# GRADE – 12
# BIOLOGY

**HANDOUT FOR SECOND SEMESTER LESSONS**

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# Unit 3
# Genetics

## 3.3 Protein synthesis

### How does a cell 'know' to make a protein?

The code for a protein is specified by DNA and has to be carried to the ribosomes so that they can assemble the amino acids in the correct sequence to form the protein. However, DNA is a huge molecule and remains in the nucleus at all times. The following events occur:

- ✓ The DNA code for the protein is *rewritten* in a molecule of messenger RNA (mRNA); this rewriting of the code is called *transcription*.
- ✓ The mRNA travels from the nucleus through pores in the nuclear envelope to the ribosome.
- ✓ Free amino acids are carried from the cytoplasm to the ribosome by molecules of transfer RNA (tRNA).
- ✓ The ribosome reads the mRNA code and assembles the amino acids carried by tRNA into a protein; this is called *translation*.

Transcription:-is the process that converts genetic information from DNA code into mRNA code.
Translation:-is the process in which the mRNA code is converted into a sequence of amino acids.

### What is the genetic code like?

**The *genetic code*** is held in the DNA molecule. It is the *sequence of bases* in the nucleotides of the DNA that makes up a gene that codes for the protein and that each amino acid in the protein is coded for by a triplet (sequence of three) of bases.

***A gene*** *is a sequence of base triplets in the DNA molecule that carries the code for a protein*.

- ➢ With *four* different bases to work with (*adenine, thymine, cytosine* and *guanine*), there are 64 possible triplet codes, but only 20 amino acids are used to make all the different proteins. But none of the remaining 44 codes is spare or redundant.

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- ➢ Only one of the strands of the DNA molecule carries the code for proteins. This is called ***the coding strand*** or the ***sense strand.*** The other strand is the *non-coding* or *antisense* strand.

- ➢ ***DNA codes are degenerate*:** Most amino acids have *more than one co*de. Only *methionine* and *tryptophan* have just one triplet that codes for them. *Arginine, serine and leucine* each have six triplets.

- ➢ Three of the triplets **(TAA, TAG and TGA)** do not code for amino acids at all. They are ***'stop' codes*** that signify the end of a coding sequence.

- ***The DNA code is a non-overlapping code:*** This means that each triplet is distinct from all other triplets. The last base in one triplet cannot also be the first base (or second base) in another triplet.
- ***The genetic code is a universal code*:** This means that the triplet TAT is the DNA code for the amino acid *tyrosine* in a human, a giant redwood tree, a bacterium or in any other living organism.

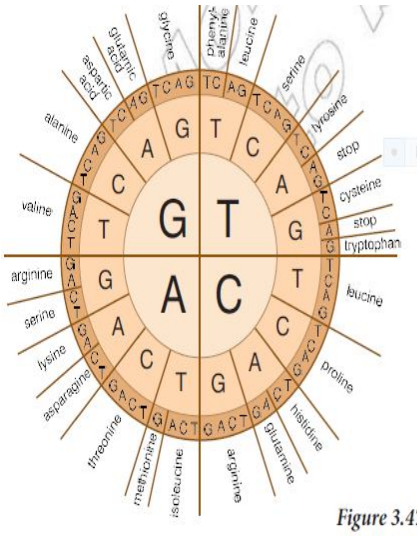


*Figure 3.47A The genetic code*

second position

| first position | T | C | A | G | third position |
|---|---|---|---|---|---|
| T | phenylalanine | serine | tyrosine | cysteine | T |
| | | | stop | stop | A |
| | leucine | | stop | tryptophan | G |
| C | leucine | proline | histidine | arginine | T |
| | | | glutamine | | C |
| | | | | | A |
| | | | | | G |
| A | isoleucine | threonine | asparagine | serine | T |
| | | | lysine | arginine | C |
| | methionine | | | | A |
| | | | | | G |
| G | valine | alanine | aspartic acid | glycine | T |
| | | | glutamic acid | | C |
| | | | | | A |
| | | | | | G |

***Figure 3.47B** Another way of representing the genetic code*

In the first method of representing the genetic code (Fig.3. 47A), start with one of the ***'biggest'*** letters in the centre. This represents the *first* base in the triplet. The letters in the next middle layer, ***medium-sized,*** represents the *second* base and the ***smallest*** letters on outer third layer represent the *third* base in the triplet. Outside that is the name of the amino acid for which the triplet codes. For example: ACC codes for *threonine*, GGG codes for *glycine*, etc.

To use the second method (Fig.3.47B), first start with the letters at the left hand side of the table this represents the first base of the triplet. Then read the letters across the top; this represents the second base in the triplet. Finally, read the letter at the right hand side of the table and this represents the third base in the triplet.

## How does transcription take place in eukaryotic cells?

- During this process, the coded information in the DNA of one gene is used to synthesize a molecule of *mRNA* that will carry the code to the ribosomes.
- *mRNA* is similar to DNA in that it is built from nucleotides; however, it is different from DNA in a number of ways:
  - ✓ it is a much smaller molecule
  - ✓ it is single stranded
  - ✓ the base thymine is replaced by uracil
  - ✓ the sugar in the nucleotides is ribose, not deoxyribose

- The triplets of bases in mRNA that code for amino acids are called *codons*. The mRNA codons are identical to the DNA triplets that code for specific amino acids, except that U (uracil) is substituted for T (thymine).
- To form the single-stranded *mRNA* when transcription takes place, only the *antisense* strand of DNA is transcribed. This is because the sense strand of this section contains the gene that codes for a protein. However, transcribing this would produce a complementary sequence of bases, similar to those in the antisense strand, which would not code for anything.

 In eukaryotic cells, transcription takes place in the following way:

- ✓ The enzyme *DNA-dependent RNA polymerase (RNA polymerase)* binds with a section of DNA next to the gene to be transcribed.
- ✓ Transcription factors activate the enzyme.
- ✓ The enzyme begins to 'unwind' a section of DNA. *RNA polymerase* moves along the antisense strand, using it as a template for synthesizing the mRNA.
- ✓ The polymerase assembles free RNA nucleotides into a chain in which the base sequence is complementary to the base sequence on the antisense strand of the DNA. This, therefore, carries the same triplet code as the sense strand (except that *uracil* replaces *thymine*).
- ✓ The completed molecule leaves the DNA; the strands of DNA re-join and re-coil.
- ✓ The mRNA molecule now contains the code for the protein that was held in the DNA of the gene.

## How does translation take place?

 *Translation* of the mRNA code into a protein depends on the interaction between *mRNA* and *tRNA* within a ribosome.

 All *tRNA* molecules have the same basic structure. The '*cloverleaf*' configuration of the molecule has, at one end, a triplet of bases called *an anticodon*. This *anticodon* will be complementary to one of the *mRNA codons*.

 The other end of the *tRNA* molecule has an *attachment site* for the amino acid that is specified by the *mRNA codon*.

 *Ribosomes* are made from *ribosomal RNA (rRNA) and proteins* organized into a large and a small subunit. Within the ribosome, there are *three* sites that can be occupied by a tRNA molecule, called the A, P and E sites. The following events take place:

- ✓ The first two codons of the mRNA enter the ribosome. Transfer RNA molecules (with amino acids attached) that have complementary anticodon to the first two codons of the mRNA bind to those codons.

- ✓ A peptide bond forms between the amino acids carried by these two tRNA molecules and the dipeptide is transferred to the tRNA in the A site.

- ✓ The ribosome moves along the mRNA by one codon, bringing the third codon into the ribosome; at the same time the 'free' tRNA exits the ribosome and the tRNA with the dipeptide moves into the P site.

- ✓ A tRNA with a complementary anticodon binds with the third codon, bringing its amino acid into position next to the second amino acid.

- ✓ A peptide bond forms between the second and third amino acids.

- ✓ The ribosome moves along the mRNA by one codon, bringing the fourth mRNA codon into the ribosome, and the whole process is repeated until a 'stop' codon is in position and translation ceases.

 The translation of the mRNA code into a protein molecule requires energy. However, this does not come from the hydrolysis of ATP as is usual in a cell, but from the hydrolysis of a similar molecule, *GTP– Guanosine Triphosphate*. It is hydrolyzed to GDP and Pi in the same way as ATP, with the release of a small amount of energy.

## How is protein synthesis different in prokaryotic cells?

### Prokaryotic cells

- ➢ prokaryotic cells *do not have a nucleus*
- ➢ prokaryotic mRNA *does not need post-transcriptional processing*
- ➢ In Prokaryotes transcription and translation are *coupled*; mRNA can be translated by ribosome at one end of its molecule while it is still being transcribed from DNA at the other end.

### Eukaryotic cells

- ✓ eukaryotes: transcription and translation are separated
- ✓ transcription occurs in the nucleus
- ✓ translation occurs in the cytoplasm
- ✓ eukaryotic mRNAs are modified before leaving the nucleus

## What becomes of the proteins that are synthesized?

 All our proteins are synthesized in the way just described, but all our cells do not synthesize all our proteins. However, we synthesize a vast array of different proteins that we can categories, broadly, into the types shown in table 3.2 below.

*Table 3.2 Some of the proteins our body synthesises*

| Type of protein | Example | Function of example |
|---|---|---|
| Structural | Collagen | Building fibres of cartilage |
| | Keratin | Building nails and feathers |
| Enzyme | ATP synthase | Producing ATP from ADP and $P_i$ |
| | DNA helicase | Unwinding the double helix of DNA |
| Peptide hormone | Insulin | Control of plasma glucose concentration |
| | Adrenaline (epinephrine) | Fight or flight response |
| Antigen | A antigen on red cells | Determine blood group |
| | CD4 | Allows binding of HIV to T-lymphocytes |
| Antibody | Anti-a antibodies | Causes clotting of red cells with A antigen |
| | HIV antibodies | Destroys some HIV antigens |

- To synthesize these proteins continually, our bodies require a constant supply of amino acids. These are obtained from the protein in the foods we eat. The average adult protein requirement per day is about 50 grams.
- The proteins are hydrolyzed to amino acids in our gut and absorbed into the blood plasma by active transport. They are then transported to the cells where they are used to synthesize our proteins.

 20 amino acids are used to make all the different proteins. Some of these can be made in our bodies by a process called *transamination*.

- ***In transamination, the amino group of an amino acid is removed and transferred to a keto acid. The keto acid then becomes a different amino acid.***
- Not all amino acids can be produced by transamination. There are some that we just have to obtain from our food. These amino acids are called ***essential amino acids***.

*Meat, fish, poultry, eggs and milk* are animal sources of protein that provide a good balance of all eight essential amino acids. The best non animal sources are *quinoa, buckwheat, hempseed and amaranth*, although these contain lower overall amounts of protein than some cereals (wheat, rice, maize) and nuts and pulses.

## What controls gene expression?

 The fact that some genes are *sex-limited* tells us that all genes aren't active all the time. There are more examples of this – the genes that control the colour of your iris are present in all your cells, but all your other cells aren't this colour – just the iris.

## How are genes switched on?

 Very often, genes are switched on by ***'transcription factors'*** that are present in the cell. These transcription factors are usually proteins that bind to a *regulatory* sequence of DNA near to the gene they influence. They operate in the following way:

- ✓ The *transcription factors* bind to a promoter sequence of DNA near to the gene to be activated.
- ✓ *RNA polymerase* binds to the DNA/ transcription factor complex.
- ✓ The RNA polymerase is 'activated' and moves away from the DNA/transcription factor complex along the gene.
- ✓ The RNA polymerase transcribes the antisense strand of the DNA as it moves along; the gene is now being expressed.

Some cancers are caused by hormones acting as transcription factors.

**Oestrogen** is steroid hormones that can diffuse through the plasma membrane of a cell.

- It binds with a receptor in the cytoplasm.
- The o*estrogen-receptor complex* moves into the nucleus and binds with and activates specific genes.
- In the breasts, and lining of the uterus, the activated genes *cause cell division*.

 Many breast cancers are said to be *oestrogen-receptor* positive. This means that the cancer cells have oestrogen receptors to which the hormone can bind, causing the same increase in cell division as it does in normal breast tissue.

 The anti-cancer drug *Tamoxifen* can bind with the *oestrogen receptors* and the tamoxifen/receptor complex binds with the DNA. However, Tamoxifen does not allow transcription factors to bind and so expression of the genes is prevented, and cell division in the cancer is slowed.

## How are genes switched off?

 Besides transcription factors that promote the expression of genes, other factors can act to *repress gene action*. One group of substances that does this is known as *short interfering RNA* (*siRNA*).

 *Short interfering RNA (siRNA)* molecules are unusual because:

-they are very short – only about 21 to 23 nucleotides long and
-they are *double stranded*.

 *Short interfering RNA* (*siRNA*) doesn't act on the gene itself, but they '*interfere with'* or '*silence'* the *mRNA* once it has been transcribed from the DNA. This is called *post-transcriptional interference*.

