase	A non-coding regualtory DNA sequence that is bound by a repressor	A non-coding regulatory DNA sequence that is bound by a repressor protein
In terms of lac operon regulation, what happens when E. Coli is grown in meidum containing both glucose and lactose?	Both CAP and the lac repressor are bound to the DNA	CAP is bound to the DNA but the lac repressor is not	Lac repressor is bound to the DNA but CAP is not	d)Neither CAP nor the *lac repressor* are bound to the DNA	Neither CAP nor the lac repressor are bound to the DNA
Which of the following can be described as "a sequence that can be several thousand base pairs upstream or downstream of a eukaryotic promoter and which increases gene expression as much as 200-fold'?	CAAT box	Enhancer	Insulator	TATA box	Enhancer

Which of the following statements, concerning regulation of *trp* operon expression by attenuation, is correct?	The leader peptide sequence encodes enzymes required for tryptophan synthesis	the leader peptide sequence contains no tryptophan residues	Rapid translation of the leader peptide allows completion of the mRNA transcript	Rapid translation of the leader peptide prevents	Rapid translation of the leader peptide prevents completion of the mRNA transcript
Which of the following is true of the *lac* operon in E.Coli?	the operon is only switched on in the absence of lactose in the growth medium	The lac operon messenger RNA is the polycistronic mRNA	The enzyme β-galactosidase is only rpoduced in large quantitites when the lac repressor is bound	The promoter is the binding site for the lac repressor	The *lac* operon messenger RNA is the polycistronic mRNA
Transcription occurs along a ------template forming an mRNA in the ------direction	5' to 3'; 5' to 3'	5' to 3'; 3' to 5'	3' to 5'; 5' to 3'	3' to 5'; 3' to 5'	3' to 5'; 5' to 3'
Which of the following statements below is false?	The genetic code is overlapping	the genetic code is not universal	Degenerate codons specify the same aminoacids	The genetic code is triplet	The genetic code is overlapping
The first mRNA codon to specify an amino acid is always	TAC	UAA	UAG	AUG	AUG
Unit V					
The branch of biology which deals with the study of prenatal development of gametes and fertilization of embroye is called:	Fertilization	Embryology	Reproduction	Anatomy	Embryology
Male gametes are named as:	Eggs	Ova	Sperms	Acronym	Sperms
The protective coat around the egg is called:	Egg membrane	Acrosomal membrane	Fertilization membrane	Cell membrane	Fertilization membrane
The region of the egg that contains more ribosomes, more mitochondria, less yolk and is metabolically more active is named	Vegetal pole	center of egg	Distal pole	Animal pole	Animal pole
A membrane-bound structure, at the tip of the head of a sperm, helping in digesting the outer surface of the egg, called as:	Sperm	Acrosome	Head of sperm	Base of ova	Acrosome

Before fertilization, the ovary has	one nucleus	two nuclei	three nuclei	more than four nuclei	two nuclei
Seeds may be	endospermic	non-endospermic	ectospermic	both A and B	both A and B
Exine refers to the	outer wall of the mature pollen grain	pollen tube germinating through the style	sticky material of the stigma	lodicule of the bracts	outer wall of the mature pollen grain
Micropyle is the	male gamete formed by the generative nucleus	pollen tube formed through the vegetative nucleus	opening in the wall of ovule	enzyme secreted by the pollen tube to dissolve stigma	opening in the wall of ovule
Intine refers to the	pollen tube germinating through the style	inner wall of the mature pollen grain	part connecting ovule with placenta	fruit chambers in the zygote	inner wall of the mature pollen grain
A bacterial cell experiences a mutation as a result of expsoure to nitrogen mustard and then divides several times to produce a toal of eight cells. How many of the resulting cells would you expect to contain the	One	two	Four	Eight	Four
In the Ames test:	mutagens cause lethal mutations, reducing the numebr of colonies	Mutagens cause mutations that disrupt the ability of the cell to	Mutagens will cause an increas in the number of revertants	only mutagens that cause transitions can be identified	Mutagens will cause an increas in the number of revertants
Which of the following forms of DNA repair doest NOT require DNA	Direct DNA repair	Base excision repair	Nucleotide excision repair	Mismatch repair	Direct DNA repair
Why is alkyltransferase only able to be used once?	The protein is hydrolyzed in the process of repairing the DNA	The protein is chemically changed by the addition of a	The protein becomes attached to the DNA strand	Inability to bind to another region	The protein is chemically changed by the addition of a methyl group