 If the *mRNA* is prevented from translating its codons into amino acids, then the protein for which the gene codes cannot be built. *The gene has effectively been silenced.*

 Biologists think that the action of siRNA is as follows:

- ✓ Double-stranded RNA (*dsRNA*) is produced in the nucleus from a range of genes.
- ✓ It is then split into the very short lengths that characterize *siRNA* by an enzyme called '*Dicer'*.
- ✓ The *antisense strand* of the *siRNA* then binds with a complex of molecules called *RISC*.
- ✓ The *siRNA* binds with *mRNA* and allows *RISC* to degrade/cleave the *mRNA* into small fragments.

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## Review questions on 3.3 (protein synthesis)

1. Gene silencing is the function of one of the following molecules.
   a. dsRNA b. mRNA c. siRNA d. tRNA
2. During protein synthesis, where in the cell does transcription takes place?
   a. Ribosome b. nucleus c. endoplasmic reticulum d. cytoplasm
3. Which molecules carry the instructions for protein synthesis?
   a. Carbohydrates and lipids c. DNA and RNA
   b. Enzymes d. amino acids
4. In the protein synthesis, what is produced during transcription?
   a. Protein b. mRNA c. DNA d. polypeptide
5. Which one of the following is not found in RNA?
   a. Adenine b. guanine c. cytosine d. thymine
6. Which process produces mRNA during protein synthesis?
   a. Translation b. replication c. mutation d. transcription
7. How many amino acids are there in all known proteins?
   a. About 10 b. about 35 c. about 20 d. about 46
8. If a codon on the mRNA is UUU, what is the complimentary anticodon on the tRNA?
   a. TTT b. GGG c. CCC d. AAA
9. The genetic code is:
   a. A triplet code, degenerate and overlapping
   b. A double code, degenerate and universal
   c. A double code, degenerate and non – overlapping
   d. A triplet code, degenerate and universal
10. When comparing protein synthesis in eukaryotic cells and prokaryotic cells it is correct to say that transcription and translation are:
    a. Separate in both
    b. Coupled in both
    c. Separate in prokaryotes and coupled in eukaryotes
    d. Separate in eukaryotes and coupled in prokaryotes

## Answer key (3.3)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. C | 2. B | 3. C | 4. B | 5. D | 6. D | 7. C | 8. D | 9. D | 10. D |

# 3.4 Mutations

## What are mutations?

 **Mutation** is any spontaneous change in the genetic material of an organism. It is a sudden and permanent change in the quality structure or arrangement of DNA on the chromosome of an organism.

Based on the specific place in which the mutation occur, there are two categories of mutations

1. Chromosomal mutation
2. Gene mutation(point mutation**)**

## I. Point mutation (Gene mutation)

 These are changes involving only a ***single base.*** They are spontaneous change in a single base on the DNA molecule.

 The different types of point mutations are:

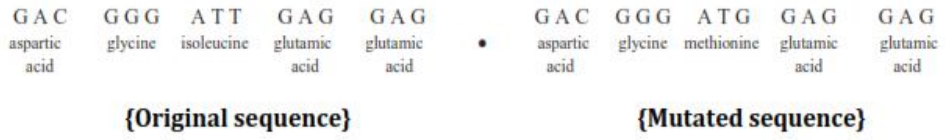
- Substitution
- Addition
- Deletions

 These mutations occur quite *randomly* when DNA is replicating and each involves a change to just one base, but the change to the gene can be dramatic and the result can be that the protein the gene should code for is not made at all or a different protein is made.

**Substitution**

In substitution mutations, ***one base is replaced by a different base***.

*Figure 3.56 A substitution mutation*




- In this substitution, *Guanine* replaces *thymine*. The triplet ATT has been changed to ATG (no other triplet is affected). The original triplet, ATT, codes for the amino acid *isoleucine*. However, the new triplet, ATG, codes for *methionine*. As a result, a different protein will be synthesised, which may or may not be significantly different from the original.
- ***One different amino acid in a protein does not always make a functional change.***

✓ If the substitution had been by any base other than *guanine*, because the DNA code is degenerate, the triplet would still have coded for *isoleucine* and the *same* protein would have been synthesised.

✓ Other substitutions can result in a ***'stop' triplet***. In this case transcription ceases when it reaches the stop code and a *nonfunctional* mRNA results.

**Example:-** sickle cell anemia is a condition caused by a mutation that affects the structure of the hemoglobin molecule in the red blood cells causing the RBC to sickle under low oxygen tension.

**GTG CAC STC ACT CCA GAG GAG = normal hemoglobin**

**GTG CAC STC ACT CCA GTG GAT = sickle cell hemoglobin**

In the above example A is replaced by T (the triplet code for the amino acid **glutamic acid** is changed into the triplet code for **valine**) which results in sickle cell hemoglobin.
Other substitutions can result in a **STOP** triplet. In this case translation ceases when it reaches the stop code and a non functional mRNA results.

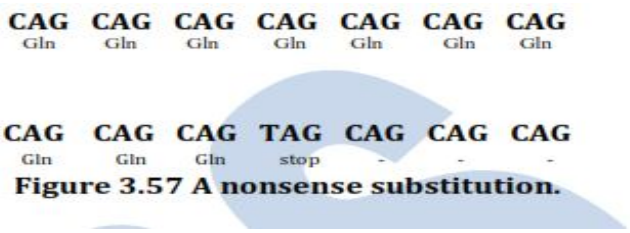


**Figure 3.57 A nonsense substitution.**

## Addition and deletion

- Both addition and deletion cause a "*frame shift*".
- These mutations *alter the DNA triplets after the point of mutation* and change all the amino acids after this point.
- Both these *are more significant mutations* than substitutions.

 **In a *deletion*** mutation a base is *'missed out'* during replication,
 **In *additions,*** an extra base is *added*.

Substitutions affects just one triplet and, because the DNA code is degenerate, may well have no overall effect – the same protein may still be produced. This can never be the case with *additions* and *deletions*.

The reason for this is that they do not just alter the triplet in which the mutation occurs. Because there is one fewer or one extra base, the whole sequence after the point of the mutation is altered. We say that there has been a frame shift and these are *frame shift mutations*. A totally different mRNA is produced (if one is produced at all) and a *nonfunctional protein* or *no protein* at all.

Sometimes, *a whole triplet is missed out or inserted*. This will result in either one extra or one fewer codon in the mRNA. In turn, this will lead to one extra or one fewer amino acid in the polypeptide chain.

### Another way of thinking about frame shifts

Look at this sequence of letters: THEMANWASHOTANDRANFORHISHAT. If we give this a 'reading frame' of three letters, it becomes: THE MAN WAS HOT AND RAN FOR HIS HAT

and it makes sense. But if we take out the "S" at the end of WAS (a deletion mutation), it becomes: THE MAN WAH OTA NDR ANF ORH ISH AT. In other words, it no longer makes sense. In genetic terms it is *mis-sense coding*

## What causes point mutations?

 Mutations occur ***spontaneously*** **and** ***randomly*** – they are accidents that occur when DNA is replicating, mistakes happen.

 Mutations are ***rare events***, which is quite surprising when you consider that each cell contains $6 \times 10$(six billion) base pairs that might mutate!

 Biologists estimate that mutations arise at the rate of 1 in $50 \times 10^9$ (one in fifty million) base pairs. This means that each new cell will have, on average, 120 mutations. This sounds rather worrying, but you should remember two things:

- ✓ most of these mistakes (mutations) are detected and repaired by DNA proof reading activity.
- ✓ because 95% of our DNA is *non-coding*, most mutations are unlikely to affect coding genes.

 The rate of mutation can be increased by a number of factors including:

- ✓ *carcinogenic chemicals*, for example, those in tobacco smoke
- ✓ *high-energy radiation,* for example, ultraviolet radiation, X-rays
- ✓ *Artificial chemicals,* for example, most hard gas, some drugs, pesticides, food preservatives, etc…

## What are the consequences of gene mutations?

 Mutations that occur in a *normal body cell* **(somatic mutations**) will have one of *four* possible consequences:

- It will be completely harmless.
- It will damage the cell.
- It will kill the cell.
- It will make the cell cancerous, which might kill the person.

This ***will not*** **be passed** on to the next generation.

However, if the mutation occurs in a *sex cell (***Germ cell mutation***)*, or a cell that will divide to give rise to a sex cell, then it may be passed on to the next generation.

Mutations in different genes will obviously produce different effects, but two types of genes are really important. Genes called ***proto-oncogenes*** and ***tumour suppressor genes*** play important roles in regulating cell division and preventing the formation of a tumour.

When *proto-oncogenes* mutate, they often become *active oncogenes*, which stimulate the cell to divide in an uncontrolled manner. Ordinarily, some growth factor would be necessary to make the cell divide.

*Tumour suppressor* genes recognize uncontrolled cell division and act to suppress cell division. If these genes mutate and become inactive, a tumour will form as uncontrolled cell division continues.

*Figure 3.62 how a tumour starts. pp. 155 text book*

## Can mutations benefit an organism?

 Mutations are the *raw material of evolution*. It is the only process that *creates new genes*. Crossing over, segregation and random assortment in meiosis together with random fusion in fertilization reshuffle existing genetic material, but *only mutation produces new genetic material.*

 If a mutated allele gives an organism an advantage, then Natural Selection will act so that frequency of that allele increases with successive generations. The numbers of the organism with the mutated allele will increase.

 Mutations in the DNA of bacteria can give them *resistance* to a specific antibiotic, such as *penicillin* or *ampicillin*. These mutations arise spontaneously, as do all mutations. They only give the bacterium an advantage if the particular antibiotic is actually being used.

 Being resistant to *streptomycin* is no advantage if *penicillin* is being used. But being resistant to *penicillin* in an environment where *penicillin* is widely used confers a considerable advantage to the organisms.

 In 1947, just four years after *penicillin* was used widely in the USA, the first *penicillin-resistant* bacterium was found – it was a bacterium called *Staphylococcus aureus.* Today over half the infections caused by *Staphylococcus aureus* are caused by *penicillin-resistant* types.

 Bacteria can also 'swap' *antibiotic resistance genes* with each other. Most of the mutant genes that confer resistance are found in the *plasmids*. They can transfer these *plasmids* to other bacteria by:

- ***Conjugation*** – the plasmid passes through a special 'conjugation' tube from one bacterium to another.
- ***Transduction*** – a virus carries the plasmid from one to another.
- ***Transformation*** – the plasmid is absorbed from a dead bacterium.

## II. Chromosome mutations

 Chromosome mutations occur when there is any change in the arrangement or structure of the chromosomes. They occur most often during meiosis at crossing over in prophase-I.

 There are several different mutation types that result in a change in the structure of a chromosome. They are *much bigger events than point mutations* and usually result in the *death of a cell*.

 They may also affect the *whole organism*. For example, if essential parts of the DNA are affected by chromosomal mutations, a *fetus may be aborted*.

## Types of chromosomal mutation

### 1. Inversion

 This occurs when an area of DNA on a chromosome *reverses its orientation* on the chromosome.

 Just one inversion on *chromosome 16* can cause *leukemia*.

 An inversion that leads to an embryo having *too few or too many copies of genes*, can cause the embryo to *miscarry*, fail to grow, or be born with *substantial medical problems*.

### 2. Deletion

 involves a loss of a region of a chromosome either from the ends or internal parts.

 A *decrease in the number of genes* occurs due to the *deletion of a large section of a chromosome*.

 Deletion can result in a variety of genetic disorders, such as *Prader-Willi syndrome*.

 This results from a *malfunction of the hypothalamus* (a small endocrine organ at the base of the brain), which plays a crucial role in many bodily functions, including hunger and satiety, temperature and pain regulation, fluid balance, puberty, emotions and fertility.

### 3. Insertion

 This type of mutation describes an *increase in the number of genes* caused when *an unequal crossover happens during meiosis*. The chromosome may become abnormally *long* or *short* and stop functioning as a result.

### 4. Duplications

 Occurs when a section of a chromosome duplicates/repeats itself thereby making an additional sets of genes.

This is usually *harmless* as the chromosome still has all its genes.

 However, *duplication of the whole chromosome* is more serious.

Having *three copies* of chromosome 16, known as *trisomy-16*, leads to babies being born with a range of medical issues, such as:

- *poor foetal growth*,
- *muscular and skeletal anomalies*,
- *Congenital heart defects* and *under developed lungs*.

### 5. Chromosome non-disjunction

This arises when *homologous chromosomes do not separate successfully* to opposite poles during meiosis.

 The results in one of the gametes *lacking* a chromosome and the other having an *extra* chromosome.

 If this happens with chromosome-21, *Down's syndrome* results. Those with the condition will have 47 chromosomes in every cell. (Because they have three copies of chromosome-21) as opposed to 46 like normal. *Down's syndrome* is characterized by:

- *mental retardation,*
- *heart defects* and
- *stunted growth*

**6. Translocations**

 A piece of one chromosome is transferred to another non homologous chromosome. This type of chromosome mutation is often responsible for *chronic myelegenous leukemia*.

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## Review questions on 3.4 (mutation)

1. Which of the following type of chromosome mutation gives rise to an extra chromosome?
   a. Inversion b. translocation c. deletion d. none of the above
2. Which process is held responsible for chronic myelogenous leukemia?
   a. Translocation b. translation c. transcription d. duplication
3. Which one of the following terms refers to the failure of sister chromatids to separate from one another during anaphase?
   a. Non – disjunction c. deletion
   b. Replication d. double inversion
4. Which of the following is an example of a chromosomal mutation?
   a. A base duplication c. A translocation
   b. A base insertion d. None of the above
5. Which of the following is frame shift mutation?
   a. Point replacement c. Inversion
   b. Insertion d. Substitution
6. The only source of new genetic material during evolution is:
   a. Crossing over
   b. Segregation
   c. Random assortment
   d. Mutation
7. The increase in bacterial resistance to a penicillin is due to:
   a. Mutation
   b. Natural selection
   c. The increase use of penicillin
   d. A combination of all of the above

8. If a substitution occurs in the DNA of an organism, which of the following also occur?
   a. The RNA also altered
   b. All the triplets after the mutation will be altered
   c. All the triplets before the mutation will be altered
   d. A frame shift will occur
9. Which form of mutation is responsible for the disease known as leukemia?
   a. Duplication b. insertion c. inversion d. deletion
10. Which one of the following types of point mutations do not cause frame shift?
   a. Substitution b. addition c. deletion d. none of the above

## 3.4 Answer key

| 1. D | 2.A | 3.A | 4.C | 5.C | 6.D | 7.D | 8.A | 9.C | 10.A |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

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# Unit 4

# EVOLUTION

## 4.1 The origin of life

**Evolution:-**is the theory which describes how the various forms of life on earth emerged and develops. It is the process of change in which new characteristics appear and are passed on to future generations. It is decent with modification.

The working definition of the process of evolution is; *the change in genetic composition of a population over successive generation, which may be caused by meiosis, hybridization, natural selection or mutation. This leads to a sequence of events by which the population diverges from other populations of the same species and may lead to the origin of a new species.*

All living organism that exist today have developed from earlier simpler forms by the process of evolution.

### What theories are there about the origin of life on earth?

There are five main theories of the origin life on earth;

1. special creation
2. spontaneous generation
3. eternity of life
4. cosmozoan theory
5. biochemical origin

### 1. Special creationism

This is a theory claiming that the different forms of life on earth were created by a supreme being. It attributes the origin of life to a divine event that was master minded by the supernatural being, GOD.

- It is nearly always linked to religion (spiritual matters).
- This cannot be seen, touched or measured effectively (that cannot be proven).
- Religion deals with philosophical matters that relates to mortality and concern between humans and their god.

Therefore, it is **not acceptable** because science describes the natural world around us using instruments. These observations then result in the development of scientific theories.

There are different versions of special creation;

### i. Young earth creationism

This suggests that the earth is only a few thousand years old. It often believes the earth was created in six 24-hr days while they agree that the earth is round and moves around the sun. They interpret all geology in the light of Noah's flood.

### ii. Old earth creationism

This accepts the evidence that the earth is very old but still maintains that all life was created by God.

### iii. Day age and gap creationism

**Gap creation** discusses a large gap between the formation of the earth and the creation of all the animals and humans. The gap could be millions or billions of years. This gets around the scientific evidence that the earth is several billion years old without having to believe in the process of evolution itself.

**Day- age** creation is similar in the length of time but talks about each of the 6 days as really a billion years or so of geological time; the days are just symbolic.

### iv. Progressive creationism

This type of creationism accepts the **big bang** as the origin of the universe. It accepts the fossil record of a series of creations for all of the organisms catalogued. However, it does not accept these as part of a continuing process. Each is seen as a unique creation. Modern species are not seen as being genetically related to ancient ones.

### v. Theistic evolution/Evolutionary creationism

This view of evolution maintains that God" **invented** "evolution and takes some form of an active part in the ongoing process of evolution.

It also involves the role of God in areas not discussed by the science. For example, the creation of the human soul.

It is promoted by the pope for the Catholic Church and is also espoused by most mainline Protestants.

### vi. Intelligent design

This is a theory claiming that life developed due to a combination o natural forces and the intervention of a supernatural being.

This is the newest version of creationism. It is a form of creationism cloaked in scientific sounding ideas.

## 2. The theory of spontaneous generation/abiogenesis

This theory suggests that life can evolve "spontaneously" from non living objects. It is a theory that claims some type of organism could come into being almost instantly from non-living materials.

Examples;

- Rotting meat turned into flies
- Wine reproduced bacteria as it went sour
- Dirty shirts and grains spontaneously generate mice
- Human sweat produced worms, flies and beetles
- Mud produced frogs, snakes and crocodiles

This theory was later disproved by a series of experiment conducted by F. Redi, L. Spallanzani and L. Pasteur.

L. Pasteur showed that broth (wine) only went sour if micro organism were allowed to enter. Also no micro organism appeared in the broth unless they were allowed to enter from the outside- they were not formed from the broth itself.

Both F. Redi and L. Pasteur showed that both macro- and micro organism can only arise from pre-existing organism, disproving the theory of a spontaneous generation.

## 3. The eternity of life theory

This theory claims that the universe has always existed and that there has always been life in the universe.

There is no beginning and no end to life on earth and so it neither needs special creation, nor does it need to be generated from non- living matter. Supporters of this theory believes that- life is an inherit property of the universe and has always existed.

Life is believed to have existed forever and will continue to exist forever and so no origin is required.

Albert Einstein (supporter of this theory) believes that the universe was unchanging. Supporters of this theory reasoned that "if life is found today in an unchanging universe, then it must always have been there".

## 4. The cosmozoan theory

This theory claims that life on earth originally come from elsewhere in the universe (possibly from another planet).

Either life forms or the organic molecules needed for the origin of life are believed to have been brought to earth by meteorites and comets (in the form o highly resistant spores).

This idea was proposed by Richter in 1865 and supported by S. Arrhenius in 1908 and other contemporary scientist. This theory lacks evidence. It is strongly linked to the "eternity of life". Lord Kelvin and Herman von Helmboltz also took the same view.

## 5. Biochemical theory

This theory suggests that life on earth originated as a result of a number of biochemical reactions producing organic molecules which associated to form cells.

This is the current idea we have about how life originated on earth (it is sometimes called abiogenesis). **It is more scientific and has wide acceptance**.

This theory owes much to two biologists:

1. Alexander Oparin (1924) - A Russian biologist who first put forward his idea.
2. John Haldane (1929) - An English biologist who independently put forward almost identical ideas (before Oparin's book had been translated into English).

They both suggested that:-

1. The primitive atmosphere of the earth was a reducing atmosphere with **no free oxygen**- as opposed to the oxygen rich atmosphere of today.
2. There was an appropriate supply of energy, such as lighting or UV- light, heat and radiation.
3. This would provide the energy for reactions that would synthesize a wide range of organic compounds, such as amino acids, sugars and fatty acids.

### Alexander Oparin

- He is a Russian scientist (biologist).
- He proposed Oparin's heterotroph hypothesis on the origin of the first form of life (protobionts).
- He suggests that the simple organic compounds could have a series of reactions leading to more complex molecules.
- The molecules might have formed colloidal aggregates called "***coacervate***" in an aqueous environment. (***Coacervates***- contain amino acids and small polymers of DNA).
- The coacevates were able to absorb and assimilate organic compounds from the environment in a way similar to the metabolism of cells.
- These coacevates were the precursors of cells and would be subject to natural selection, eventually leading to the first true cell.

### John Haldane

- J. Haldane was an English biologist.
- His ideas about the origin of life were very similar.
- He proposed that the primitive sea served as a vast chemical laboratory powered by solar energy.
- As a result of all the reactions powered by solar energy, the sea becomes a" **hot and dilute soup"** of organic monomers and smaller polymers.
- Haldane called this the **"pre-biotic soup"** and this term came to symbolize the Oparin-Haldane view of the origin of life.

## Evidence for this theory

### Stanley miller's spark discharge experiment.

- S. Miller conducted a now famous spark discharge experiment in 1953.
- He showed that the organic molecules essential for life could be synthesized in the conditions on earth 4.5 billion years ago.
- In this investigation, he passed electric spark repeatedly through a mixture of gases that were thought to represent the primitive atmosphere of the earth. These gases were methane ($CH_4$), ammonia ($NH_3$), water ($H_2O$), and hydrogen ($H_2$).
- He attempted to simulate the primitive atmosphere and hypothesized life forming processes.
- When he analyzed the liquid in the water trap, he found it contained a number of simple organic molecules. E.g.:- HCN (hydrogen cyanide). By leaving the equipment for longer time, a larger variety of more complex organic molecules were formed including;
    - ✓ **Amino acids**- essential to form proteins
    - ✓ **Pentose sugars**- needed form nucleic acids
    - ✓ **Hexose sugars** – needed for respiration to form starch and cellulose
    - ✓ **Hydrogen cyanide**- to synthesize the nitrogenous bases found in the nucleotides.

This is a strong evidence to support the ***Oparin – Haldane hypothesis.***

### Problems to this hypothesis

1. Why are only "left handed" amino acids found in living things when both left handed and right handed types are possible?
2. Although Nitrogenous bases are synthesized in the laboratory, Purines (A and G) are not synthesized under the same condition as pyrimidines (A, C, U).
3. Although Miller was able to demonstrate the formation of monomers, he was unable to demonstrate the next significant step of polymerization of those monomers.

Recently, progress has been made in all of these areas. In 2009, John Sutherland, a chemist at university of Manchester in England, found that, instead of making the N- bases and sugars separately from the chemicals to have existed on the primitive earth under the right conditions, the bases and sugars could be built up as a single unit and so did not need to be linked.

It has been shown that polymerization can occur under appropriate conditions and a solution is in sight for the handedness problem.

The biologist John Desmond Bernal suggested that there were a number of clearly defined "stages" in explaining the origin of life.

Stage 1 the origin of biological monomers

Stage 2 the origin of biological polymers

Stage 3 the evolution from molecules to cell

Bernal suggested that evolution may have commenced at the same time between stage 1 and 2. The first two stages have been demonstrated as being possible in the conditions of the primitive earth, and research on stage 3 is well advanced.

### Other ideas on the biochemical theory

Professor William Martin Dusseldorf and Dr. Michael Russell Glasgow claim that cells come before the complex organic molecules. Not living cells but inorganic ones made of Iron sulphide (FeS) formed at the bottom of the oceans.

In their theory, a fluid rich in compounds such as $H_2$, CN, sulphide and CO emerged from the earth's crust at the ocean floor.

It then reacted inside the tiny metal sulphide (FeS) cavities; they provided the right micro-environment for chemical reaction to occur.

That kept the building blocks of life concentrated at the site where life began. The iron sulphide cells are where life begun.

## How did autotrophs evolve on earth?

The First forms of life that appeared about 4 billion years ago were ***Heterotrophic prokaryotic and anaerobic*** and dependent on organic molecule which had accumulated in the seas.

- they had no true nucleus
- they had RNA rather than DNA as their genetic material
- they gave rise to three distinct lines of evolution leading to;

**i.Archaebacteria: -** prokaryotes include *thermophilic, sulphobacteria and halophilic bacteria.* Are the first bacteria (thus the first living organism) to develop on earth. Now found in extreme conditions.

**ii.Eubacteria:-** prokaryotes, ordinary bacteria and cyanobacteria blue green bacteria (blue green algae)

**iii.Eukaryotes: -** eventually evolving into protoctistans, fungi, plants and animal (nearly all are aerobic).

N.B. *Thermophilic*= heat loving

*Methanobacteria*= live in high concentration of methane

*Halobacteria* = live in high concentration of salt

Later the organic molecules were depleted. In such an environment the earliest autotrophs (chemosynthetic or photosynthetic) started to evolve.

These autotrophs lack the biochemical pathway to produce $O_2$ while utilizing solar energy. However, at later stages, $O_2$-producing autotrophs are believed to have evolved which must have made it possible for the accumulation of $O_2$ in the atmosphere. The evolution of aerobic organism is linked with this process. i.e. the shift for reducing atmosphere to an atmosphere containing $O_2$ (about 2.4 billion years ago).

The fossil records shows that cyanobacteria had been producing $O_2$ by photosynthesis from about 3.5 billion years but its level did not raise for about 1 billion years because it was absorbed by the vast amount of iron in the earth- it rusted. But by 2.4 billion years the concentration began to rise. The rate was accelerated from 2.1 billion years ago.

## Cyanobacteria

- Are the oldest autotrophs. They were responsible for the increase in the free $o_2$ in the atmosphere.
- They are photo autotrophic.
- they use light as a source of energy and $Co_2$ as a source of carbon (photosynthesis)
- they are among the earliest of autotrophs using phycocyanine ( give them their blue green appearance) to capture light. Phycocyanine absorbs different wave length of light from both chlorophyll-a and chlorophyll-b.