how does recombinational repair differ from nucelotide excision repair (NER)?	Unlike NER, recombinational repair is unable to repair damage caused by thymine	NER replaces the thymine dimer while recombinational repair leaves it in	NER requires DNA polymerase and ligase function, while recombinationalrep	NER involves nick translation, which recombinationa	NER replaces the thymine dimer while recombinational repair leaves it in
A point mutation that replaces a purine with another purine, or a pyrimisine with another pyrimidine	Transition	Transversion	c)Nonsense	Missense mutation	Transition
A point mutation that involves a purine being replaced by a pyrimidine or vice versa	Transition	Transversion	Nonsense	Silent mutation	Transversion
A change in a DNA sequence that has no effect on the expression or functioning of any gene or gene product	Transition	Transversion	Nonsense	silent mutation	silent mutation
An alteration in a nucleotide sequence that converts a codon for one amino acid int a codn for a second amino acid	Transition	Transversion	missense	Silent mutation	missense
An alteration to the normal chemical or physical structure of the DNA	Transition	Transversion	c)Lesion	Missense mutation	Lesion
5-bromouracil is an analog of -----that can react with deoxyribonucleic acid to produce a polymer with increased susceptibility to	Thymine	Guanine	cytosine	Uracil	Thymine
All transposons encode a ----which catalyzes the insertion	DNA glycosylase	Excisionase	Transposase	d)integrase	Transposase
Small DNA sequences that can move to virtually any position in a cell's genome	Exons	introns	LTRs	Transposons	Transposons
In base excision repair, the lesion is removed by-----	DNA glycosylase	Transposase	Excisionsase	DNA polymerase	DNA glycosylase
The exchange of non homologus regions of DNA at specific sites is independent of ----	IS elements	Illegitimate recombination	Retrotransposons	RecA	RecA

Cyclobuitane pyrimidine dimers can be monomerized again by -----in the presence of visible light	Exonuclease	DNA photolyases	Transposases	DNA polymerase	DNA photolyases
The dispersed repetitive sequences found in higher eukaryotic DNA (eg LINES and SINES) probably spread through the	Transposition	homologus recombination	site specific recombination	General recombination	Transposition
The enzyme of E.Coli is a nuclease that initiates the repair of double stranded DNA breaks by homologus recombination	RNA polymerase	b)DNA polymerase	RecBCD	DNA ligase	RecBCD
Which of the following DNA mutation that result in the appearance of a stop codon in the resulting mRNA synthesis	Transition	Transversion	Nonsense	Missense mutation	Nonsense
Which type of mutation is most likely to	deletion	translocation	inversion	transition	inversion
Which type of mutation is least likely to	Deletion	translocation	inversion	transition	deletion
The hydrolysis of an -NH2 group from a base is called----, while intercalating agents such as proflavin function as mutagens by	deamination; transversions	deamination; deletions or insertions	excision repair; deletion or insertions	excision repair; transversions	deamination; deletions or insertions
ultraviolet radiation is most likely to produce what form of mutation?	deaminations	b)depurination	double stranded breaks	thymine dimers	thymine dimers
Duplication of multiple three- nucelotide repeats is responsible for	Sickel cell anemia	b)trisomy 21	alkaptonuria	xeroderma pigmentosum	alkaptonuria
Errors in DNA replication are most often corrected by	SOS systems	Base excision repair	Nucleotide excision repair	methyl-directed	Base excision repair
A mutation in the UvrC protein of E.Coli would result in which of the following?	an increase in overall mutation rate	a decrease in over allmutation rate	an increase in transposition events	a decrease in transposition events	a decrease in transposition events
The---------- are heritable changes in base sequences that can affect phenotype	mutation	duplication	replication	d)transcription	mutation
A mutation that changes a wild type allele of a gene to a different allele is called a -----	forward	reverse	inversion	deletion	forward