Other primitive autotrophs use chemical reactions as a source of energy and are called **chemo-autotrophs** i.e. they use inorganic energy source. For example, sulphobacteria uses hydrogen sulphide ($H_2S$) as energy sources.

- Most are bacteria or Achaea that live in hostile environment such as the deep sea vents and they are the primary producers in the sea beds.
- Some of the first organisms to inhabit the earth were chemoautotroph.

Bacteria are the only life forms found in the rocks for a long time, 3.5 to 2.1 billion years ago.

Eukaryotes become numerous 1.9 to 2.1 billion years ago.

Fungi like organisms appeared about .9 billion years ago.

The $O_2$ produced by photoautotroph had made it possible for aerobic respiration to evolve as an energy releasing path way. As this process releases far more energy than the anaerobic path way more active organisms could now evolve "the animals, perhaps 600 up to 700 million years ago.

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## Review questions

1. In which geologic period is the evolution of humans most probably believed to have happened?
   a. Tertiary period b. Jurassic period c. cretaceous d. quaternary period
2. With a few weeks after heavy rains, pools become teemed with tadpoles. What is the source of the tadpoles?
   a. The rain water
   b. The mud on the floor
   c. The decaying vegetation of the pond
   d. The eggs laid by frogs
3. Which one of the following is a common idea held by all/the entire creationist?
   a. Life is eternal
   b. All life was created in six days
   c. Life was created by supernatural being
   d. Life come to earth from elsewhere in the universe
4. Lamarck's theory of evolution is known as:
   a. Natural selection C. mutation theory
   b. The survival of the fittest D inheritance of acquired traits
5. Among the theories about the origin of life, which one better agrees with the concept of change in organisms and their genetic composition over generations being caused by meiosis, hybridization, natural selection or mutation?
   a. Cosmozoan theory c. special creationism theory
   b. Bio chemical origin theory d. spontaneous generation theory
6. Which of the following is the most accepted theory about the origin of life on earth?

a. Theory of spontaneous evolution
b. The theory of chemical evolution
c. The cosmic theory
d. The theory of special creation

7. Which one of the following comes first in the course of organic evolution?
   a. Photosynthesis organisms  c. land plant
   b. Free oxygen in the atmosphere  d. multi cellular organisms
8. In which geologic period does the fossil record show more diverse and relatively higher forms of organisms?
   a. Devonian  b. cretaceous  c. Jurassic  d. Permian
9. From the time oxygen was first produced on the planet, it took approximately how many years for the levels to begin to rise?
   a. 1,000,000  b. 10,000,000  c. 100,000,000  d. 1,000,000,000
10. The scientists who developed the theory of abiogenesis were:
    a. Miller and Bernal  c. Bernal and Haldane
    b. Miller and Oparin  d. Oparin and Haldane

**Answer key**

1. D  6. B
2. D  7. B
3. C  8. B
4. D  9. D
5. B  10. D

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## 4.2. The theories of evolution

We owe much of our current thinking of natural selection to the idea of Charles Darwin who put forward the idea to the royal society in 1858. His paper suggested that ***"*** *those organism that were best adopted to their environment would have an advantage and be able to reproduce in greater numbers than other types, and pass on the advantageous adaptation"*. Because he knew nothing of genetics, he was unable to suggest how this might take place.

For many years in Europe, the Christian belief had been that the earth and all species had been created about 6000 years ago. In the mid $1700_s$, George Buffon challenged this idea, suggesting that; -the earth was much older than this and

-organisms changed over time in response to environmental pressure and random events.

He suggested that the external environment has a direct influence on the structure of organism and such changes are heritable. He also suggested the concept of struggle for survival.

# Lamarckism

**Lamarckism** Is a theory developed by the French biologist Jean Baptiste Lamarck that claimed that organism passed onto subsequent generation traits acquired during their life time.

He proposed"*the theory of inheritance of acquired characteristics*".

In 1809, he published a paper (book) entitled"philosophie zoologique" in which he described a two part mechanism by which change was gradually introduced into the species and passed down through generations.

His theory is called "*the theory of transformation*" or "*Lamarckism*".

His theory has two points;

1. Use and disuse
2. Inheritance of acquired traits

## 1. Use and disuse

This theory suggests that by continually using a structure or process, that structure/ process, will become enlarged or more developed. Conversely, any structure/process that is not used or little used will become reduced in size or less developed.

Examples (how use could change a trait);

1. *The elongated neck of the giraffe*
   The long necks and long legs of the modern giraffe were the result of generation of short necked and short legged ancestors feeding on leaves at progressively higher levels of trees.
   i.e. each generation received slightly longer necks and legs from its parents, which in the long run resulted in the present day long necked and long legged giraffes.
   (See figure 4.14 in page 184 of your text book).
2. *The toes of water birds*
   The webbed feet in aquatic birds are the result of the constant spreading of the toe bones and the skin between them so that they would be able to swim to find and escape from predators.
3. *The large and strong biceps muscles of black smith* are due to his arm continuously pounding on his anvil.

### The effect of disuse

Disuse brings about degeneration extinction of structure**. For example;**

1. The wings of penguins;-Their wings become smaller than other birds because penguins do not use them to fly.
2. The eyes of mole rats are lost because these animals spend most of their time in dark, underground tunnels.
3. The continuous creeping, through holes and crevices, life of snakes made the limbs continually useless for locomotion, which eventually resulted in the loss of the limbs.

## 2. Inheritance of acquired traits

This theory states that "*all the changes in an individual during its life time are transmitted to its offspring by reproductive processes"*.

i.e. traits changed or acquired during an individual's life time could be passed on to its offspring.

The long necks/legs of the modern giraffe were the result of generation of short necks/legs ancestor feeding on leaves at progressively higher levels of trees.

This type of inheritance (Lamarckian inheritance) has since been disproved by the discoveries of genetics.

**Epigenetics:-** is a relatively new branch of genetics. One of the important findings is that the way a gene expresses itself may become altered during an individual's life time. These changes may be passed on to the future generations.

However, Lamarck did believe that evolutionary change takes pace gradually and constantly. He studied ancient seashells and noticed that the older they were, the simpler they appeared. Species started out simple and constantly moved towards complexity. Or as he termed it closer to perfection. These ideas we still retain today.

### Questions

1. Why were Lamarck's theories of evolution not fully accepted by philosophers?
   **Answer** – his theories could not be verified thoroughly experimentation.
2. In what way was Lamarck's theory correct?
   **Answer** – the environment did play a role in producing phenotypic changes in the individual.
3. Which philosopher criticized Lamarck's work and why?
   **Answer-** August Weismann, he experimented on white mice by cutting their tails. After 22 generations producing 901 young, none of the offspring showed a reduction of the tail.

## Charles Darwin and natural selection

Charles Darwin was the greatest naturalist and philosopher of the 19th century.

Charles Darwin, in 1858, published his famous paper on natural selection.

- He established the theory of evolution by natural selection.
- he developed the idea some 20 years earlier(in 1831, when he was 22 years)
- In 1858, another biologist Alfred Russell Wallace had come to similar conclusion and they jointly published a scientific paper to the Linnaean society of London that would change our thinking an origin of species forever.
- some of Darwin's evidences came from a visit to the Galapagos islands in the pacific ocean about 600 miles off the coast of Ecuador in south America

As a young boy, Darwin was extremely curious about the natural world. In1831, when he was 22 years old, he was invited to join the HMS beagle, a surveying ship, as a chief naturalist. The ship was chartered to conduct a 5 year mapping expedition to South America and the South Sea Islands. His main task was to make field observation and collection of plants and animals throughout the voyage.

Darwin visited 5 Galapagos Islands and made drawing and collected specimens. In particular, he studied the finches found in the different islands and noted that were many similarities between them and also obvious differences.

He concluded that an' *ancestral finches'* had colonized the islands from the mainland and in the absence of predators, they were able to adapt to the different conditions in the islands end eventually evolve into different species.

- ✓ Some finches evolved into insect eaters-with pointed beaks.
- ✓ Others evolved into seed eaters- with beaks capable or crushing seeds.
- ✓ Other evolved into fruit eaters- with parrot like bill.

150 ears later, geneticist have been able to confirm Darwin's discoveries and even produced a 'family tree' based on the similarity of their DNA.

See figure 4.16 on page 185 grade 12 text book

Scientist tested how well the finches were adapted to their "niche". They analyzed the sizes of the seeds eaten by three different ground finches.

Although there is a little overlap, each finch eats seeds of a different size and their beaks are adapted to obtain and crush these different sized seeds.

Darwin called this "***descent with modification"*** and believed it to be key evidence in support of his theory of natural selection. We know call this ***"adaptive radiation".***

**Adaptive radiation:-** is the formation of new species by the successful invasion of new environment and niches. For example, the Darwin's finches.

The finches of the Galapagos Islands are now different to those in the main land. Because the geographical isolation of the islands caused reproductive isolation. This reproductive isolation is a barrier to gene flow among members of the same species. This result is **speciation**. Speciation is the formation of new species.

Darwin summarized his observations in two main ideas:

1. All spices tend to produce more offspring's than can possibly survive (overproduction or fecundity)
2. There is variation among the offspring's.

From the observation he deduced that:

1. There will be a "***struggle for existence***" between members of a species, because they over reproduce and resources are limited.
2. Some members of a species will be ***better adapted than others*** to their environment. Because there is variation in the offspring's.

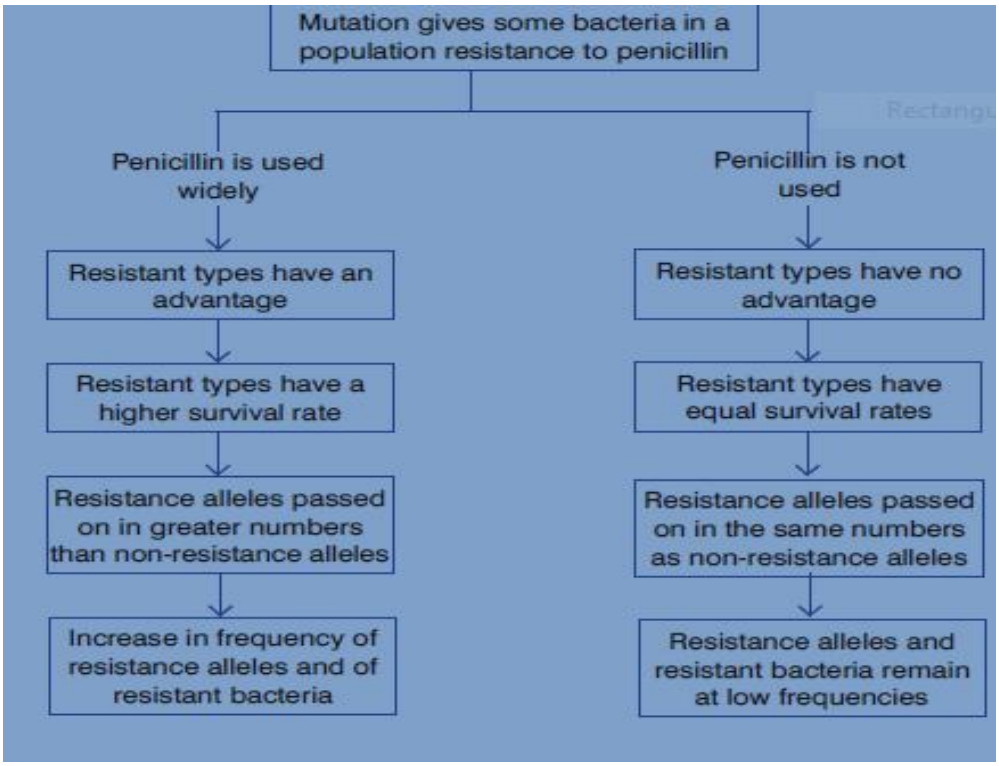
Combining these two dedications, Darwin proposed:

- *Those members of a species which are best adapted to their environment will survive and reproduce in greater numbers than others less well adopted.*

The following table shows comparison of Lamarck's theory of use and disuse with Darwin's theory of natural selection.

| **Aspect of theory** | Lamarck's theory of use and **disuse** | **Darwin's theory of natural selection** |
|---|---|---|
| Variation | Environment changes creating a need for the organism to change | There is natural variation in the features and the variations are heritable |
| Survival | Development of new features in order to survive. E.g. Long neck of giraffes. | Environment selects infavour of those traits that adapt the organism to the environment and against those that do not. |
| Inheritance | New features acquired during life time of an individual are passed on to off springs. | Individuals with advantageous variation of traits survive in a great numbers and pass on those advantageous variations to their offspring. |
| Evolution | New species over time | New species over time |

**Do you know?** Antibiotic resistance:- a modern example of selection in action. Mutations in bacteria can make them resistant to an antibiotic, for example penicillin. If they are resistant to penicillin, it will have no effect on their growth and reproduction. What happens next depends on whether the bacterial population is exposed to the antibiotic, or not. This is summarized in the flowchart below.




## What is neo-Darwinism?

This is revised version of Darwin's theory of evolution by means of natural selection. This theory, which is now accepted by most biologists, combines Darwin's original theory, genetic theory and theories about animal behavior.

Since the publication of Darwin's theory of natural selection, there have been many researches and findings that made enormous contribution and modification to the theory.

Major contributions in the modification of Darwin's theory come from scientist such as Mendel, de veries and Weismann. Especially the contributions of Mendel were substantially important to upgrade Darwin's theory.

This resulted in the advent of a new school of thought called neo-Darwinism, which could be defined as the theory of natural selection of inherited characteristics. This concept bases itself on

modern evidence from Mendelian genetics, molecular biology, paleontology, ecology and ethology.

Neo-Darwinism takes into account our knowledge of genetic bio chemistry and ethology to modify Darwin's original theory to include the effect of selection of an allele frequency of behavioral patterns.

Our better understanding of what derives evolution comes from:-

1. Our knowledge of genes and gene actions or alleles of genes.
2. Mutation

**Genes** or more accurately, alleles of genes determine features. Populations evolve into new species due to alleles carried by each individual and also all the alleles (of all the genes) present in the population (gene pool).

Suppose an allele determines a feature that gives an organism an advantage in its environment. The following will happen:-

- Those individual with advantageous allele of the gene will survive to reproduce in greater numbers than other types.
- They will pass on their advantageous alleles in greater numbers than the other types pass on their alleles of the same gene.
- The frequency of the advantageous allele in the gene pool of the population will be higher in the next generation.
- This process repeats over many generations and the frequency of the advantageous allele in the gene pool increases with each other generation that passes.

**Mutations** are also very important in introducing variation into populations. Any mutation could produce an allele which;

- Confers a **selective advantage**
  The frequency of the allele will increase over time.
- Is **neutral** in its overall affect
  The frequency may increase slowly, remain stable or decrease.
  The change in frequency depends on what other genes/alleles as associated with the mutant allele.
- Is **disadvantageous**
  The frequency of the allele will be low and could disappear from the population.

But neo-Darwinism does not just take into account our knowledge of genetics. It also encompasses our understanding of animal behavior (ethology)

Behavioral patterns can also be advantageous- or not behavioral patterns that confer a survival advantage will be selected for, and those that do not will be against.

Example of advantageous behavioral is imprinting in geese.

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## Review questions

1. Which of the following features does analogous structure mostly share?
   a. Phylogenetic similarity c. mutation theory
   b. Developmental similarity d. in heritance of acquired traits/characteristics
2. The evolution of species which is based up on the sum total adaptation changes could be preserved by:-
   a. Natural selection b. speciation c. human conservation d. isolation
3. Which one of the following is primarily contribution of Darwin to biological theory?
   a. An important mechanism of biological evolution is natural selection
   b. New alleles arise through mutation
   c. Evolution is change in gene frequency over time
   d. Genes are the unit of inheritance
4. Which of the following points do Lamarck's and Darwin's theory of evolution agree?
   a. Evolution occur by natural selection c. all living things tend to over produce
   b. Evolution produce new species d. new structure arise by use and disuse
5. Which of the following concepts is attributed to Charles Darwin?
   a. In the struggle for existence, the fittest would survive
   b. Every cell must come from a pre existing cell
   c. Use and disuse of organs is a great importance in evolution
   d. The genes will carry only one of a pair of contrasting characteristics
6. Which one of the following phenomena supports Darwin's concepts of natural selection in organic evolution?
   a. Development of transgenic organisms
   b. Prevalence of pesticide resistance insects
   c. Production of "dolly" the sheep by cloning
   **d.** Development of organs from stem cells for organ transplantation

**Answer key**

1. B
2. **B**
3. **A**
4. **C**
5. **A**
6. **B**----------//////////////----------

# 4.3 The evidences of evolution

## 1. How does paleontology support the theory of evolution?

The word paleontology refers to the study of ancient life. It comes from the Greek words "palaios" meaning ancient and "logos" meaning study.

**Paleontology** is a branch of biology that deals with the study of fossils. By comparing the fossils of ancient organisms and the present day organisms, this science gives evidence to support evolution.

**Fossils** (Fossil is a Latin word; "fossus" means having been dug up).

- Are the basis of this science.

-They are the main direct evidences about past life.

-Are remains or traces of animals, plant and other organisms from remote past.

-Are grouped in to two categories.

**Category 1** – the remains of dead animals or plants or the imprint left from the remains, including:-

Bones ,Teeth, Skin impressions, Hair, the hardened shell of an ancient invertebrate such as trilobite or ammonite, an impression of animal or plant, even if the actual parts are missing.

**Category 2** – Something that was made by animals while it was living that since hardened in to stones. These are called trace fossils and include:-

Foot print, Burrows, and Coprolites (animal faeces)

Type-1 fossils can be the actual organisms or part of an organism, like a piece of bone or hair or feather as it actually was. For example: this spider has been trapped, completely unchanged, inside the amber for millions of years. Fig. 4.18 on page 191 text book)

Note that amber – is a fossilized resin from trees.

In many fossils the soft parts of the body have been lost but the exoskeleton is perfectly preserved. In some cases however, the entire body remains. However, when you think of fossils, we usually think of imprints of whole organisms or parts of organisms.

## How do these fossils form?

Clearly death of the organism is the first stage. But death is nearly always associated with decomposition which of obviously does not happen when fossils are formed.

There are 4 main stages of fossil formation.

1. *Death without decomposition*
   An animal or plant must die in or so close to water that is covered by water immediately after death. The water insulates the remains from the elements that contribute to decomposition. Bacteria will still decay the soft parts over long period but leave any hard body parts unaltered.
2. *Sedimentation*
   As time passes, sediments (tiny particles of solid matter settling out of the water) burry the remaining hard parts of the organism. Fossilization is more likely if this happens quickly sedimentation further insulates the organism from complete decay.
   The nature of the sediment influences the nature and quality of the fossil. Very fine grained particles for example, clay will create a more detailed fossil than coarser- grained sediment. For example, sand.
   The chemical makeup of the sediment affects the color of the fossil.
   For example: - Iron rich sediment could give the fossil reddish color.
   Phosphate may darken the rock so that it is gray or black.
3. *Permineralisation*
   As the sediment accumulates, the lower layers become compacted by the weight of the top layer. Over time, this pressure turns the sediment into rocks. If water rich in mineral percolates (seeps) through the sediment, the mineral particles stick to the particles of the sediment, gluing them together into solid mass.

Over the course of millions of years, these mineral particles dissolve away the original hard parts of the organism, replacing the molecules of exoskeleton with molecules of calcite ($caco_3$) or anther mineral. In time, the entire shell is replaced by mineral particles and these are also compressed in to a rock, in the shape of the original organism. As this rock is not the same as the surrounding rock, it is visible as fissile in the exact shape of the original organism.

4. *Uplift*
   Earth movements may expose rocks that were deep beneath the surface. What were sea floors are lifted up and become dry land. Other earth movements cause rocks to slip and parts of different strata to become exposed. When this happens, rocks that contain fossils

become lifted to the earth's surface. Rain, wind, earth, quacks, freeze and thaw erode rock and may expose a fossil (see fig: 4.20 on page 193of your grade 12 text book).

**How can we date fossils?**

There are two ways;

1. **Stratigraphy**: because sedimentary rocks are laid down in layers (strata) we can use the sequence of the strata and the fossils that occurs in them to deduce how the organisms have changed over time.

The oldest strata (fossils) will be in the lower layer and more recent rocks and fossils in layers above them, with the most recent being nearest to the surface ( Refer fig:4.21 page 194 of your text book).

But how do we find out how old each layer is? How do we actually date rocks?

To do this we use one of the two techniques of radiometric dating methods:

2. **Radiometric dating**
    a. Radio carbon dating (The half-life of Carbon is 5730 years)
    b. Potassium-argon dating (The half-life of potassium is 1.3 million years)

Both these techniques rely on the principle that radioactive atoms decay in to other atoms over time. E.g.:-Radioactive carbon atoms ($C^{14}$) decay in to non-radioactive nitrogen atom ($N^{14}$).

Radioactive potassium atoms ($k^{40}$) decay in to non radioactive argon atom ($Ar^{40}$). Each has a half life.

**Half life:** - is the time needed for half the atoms of the radioactive substance to decay. After two half lives ¾ of the atoms will have decayed and so on.

So starting with a certain number of radioactive potassium atoms, after one half life 50% will still be radioactive. After a second half life 50% of this 50% will have decayed and 25% of the original number will still be radioactive.

Potassium- argon dating works in the same way, but the half life in this case is 1.3 million years. This makes K-Ar dating suitable for dating rocks millions of years old. Whereas radio carbon dating is rely only accurate with rocks up to 60,000 years old.

**Example: 1**. If a fossil contains one fourth of its original contents of carbon-14, its estimated age would be (assume the half life of carbon-14 is 5,730 years). **Answer:-** 11,460 years.

**Example 2**.The age of fossils containing 3.125% of the original carbon 14 atoms is;
**Answer:**-28,650 years.

## 2. How does comparative anatomy support the theory of evolution?

- ✓ This is one of the strongest forms of evidence for evolution.
- ✓ It looks at the structural similarities of organisms and uses these to determine their possible evolutionary relationships.
- ✓ It assumes that organisms with similar anatomical features are closely related evolutionary and that they probably share a common ancestor.
- ✓ Ancestrally related organisms have homologous organs.

**Homologous structure: -** are structures with the same basic anatomy and common evolutionary origin, but having a different function. (i.e. Similar structures but different in functions).

- This indicates evolutionary relationships and a common ancestor.

E.g.: The fore limbs of mammals are homologous structures.

- *Human's arm* -used for manipulation
- *Whale's flippers*- used for swimming
- *Cat's legs*- used for running
- *Bats wing* -used for flying

Each of these posses the same number of bones arranged in almost the same way, while they have different external features and they function in different ways. i.e. they are very similar in structure and therefore they are homologous structures.

By comparing the anatomy of these limbs, scientists have determined that the basic pattern, called a **pentadactyl limb** (five finger limb), must have evolved just once and that all this kind of limb are descended from that original type - they share a common ancestor.

Sometimes organisms have structures that function in a very similar ways. However morphologically and developmentally they are very different. These structures are called **analogous structures**.

**Analogous structures:-** are structures having the same function but different anatomy and different evolutionary origin. These cannot indicate that two species share a common ancestor. E.g. The wings of birds and the wings of mosquitoes.

## 3. How does comparative embryology support the theory of evolution?

**Embryology**-is the study of the embryological development of vertebrates before they hatched or are born. This development shows similarities and therefore supports common ancestry.

E.g. Early in the development, all vertebrates embryo (lizard, tortoise, pig and humans) have **gill slits** and **tails**. (Refer 4.26 on page 198 of grade 12 text book). The more similar the patterns of development, the more closely related the species are assumed to be. The similarity in the pattern of development of vertebrates suggests again a common ancestor. The embryo of closely related forms goes through very similar stages of development.

## 4. How does comparative biochemistry support the theory of evolution?

If organisms share very similar molecules and biochemical pathways, then they must be closely related evolutionarily. Chemicals that have been used in such analysis include:

1. **DNA**-the base sequence of different organisms is compared.

2. **Proteins** such as *cytochrome-C* found in the electron transport chain (ETC) of respiration and *hemoglobin* are compared in terms of amino acid sequences.

Closely related species have most similar DNA and proteins and distantly related species share fewer similarities.

Table 4.3. Comparison between DNA of humans and other primates

| **Primate** | **Degree of relatedness** |
|---|---|
| Chimpanzee | 98% |
| Rehesus monkey | 91.1% |
| Vervet monkey | 84.2% |
| Galago | 58.0% |
| Banana | 50% |

The technique used to measure the similarity of the DNA of two species is called ***DNA hybridization***. This technique measures the extent to which a strand of DNA from one species can bind with (hybridize) a strand of DNA from another species.

## 5. How does plant and animal breeding support the theory of evolution?

Selective breeding experiments have shown that genetic and physical modification of species is possible and so should be possible as a result of natural selection rather than human selection.

**Selective breeding** is a technique used to produce organisms with desired traits by allowing only these organisms with that trait to reproduce. Humans have been trying to improve the yields of their crop plants and stock animals by selective breeding.

E.g. Animals with high milk yield, plants with number of seeds per pod, etc. are selected and mated. The off springs are monitored carefully and again only those with the desired traits are allowed to breed.

If new varieties can be produced by selective breeding, then natural selection should also be able to produce new varieties and eventually new species. The accumulation of such changes in the population would gradually bring about evolution.

### CHECK POINTS

1. Give two examples of radio isotopes.
2. What do we mean by half life?
3. Distinguish between homologous and analogous structure.
4. How do evolutionary biologists consider selective breeding as an evidence for evolution?