A -------mutation causes a novel allele to be converted back to a wild type allele	forward	reverse	inversion	deletion	reverse
An----------is a type of mutation where a segment of a chromosome is rotated 180°	forward	reverse	inversion	d)deletion	inversion
Any physical or chemcial agent that increases the rate of mutation above the	mutagens	b)plasmogens	antigens	antibodies	mutagens
A mutation in which parts of two homologus chromosomes change places is	translocation	transition	transversion	deletion	translocation
The hydrolysis of a purine base from the deoxy-ribose phosphate backbone is called	depurination	deamination	replica plating	excision repair	depurination
UV light is a mutagen that can cause:	depurination	deamination	alkylation	thymine dimers	thymine dimers
unequal crossing over results in	an exchange between nonhomologus	a loss of genetic material	repair of UV induced damage	a creation of deletions and duplications	a creation of deletions and duplications
Base analogs differ from other classes of mutagen in that they	only alter bases	can only cause transversions	only work during DNA replciation or repair	will not function in bacterial cells	only work during DNA replciation or repair
Intercalating agents such as acridine orange function as mutagens to------	promote transitions	remove amine groups	fit between stacked bases and disrupt replication	add ethyl or methyl groups	fit between stacked bases and disrupt replication
A complementation group is	a group of mutations that produce the same phenotype	a group of mutations that are in the same gene and complement each other	a group of mutations that are in the same gene and do not complement each other	group of mutations in two different genes that do not complement	a group of mutations that are in the same gene and do not complement each other
The condition sickle cell anemia is due to	the insertion of an amino acid	the deletion of an amino acid	substitution of an amino acid	failure to synthesize a hemoglobin molecule	substitution of an amino acid

Mutations that abolish the function encoded by the wild type allele are known as	null mutations	hypomorphic mutations	hypermorphic mutations	conditional mutations	null mutations
Choose the condition below that does not involve a defect in an enzymatic pathway	alkaptonuria	albinism	sickle cell anemia	phenylketonuri a	sickle cell anemia
The Ames test for mutagenicity is useful to identify potential carcinogens because	since bacteria do not get cancer they can survive lethal carcinogens	mutagens that affect bacterial DNA are likley to casue human mutation	c)bacteria thrive on substances that could cause cancer in humans	the same genes that cause cancer in humans can be mutated in	mutagens that affect bacterial DNA are likley to casue human mutation
In the Ames test for mutagenicity:	auxotrophic bacteria are converted to protrophs which survive	prototrophic bacteriaare converted to auxotrophs which survive	cells are treated with mutagen and only thos ewith no mutations survive	cells are treated with excess amino acids killing cells that carry	auxotrophic bacteria are converted to protrophs which survive
If a base analog such as 5- Bromouracil is used as a mutagen, how many generations will be required to mutate the codon for proline (CCin to the codon for alanine	one generation	two generations	three generations	it will not occur	it will not occur
The duplication of the triplet sequence CGG resulting in elongation or breakage of the X-chromosome is termed	Barr-eyed	huntington's disease	unequal crossing over	fragile X chromosome	fragile X chromosome
The genetic condition xeroderma pigmentosum, which can lead to skin	inability to correct UV induced dimers	inability to process	inability to produce functional	breaks in the X chromosomes	Inability to correct UV induced dimers
Excision repair corrects DNA by:	removing a double stranded fragment of damaged DNA	detecting, removing and replacing a single stranded fragment	excising the incorrect base from a nucleotide	correcting A=T to G=C transitions	detecting, removing and replacing a single stranded fragment of
The unit of gene mutation is---------	cistron	recon	muton	photon	muton
Mutations that occurs under natural conditions are called-------	point B	Induced C	base	Spontaneous	spontaneous

A-----phenotype mutations result in the death of cells or organisms	Sub vital	Lethal	Super Vital	Induced	Lethal