## Review questions

1. Among the following fossil hominid species, which one is the oldest fossil?
   a. *Homo erectus* c. *Australopethecus afarensis*
   b. *Ardipithecuse ramidus* d. *Australopethecus africanus*
2. What are the most likely causes of variations with in species?
   a. Mitosis and sexual replication c. vegetative propagation and cloning
   b. Overpopulation and overproduction d. mutation and sexual reproduction
3. In which hominid species do scientists find the smallest brain size?
   a. *Homo sapiens* b. *Homo habilis* c.*Homo erectus* d. *Homo neanderthalensis*
4. To which genus of primates are neanderrthal humans classified? The genus:
   a. *Ardipithecus* c. *Homo*
   b. *Australopethecus* d. *Zinjanthropus*
5. Homologous structures can :
   a. Have different structure c. often have different functon
   b. Have different evolutionary origin d. develop differently in the embryo

**ANSWER KEY= 1.B 2.D 3.B 4.C 5. C**

# 4.4 The processes of evolution

## What are the different types of natural selection?

**Natural selection –** is the theory that explains the origin of species in terms of survival of those best adapted to a specific environment.

The modern view of natural selection is stated briefly below:-

***"Those members of a species which are best adapted to the environment will survive and reproduce in greater numbers than those less well adapted. They will pass on their advantageous alleles to their off spring and, in successive generations; the frequency of these alleles will increase in the gene pool. The advantageous types will therefore, increase in frequency in successive generations".***

Natural selection is the "***driving force***" behind evolution. It is the process that brings about changes (over time) in population that can, eventually, lead to different population of the same species becoming different species.

**Species**: - Refers to a group of a related organism that can reproduce with each other so that they produce fertile off springs.

The current definition of species is a group of similar organism with a similar biochemistry, physiology, and evolutionary history that can interbreed to produce off spring that re fertile.

**Speciation: -** is the process by which a new species evolves.

Example, A horse and donkey can breed to produce a hybrid mule. However mule is sterile. So, horse and donkey must belong to different species.

### Types of natural selection

There are three types of natural selection.

1. Directional selection
2. Stabilizing selection
3. Disruptive selection

#### 1. What is directional selection?

A feature may show a range of values. *Individuals at one extreme could have a disadvantage where as those at the other extreme have an advantage.* **For example;**

- Thicker fur (longer fur) in foxes is an advantage in cold climate
- Thinner fur in foxes is an advantage in hot climate

Now, if the environment were to change so that it becomes significantly colder, there would be a selection pressure in favors of the foxes with long fur and against those with short fur.

Overtime, selection operates against the disadvantaged extreme and favors of the other extreme. The mean and range of values shift towards the favored extreme. The frequency of the alleles causing longer fur will increase.

Figure 4.30 directional selection pages 205grade 12 text book.

Foxes in the shorter fur could not survive in the new environment. but there are foxes with fur length that are longer than any of those in the original distribution. Where have they come from?

**Answer**:- They must be result of either

1. New mutations or
2. New combinations of alleles.

**Conclusion: -** In the directional selection one extreme of the range of values for a feature has a survival advantage. The range of values for the population shifts towards the extreme with the selective advantage.

### 2. What is the stabilizing selection?

In the stabilizing selection, *the two extremes are at a selective disadvantage compared to those showing the mean values for a particular feature*. The range is compressed around the mean in stable environment; individuals at both ends of the range of values for a feature are the least well adapted. Selection often operates against both these extremes to reduce the variability in the population and to make the population more uniformly adapted.

**Example:** - Birth mass in humans

Babies who are very heavy and very light show a higher neonatal mortality rate (die more frequently at, or just after birth) than those of medium mass.

Over time selection is operating to reduce the number of heavy and light babies.

Fig: 4.31 stabilizing selection

### 3. What is disruptive selection?

This is the converse of stabilizing selection. In disruptive selection *both extremes have a selective advantage compared with the mean*. Two distinct types begin to emerge showing the extreme values of the original population.

As a result, the frequency of those individuals at the extremes of the range will increase over time and those in the middle of the range will decrease over time.

**Example: -** Darwin's finches

A finch with an average length of beak may not be able to obtain insects out of cracks in the bark of trees as well as one with the larger beak. It may also not be able to crush seeds as well as one with a shorter, more powerful beak.

Over time those with the thinner, longer beaks and those with the shorter and more powerful beaks will increase in their numbers, whilst those with average length of beak will decrease in numbers.

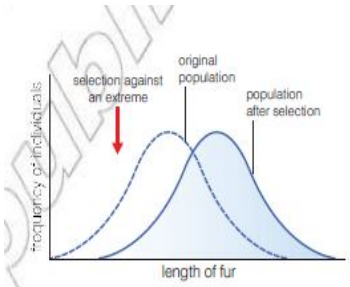

*Figure 4.30 Directional selection*

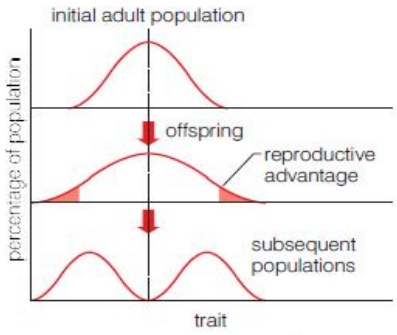

*Figure 4.32 Disruptive selection*

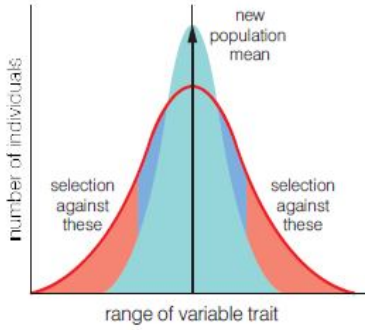

*Figure 4.31 Stabilising selection*

Fig: - 4.33 above show summery of the different types of selection.

## How can natural selection lead to the formation of new species?

Natural selection provides a mechanism by which new population of spices can arise. But at what point can these populations can be considered as distinct species?

*A **species** is a group of similar interbreeding organisms that produce fertile offspring.*

If two populations become so different that individuals from different populations cannot interbreed to produce fertile offspring, then we must think of them as different spices. There are number of ways in which this can occur.

1. Allopatric speciation
2. Sympatric speciation

Both allopatric and sympatric involve isolating mechanisms that prevent different populations from inter breeding for a period of time. During this period, mutations that arise in the one population cannot be passed to the other.

As a result of this and different selection pressures in the different between the two populations will become so different that they will be unable to interbreed and at this point, we say that they are reproductively isolated. Effectively they will have become distinct species.

## What is allopatric speciation?

**Allopatric speciation** occurs when the population from *an existing species becomes geographically isolated* and the isolated population develops into a new species (if intra specific speciation occurs whilst the populations are separated).

**Sympatric speciation** occurs when a population from an existing species develops into a new species *without becoming geographically isolated* from other members of the original species (if the process occurs whilst the populations are occupying the same geographical area).

In allopatric speciation the species become isolated by some feature. It is characterized by the occurrence of spatial separation.

**Example:-**

- A river changing course
- A mountain range being created
- A land mass separating two bodies of water
- A habitat preference

This type of isolation is called "**geographic isolation"**. Interbreeding between the populations becomes impossible and species could result.

- Geographic isolation produces a barrier to gene flow.
- This inability of organisms (their gametes) to meet leads to reproductive isolation
- Adaptations to new condition or random genetic drift in small population lead to new changes in allele and genotype frequencies.
- Prolonged separation of population may result in them genetically isolated. In this way new species arise.

**Examples:-**

- The Galapagos finches of the family Geospizidae
- The shrimp population of the Caribbean sea and the north pacific ocea**n**

## What is Sympatric speciation?

Here, speciation need not involve physical separation. It occurs whilst the populations are occupying the same geographic area. The two diverging populations may inhabit the same area, but be prevented from breeding a number of ways.

1. **Seasonal isolation:-** members of the two populations reproduce at different times of the year (different populations sexually mature at different times).
   **Example** *Bufo americans* – mate early spring
   *Bufo fowleri* – mate late spring

**Example 2.** Palms growing calcareous soil tend to flower later than those growing in volcanic soils.

2. **Temporal isolation:-** members of the two populations reproduce at different times of the day.
3. **Behavioral isolation:-** member of the two populations have different courtship patterns ( absence of sexual attraction between the males and females).
   **Example;** *Visual stimuli* – color, form, movement
   *Auditory stimuli*- birds songs, frog calls
   *Olfactory stimuli*- pheromones

## What is polyploidy and why is it important in plant evolution?

**Polyploidy** is a condition in which a cell (organism) has one or more extra chromosome or extra complete sets of chromosomes.

- It is caused by failure of normal meiotic divisions.
- Polyploid cells have many sets of chromosome per cell.

**Example**; 3n=triploid, 4n= tetraploid, 5n= pentaploid

- It is much common in plants than in animals.

Some human liver cells have 92 chromosomes per cell (tetraploid) i.e. they have 4sets of chromosome per cell

Polyploidy has been important in plant evolution. Because it has allowed infertile hybrid to become fertile again.

**Example;** When different species form hybrids, the hybrid cannot produce offspring because all the chromosomes cannot form bivalents (homologous pairs) in meiosis. So they cannot form sex cells and cannot reproduce. If the chromosome number were to double, then all the chromosomes are able to form homologous pairs. Meiosis and sex cells formation can take place and the hybrid is now fertile.

Polyploidy and hybridization have both been important in the evolution of modern wheat from wild grasses.

Polyploidy is often associated with advantageous features such as increased size, hardiness, resistance to disease, etc

## What are divergent evolution and convergent evolution?

**Divergent evolution: -** Is also called "adaptive radiation".

In divergent evolution, a basic type "*diverges"* along different lines because of different selection pressure in different environments. If different selection pressures are placed on populations of a particular species, a wide variety of adaptive traits may result.

If only one structure on the organism is considered (example limb), these changes can either improve the original function of the structure, or they can change it totally.

Divergent evolution leads to the development of a new species.

**Example 1**. The evolution of different species of finches on the Galapagos islands (page 209 figures 4.37 of grade 12 text book). A single ancestral species can develop into different species. E.g.- *Seed eaters* -have crushing beaks.

-Large ground finches
-Medium ground finches
-Small ground finches

*Cactus eaters*- have probing beaks -cactus finches

*Insect eaters*- have probing beaks and grasping beaks

-walbler finches

-Wood peaker finches

-Small tree finches
-Large tree finches

*Fruit eaters*- have parrot beaks- vegetations finches.

**Example 2**. The evolution of different forms of the pentaductyl limbs into flippers, legs, wings, arms. etc…

## What is Convergent evolution?

Convergent evolution is the process by which unrelated organism evolve similar structure, adapted for the same function.

It takes place when different organisms occupy similar niches.

The selection pressures are the same and so similar adaptation evolve over time.

**Example 1**. Convergent evolution of ant eaters;

- The giant armadillo in north America

- The giant pangolin in Africa
- The giant ant eater in south America
- The spiny ant eater in Oceania

These are not related evolutionarily but all feed on ants from narrow cracks in the ground. The same selection pressure result in similar structure appearing in unrelated organisms.
**Example 2**. The wings of birds, bats and the extinct pterodactyl.

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## Review question

1. For which of the following can divergent evolution be taken as an alternative name?
   a. Allopatric speciation d. sympatric speciation
   b. Adaptive radiation c. disruptive selection
2. Among the following which one is the best criterion to show that two populations belong to the same species?
   a. Morphological similarity d. temporal isolation
   b. Behavioral isolation c. isolation by distance
3. What does an evolutionary selective pressure that acts around the mean do?
   a. It stabilize c. it converges
   b. It terminates d. it disrupt
4. In sympatric speciation, the isolating mechanism could be:
   a. temporal b. seasonal c. behavioral d. all of the above
5. polyploidy is often associated with advantageous features:
   a. increased size
   b. resistance to disease
   c. large fruits
   d. all of the above

## Answer key

**1. B 2. A 3. A 4. D 5. D**

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## 4.5 The evolution of humans

### Who are we and where have we come from?

We are *Homo sapiens* (the species that all humans alive today belong to) and we are the latest of several humans to live on the planet. All humans belong to the genus *Homo*.

We have two features in particular that distinguish us from other primates. These are:

1. A very large brain
2. Bipedalism – the ability to truly walk on two legs

Modern humans and other primates have evolved from a common primate ancestor that lived before the dinosaurs become extinct.

Modern humans and chimpanzee have evolved from a common ancestor that lived about 6-million years ago.

### What is significant about Lucy and Ardi?

- The fossil Lucy was significant because ***it showed that Bipedalism evolved before large brains.***
- The fossil Ardi was significant because ***it showed that the common ancestor of humans and chimpanzee cannot have resembled a chimpanzee.***
- Brain size has increased as hominids have evolved.

Both Lucy and Ardi are important fossils in explaining the evolution of modern human and chimpanzee from a common ancestor.

Lucy;

- Was discovered by Donald Johansson and Tom Gray in 1974 in Hadar in Ethiopia.
- Is a fossil dated about 3.2 million years
- She was an adult female of about 25 years old.
- She belonged to the species *Australopithecus afarensis*.
- Her skeleton was 40% completed an unusually high proportion for a fossil skeleton.
- Her pelvis, femur (upper leg bone) and tibia show that she was bipedal (could walk upright on two legs). However, there is also evidence that Lucy was also partly arboreal (tree-dwelling)
- She was about 107cm tall and about 28kg (62lbs) in weight
- At the time she was discovered, Lucy represented one of the oldest fossil hominine.
- The proportion of her humerus and femur were mid-way between those of modern humans and chimpanzee.

- Lucy had brain about the same size as that of a chimpanzee, so her discovery was able to settle a debate amongst biologists at the time – which came first, large brain or Bipedalism? Clearly Bipedalism came before big brain.

**Did you know?** At the time of the discovery, a Beatles song was playing…. "Lucy in the sky with diamonds" the fossil was named Lucy after the song.

Ardi: - The Ardi fossil (together with many other similar fossils) was first discovered in 1992, in the Afar desert in Ethiopia, but it was finally published that gave Ardi a unique position in human evolution.

Ardi was 1.2 million years older than Lucy, was also female and belonged to the species *Ardipithecus ramidus*. One significant feature about Ardi was that she was also bipedal.

At 4.4 million years old, Ardi is the nearest fossil to the "common ancestor" of humans and chimpanzees that have so far been found. This find finally proves that the common ancestor of humans and chimpanzees could not have resembled a chimpanzee, as chimpanzees are not truly bipedal.

**How was brain size changed during human evolution?**

During the course of human evolution, the brain size has got bigger. From comparing fossils, the cranial capacity has increased with each new hominid species that evolved.

Besides becoming bigger over all, the brain has increased in size as a proportion of body mass.

**Example**; Species of *Australopithecus* have a brain size between 0.7% and 1.0% of their body mass. Modern humans have the brain size between 1.8% and 2.3% of their body mass.

- The brain of *Homo sapiens* uses 25% of the resting energy requirement.
- The brain of great apes uses 8% of the resulting energy requirement.

A larger brain allows humans to;

- Run faster and in a more upright posture
- Plan in advance to avoid attack
- Develop and use tools and weapons.

These abilities clearly also depend on other physical adaptation such as longer legs, more nimble fingers and a straighter spine, but, without the larger brain to coordinate the activities, the physical changes would not confer the same advantage.

Are we still evolving?

*Homo sapiens* (modern human) first appeared in Africa and have since migrated to all other parts of the world.

As humans moved from Africa into different areas of the world, they encountered different environments. Different selection pressures in the different environments resulted in the different human population evolving along different lines.

For example, as humans encountered colder climates, body features that give a survival advantage by helping to conserve heat were selected for. These included:-

- the shorter, squatter body shape; this reduces the surface area to volume ratio and so reduces the rate of heat loss by radiation.
- an increased layer of adipose tissue under the skin to act as insulation.
- increased hairiness; this reduces heat loss by convection.

Humans evolved into different 'races' for thousands of years. Because natural selection favored different features in different environments. There are 3 main races of humans, with several sub divisions. This is based on a recent genetic analysis of the different races.

1. **African (Negroid)**, 100 million people from Africa and Melanesians of the south pacific.
2. **Eurasian (Caucasoid),** 1000 million people with variable skin colour ranging from white to dark brown. Three sub divisions exist:-
   - **i.** **Nordic-** often tall, blonde and narrow headed; including people from Scandinavian and Baltic countries, Germany, France, Britain**.**
   - **ii.** **Mediterranean-** usually lighter in body build, dark and narrow headed. Includes people from southern France, Spain, Italy, Wales, Egypt, Jews, Arabs, Afghanistan, Pakistan, and India**.**
   - **iii.** **Alpine-** usually broad- headed, square jaws, olive skin brown hair; Includes people from countries from Mediterranean to Asia.
3. **East Asian (mongoloid)-** most numerous of the present day populations and split into three group;
   - **I.** East Siberian, Eskimos, and the northern American Indians.
   - **II.** Japanese, Koreans and Chinese
   - **III.** Indonesians and Malays

However, this classification does not include the central African pigmies, the Bushmen and the Australoids.

Despite genetic difference between the races, it seems unlikely that they will evolve into different species because of;

1. Increasing interbreeding between the races as a result if increased travel
2. Increasing ability to modify the environment

It seems that some thousands of years ago the human populations or races might have been beginning to evolve into separate species. Certainly physical and genetic differences were

emerging between the different races. However, our large brain has intervened in two major ways:

- ✓ We developed the skill to design and manufacture all kinds of things. This effectively allowed us to become able to modify our environment, rather than having to evolve to adapt to it.
- ✓ We developed global travel. This has allowed humans of all races to interbreed throwing many of the genetic difference that have evolved into a huge human melting pot.

We may still evolve into diverse species. But, at the moment, the mechanisms that usually derive speciation have been modified by our large brains.

*Table 3.2* Some of the proteins our body synthesises

| Type of protein | Example | Function of example |
|---|---|---|
| Structural | Collagen | Building fibres of cartilage |
| | Keratin | Building nails and feathers |
| Enzyme | ATP synthase | Producing ATP from ADP and $P_i$ |
| | DNA helicase | Unwinding the double helix of DNA |
| Peptide hormone | Insulin | Control of plasma glucose concentration |
| | Adrenaline (epinephrine) | Fight or flight response |
| Antigen | A antigen on red cells | Determine blood group |
| | CD4 | Allows binding of HIV to T-lymphocytes |
| Antibody | Anti-a antibodies | Causes clotting of red cells with A antigen |
| | HIV antibodies | Destroys some HIV antigens |

**----------THE END----------**

## Review exercises on unit 4

1. Which of the following do biologists consider ancestral to the higher organisms today?
   a. Plantae b. Animalia c. fungi d. protista
2. Which of the following reproductive isolating mechanisms keeps the horse and donkey as two independent species?
   a. Hybrid inviability
   b. Hybrid infertility
   c. ecological isolation
   d. habitat isolation

3. Which one of the following groups is believed to be the first photosynthetic organisms to evolve on earth?
   a. Green plants c. blue green algae
   b. Green algae d. lichens
4. Which of the following was the most possible mode evolution by which the many species of Darwin's finches evolved on the Galapagos Island?
   a. Phyletic evolution c. convergent evolution
   b. Divergent evolution d. sympatric evolution
5. Which one of the following is the result of similarity observed between the wings of a birds and pterodactyls?
   a. Convergent evolution c. stabilizing selection
   b. Directional selection d. divergent evolution
6. Among the following four processes, identify the one that probably evolved before all the other three?
   a. Aerobic respiration c. oxidizing atmosphere
   b. Anaerobic respiration d. photosynthesis
7. What did Francisco Redi prove through his scientific experiment?
   a. Maggots appear spontaneously on foods placed any where
   b. Maggots do not appear in foods kept in jars that are protected with a cover
   c. Maggots do not appear in foods kept in open jar
   d. Flies appear spontaneously on the rotting meat kept in closed or open jars alike
8. Suppose a fossil initially contains 100,000 atoms of a certain radioactive elements whose half life is 10,000 years, after how many years would the number of atoms be 12,500?
   a. 10,000 years c. 30,000 years
   b. 20,000 years d. 40,000 years
9. What is the branch of biology that study about the origin and gradual change in living things?
   a. Microbiology b. evolution c. mutation d. reproduction
10. If a radioactive substance that weights one kilogram has a half life time of 100 years, what would be the percentage of the substance life after 300 years?
    a. 50 b. 30 c. 25 d. 12.5
11. According to Lamarck's theory of evolution, what is the mechanism by which evolving organisms acquire new structures?
    a. Mutation c. use and disuse of body parts
    b. Hereditary variation d. recombination of ancestral genes
12. Which one of the following characteristics can show the evolutionary relationship among organisms?
    a. structure having similar functions
    b. Presence of analogous structure s
    c. Presence of homologues structures

d. Structure having different origin

13. Based on similarity in number of amino acid found in hemoglobin which one of the following animals has closer phylogenetic relation to human being?
    a. Chicken b. hors c. frog d. gibbon
14. What do we call structures that have the same evolutionary origin even though they may now have different structural make ups or functions?
    a. Endemic b. analogous c. homologous d. indigenous
15. "Rat can be produced by keeping rags and grains at corner of a room" which of the following line of thinking supports this statement?
    a. Darwin's evolution
    b. Spontaneous generation
    c. Alteration of generation
    d. Sexual reproduction
16. Which of the following pairs are ANALOGOUS structures?
    a. The human arm and the front leg of mule
    b. The front leg of a frog and the wing of a bat
    c. The wing of bird and the wing of butterfly
    d. The wing of bat and the wing of a bird
17. Choose the one that had the **least** contribution to human evolution?
    a. Development of bipedalism c. attaining opposable thumb
    b. Adaptation to flight d. increasing brain size
18. How many years have passed since Darwin's book on the theory of evolution was published?
    a. About 50 years b. About 160 years c. About 120 years d. 1100 years
19. Which one of the following is an evolutionary requirement for two sub populations of species to evolve in to independent species?
    a. Free exchange of genes
    b. Geographic isolation
    c. Free migration between population
    d. Absence of natural selection
20. If a substance that weighs 2000g and has a life time of 100 years is left with only 250g , for how long have the radioactive decaying actively been undergoing?
    a. 200 years b. 250 years c. 300 years d. 500 years
21. Which of the following is prevented from taking place if populations are separated by geographic barrier?
    a. mutation b. evolution c. gene flow d. natural selection
22. The half life of carbon-14 is 5,730 years. If a fossil is 17,200 years old, about what percent of it s original carbon is still present?
    a. 75% b.50% c.25% d. 12%

23. Which of the following pairs are analogous structures?
    a. Wing of bird and wing of butterfly
    b. Front leg of horse and human arm
    c. Wing of bird and wings of bat
    d. Front leg of a frog and wings of bat
24. Which one of the following factors is **not** important for evolutionary change of population?
    a. Over reproduction
    b. Insufficiency of natural resource
    c. Existence of heritable variations
    d. Survival of all that are born
25. During the course of evolution which of the following event come before the others?
    a. Origin of dinosaur and other reptiles
    b. Availability of free oxygen in the atmosphere
    c. Origin of the oldest eukaryotic organism
    d. Origin of the first multi cellular animals and plants

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Answer key for review question on unit four (evolution)

| | | | | |
|---|---|---|---|---|
| 1.D | 6. B | 11.C | 16.C | 21.C |
| 2 B | 7. B | 12.C | 17.B | 22.C |
| 3 C | 8. C | 13.D | 18.B | 23.A |
| 4 B | 9. B | 14.C | 19.B | 24.D |
| 5 A | 10. D | 15.B | 20.C | 25.B |

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# Unit 5

# BEHAVIOR

**Contents:-5.1 Introduction to Behavior**

**5.2 Innate Behavior**

**5.3 Learned Behavior**

**5.4 Examples of Behavior Patterns**

## 5.1 Introduction to Behavior

### What is behavior?

Behavior can be defined in a number of ways, depending on your perspective or view point. The following are some definitions of behavior.

- The observable response a person makes to any situation.
- A manner of acting or conducting yourself.
- The way a person behaves towards other people.
- The action or reaction of a person or an animal in response to external or internal stimuli.
- The responses or reactions or movements made by an organism in any situation.

From a biological view point none of these is complete and a better definition would be:-

- *The coordinated response of an organism to an internal or external stimulus.*

  **A stimulus**- Is a change in the external or internal environment of an organism.

For an organism to show a coordinated response, then any behavior must have these components:

i. **A receptor** of some kind to detect the stimulus.
   Receptor is a cell or group of cells that receives and processes
ii. **An effector** of some kind to produce the response.
   Effector is any part of an organism that produces a response.
iii. Some kind of linking system or **coordinating system** that is influenced by the receptor and can influence the effector.

A generalized model of the components of behavior is summarized as follows;

**Stimulus → Receptor →Coordinating system → Effector → Response**

This model can be applied to specific behavior in both animal and plant**s .**

## How do plants respond to unidirectional stimuli?

Plants show behavior patterns that involve tropisms (growth responses to unidirectional stimuli).

A plant on a windowsill (where the intensity the light will be greater on the window side than the other side);-

- the plant shoots grow towards the window.
- they grow towards the greater light intensity. This behavior is called **phototropism.**

***Phototropism;-*** *is the tendency for parts of plants to grow towards light (positive phototropism) or away from light (negative phototropism)*

Plant shoots are positively phototropic because they grow towards light. The response is even more marked in young seedlings.

The benefit in plant stems growing towards the greatest intensity of light is to direct their leaves in the direction of light. i.e. chlorophyll and other pigments in the leaves can absorb the maximum amount of light for photosynthesis. This response is coordinated by plant growth substance called auxins.

**Auxins-***are hormones that help to produce phototropic response.*

- They are produced in the shoot tip in response to light.
- Move downward and away from light to the dark side of the shoot.
- Stimulate the shoot cells to divide and enlarge, so growth is greatest on the side away from light. As this side grows more, it causes the shoot to bend towards the light.

Phototropism in plant shoots is summarized as follows.

**Light from one side** (stimulus)→ **receptor cells in the shoot tip** (receptor)→ **auxins produced and move away from light** (coordinating system) → **cells on dark side of stem grow fastest**(response) → **shoot grows towards light** (effector) .

Plant stems grow upward and roots grow more or less down wards.

The unidirectional stimulus producing this response by plants to gravity is called **gravitropism.**

**Gravitropism**-is the response by plants to gravity.

Roots- are positively gravitropic, because they grow towards gravity.

-This means that the roots will grow towards gravity.

-This means that the roots will grow towards an environment in which they can anchor the plant, absorb $H_2O$ and absorb mineral ions.

**Roots** -are negatively phototropic because they grow away from the direction of sunlight.

-are positively gravitropic because they grow towards gravity i.e. they grow more or less downwards. The unidirectional stimulus producing this response is gravity

Note that;-The importance of these responses is to serve maintain the plant in favorable environment. Some examples of behavior in plant include;

- the positive phototropism of plant shoots,
- the negative gravi-tropism of plant shoots,
- the negative phototropism of plant roots.

## How do simple animals respond to stimuli?

As some plants responses serve to maintain the plant in a favorable environment, some responses of simple animals do the same.

There are two types of responses in simple organisms.

1. **Taxes (singular taxis);-** is the movement along a gradient of intensity of a stimulus. It is a directional response to a directional stimulus.

Here, the animal moves along a gradient of intensity of a stimulus towards the greatest intensity of the stimulus **(positive taxis)** and sometimes away from the greatest intensity **(a negative taxis).**

*Example*; the unicellular protoctistan *euglena* swims using its flagellum towards area of increased light intensity. This is positive photo taxis and allows the organism to photosynthesize efficiently.

2. **Kineses (singular kinesis);-**is a response to a stimulus that involves increased movement as the intensity of the stimulus increases.
    - A change in the intensity of the stimulus brings about a change in the rate of movement not a change in the direction of movement.

***Example***; woodlice increases their rate of movement in bright light. This increases the probability that they will move into a dark, where it is usually more humid and they will lose less water.

Light/dark→ detected by oelli (simple eyes) → nerve cells transmit impulse to/from CNS→ increased the rate of muscle contraction → increased movement

***Fig.*** The response of woodlice to light

## Why is it important to study behavior?

It is important because we can gain information that can be used in

- **neuroscience**
- **the environment and resource management**
- **animal welfare**
- **science education**

Behavior in its widest possible sense includes the responses of all organisms. The study of animal behavior is often called ***ethology*** and the biologist who work in this field is known as ***ethologist***.

**The impact of the study of animal behavior on human society**

Many problems in human society can be related to the interaction of environment and behavior, or genetics and behavior. Social scientists often now turn to animal behavior as a base for interpreting human society and understanding possible causes of problems in society.

Specific examples include;

- Research by de Waal on chimpanzee and monkeys has illustrated the importance of cooperation and reconciliation in social groups. This work has implications for aggressive behavior among human beings.
- Harlow's work on social development in rhesus monkey (an investigation on weather food or comfort was more important in forming attachments) has been of major importance to theories of child development and attachment formation.
- Basic research on circadian and other indigenous rhythms in animals has led on to research relevant to humans in areas such as coping with jet-lag (extreme tiredness after flight) or shift- working.

**The impact of the study of animal behavior on neuroscience**

**Neuroethology** is the study of how behavior is linked to neural path ways. And neural path way is a sequence o nerve cells involved in bringing about a specific behavior.
**Neuroscience** is the branch of science concerned with the brain and the nervous system
some specific examples include;

- Carefully collected behavior data allows neurobiologists to focus their studies on specific stimuli and specific responses to determine neural pathways.
- Recent work in animal behavior has demonstrated the influence of behavior and social organization on physiological and cellular process. Variations in social environment can inhibit or stimulate ovulation, induce miscarriage and so on.

- Other animal studies show that the quality of the social environment has a direct effect on immune system functioning. Research is being undertaken to discover the neural pathways controlling these responses.

**The impact of the study of animal behavior on management of the environment and resources**

The behavior of animals often provides early clues of environmental damage. Change in sexual and other behavior occurs much sooner and at lower levels of environmental disruption than change in population size.

Specific Examples include;

- Research on how salmon fishes migrate back to their home streams has thought us much about the mechanism of migration. This has been valuable in preserving the salmon fishing industry.
- Knowledge of honey bees foraging behavior has given important information about mechanisms of pollination, which intern has been important for plant breeding and propagation**.**

**The impact of animal behavior on animal welfare**

Animal behavior researchers look at the behavior and wellbeing of animals in the laboratory and in the natural environment. Such research has insured reasonable and effective standard for the care and wellbeing of research animals. Improved conditions for farm animals, breeding of endangered species and proper care of companion animals all require information about behavior patterns.

**The impact of the study of animal behavior on science education**

Courses at universities in animal behavior and behavioral ecology often interest students in behavioral biology and may lead them on to wider scientific studies.

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## 5.1. Review questions

Choose the correct answer from a to d.

1. The correct sequence of the components of any behavior is:
   a. Stimulus---coordinating system--- receptor---effector---response
   b. Coordinating system- --receptor--- stimulus- --effector--- response
   c. Coordinating system---stimulus---receptor---effector---response
   d. Stimulus---receptor---coordinating system---effector---response

2. The best definition of behavior is;
    a. The pattern of response shown by animals
    b. The pattern of response shown by an organism
    c. The coordinated response of an organism to an internal or external stimulus
    d. The coordinated response of an animal to an internal or external stimulus
3. Example of behavior includes;
    a. The positive phototropism of plant shoot
    b. The positive photo kinesis of woodlice
    c. The negative gravi-tropism of plant shoot
    d. All
4. A response to a stimulus that involves increased movement as the intensity of the stimulus increases is called a:
    a. Tropism
    b. Taxis
    c. Kinesis
    d. None
5. Reasons to study animal behavior includes;
    a. Finding from animal behavior experiments may help to predict human behavior
    b. Understanding animal foraging behavior can help in conservation
    c. It is valid study in its own right
    d. All

## 5.2. Innate Behavior

The word **innate** literally means "**inborn**".

- Innate behavior is the behavior that is present (potentially) at birth or hatching.
- It does not have to be learned.
- it is any behavior that is inborn and genetically preprogrammed in some way.

**Example;** the young herring gull **"knows**" that if it pecks the orange spot on the beak of the adult gull, it will receive food. It did not have to learn this behavior. However, this is not quite the same as saying that the behavior is coded for directly in the genes.

### Types of innate behavior

There are 3 types of innate behavior:

- ✓ **Reflex action: -** these are the simplest of innate behaviors. A single action is performed in response to a specific stimulus. They are nearly always protective. i.e. they have survival value.
  **Example**; The withdrawal reflex in which a limb is moved from a stimulus such as heat or pain. The neural pathway is as follows.
  Receptor→ sensory neuron→ relay neuron (interneuron) → motor neuron
- ✓ **Orientational :-** these are more complex behaviors that result in the organism to behave in a way that it is most likely to move from unfavorable conditions and remain in favorable conditions.
  **Example** kinesis and taxis of woodlice and other simple animals
- ✓ **Instinctive:-** these often involve the most complex behavior, there is always a **fixed action pattern(FAP)** for each key stimulus. Once began, the FAP is carried out to completion, even if other stimuli intervene.
  ***FAP;-*** *is the predetermined behavior produced as a response to the key stimulus.*
  ***KEY STIMULUS;-*** *is the stimulus that triggers the FAP response.*

**Example of innate behavior;**
-The withdrawal of our hand from a hot object (reflex)

-Blinking when some dusts gets into your eyes(reflex)

-The kinesis of woodlice in response to changes in light intensity and humidity (orientational)

-**Nest** building (instinctive)

-Imprinting (instinctive)

-Weaving a web (instinctive)

## How are human reflex actions brought about?

There are two main kinds of reflex actions;

1. Somatic reflexes
2. Autonomic reflexes
    1. Somatic reflexes involve our special senses (eyes, ears, pressure detectors etc.) and produce a response by a muscle called somatic reflexes.
    -Many of these are protective
    **Examples**;- 'The knee-jerk reflex 'in which a limb is moved from a heat or pain stimulus.
    2. Autonomic reflex are those that involve sensors in internal organs and produce responses also in internal organs. These include the reflex actions controlling heart rate and breathing rate.

Note that Somatic reflexes are usually protective, where as autonomic reflexes control the rate of working of internal organs.

To understand how these two types of reflex actions operate, we must look at the structure of the nervous system (NS).

Our NS is divided *physically* in two major components;

1. **The Central Nervous System (CNS):-** comprising the brain and spinal cord, and
2. **The peripheral nervous system (PNS):-** comprising the cranial and spinal nervous

We can also divide our nervous system *functionally* into two;

1. **The somatic nervous system (SNS):-**which integrate information from the special senses to produce in skeletal muscles.
2. **The autonomic nervous system (ANS):-** which integrates information from receptors in internal organs and produces responses in the same or other organs or glands.

The autonomic nervous system is further subdivided into three;

A. **The sensory division** which transmits sensory nerve impulses into the CNS.
B. **The sympathetic division** which transmit impulse from the CNS to the organs, generally preparing the body for "fight or flight". for example by increasing cardiac output and pulmonary ventilation.
C. **Parasympathetic division** which acts antagonistically to the sympathetic branch and prepares the body for "rest and repair", decreasing cardiac output and pulmonary ventilation.

## What are biological clocks?

**Biological clock** is an internal regulatory mechanism that controls a cyclical process in an organism. Both plants and animal show yearly, monthly, daily and other changes that are genetically programmed. Biologists believe that they have evolved independently in different groups of organisms and are examples of convergent evolution.

- **Circadian-**controls a daily cycle. **(Circadian-Latin; *circa*=about and *dies*=day).** **T**hey persist with a period of about 24 hours in the absence of environmental cues. They can synchronize to a 24 hour cue, such as the light-dark cycle; this is called entrainment.
- **Lunar-** controls a monthly cycle.
- **Circannual-** controls a yearly cycle.

The biological clocks of mammals of some other animals are found in small area of the hypothalamus of the brain called the supra chiasmatic nucleus (SCN).

This sends impulses to a gland called the pineal gland, which secretes a hormone called melatonin during the night, which promotes sleep fullness and so the sleep-wake cycle.

Changes in the light-dark ratio can control reproductive behavior on annual basis. Such rhythms are called circannual (yearly rhythms). As the day length changes, so will the duration of melatonin secretion. This change in duration links reproductive behavior in many animals to specific times of the year. Some animals are long day (summer) breeders and others are short day (winter) breeders. The point is that it is day length that triggers the changes. Many other animals show circannual rhythms in behavior such as;

- Migration (e.g. Swallows)
- Hibernation (e.g. Hedgehogs)
- Coat growth (e.g. Arctic fox)
- Camouflage coloring (e.g. Arctic foxes)

## Instinctive behavior

Instinctive behaviors:-

- Are preprogrammed patterns of behavior?
- Are not just single actions in a response to a simple change in the environment like the reflex action.
- They often involve a complex sequence of actions.
  Example; spinning of webs by spiders.
- Are Common to all members of a species.
- They are fully functional the first time they are performed (they require no learning).

- There is a key stimulus that triggers the behavior.
- They are mediated by an innate releasing mechanism and a FAP.
- They are adaptive, i.e. they confirm a survival advantage.

**Example-1** :- the feeding behavior of herring gulls.

The orange spot on the beak is the key stimulus and pecking it is the FAP.

**Example 2** :- aggression in stickle back (fish)

Male stickles are very territorial. They will attack any other male that invades their territory.

In some famous experiments the ethologist ***Niko Tinbergen*** was able to show that the key stimulus was the red belly of the entering male. The defending male attacked any non-fish model that had red on its ventral lower surface. However, it turns out that the red belly (the key stimulus) provokes a very different FAP in female stickle backs. They find it irresistible and it stimulates mating behavior.

There is some evidence that some FAP can be modified slightly by experience. For example nesting behavior in love birds.

**Imprinting** is another kind of instinctive behavior in which the FAP is for newly born/hatched organisms to imprint on (become attached to) the first thing they see that has certain general features (those of an adult of its species).

***Imprinting*** *is a process in which an animal learns to make a strong association with another organism or sometimes an object and it is characterized by a short sensitive phase, which in all cases occurs early in the animal's life.*

**Example;-** Experiment conducted by Konrad Lorenz on goose.

- There is a "time window"(critical period) for imprinting to take place (the first two days after hatching), then the goslings will not imprint.
- This too may have survival value.

Many evolutionary psychologists believe that a similar pattern of behavior is found in human infants. It is called **attachment formation** and involves the formation of a strong emotional bond between an infant and its primary caregiver note exclusively the mother. This occurs in three stages:

- 0-2 months – pre-attachment, the infant prefers people to object but does not really discriminate between different people.
- 2-7 months- indiscriminate attachment, the infant begins to show a preference for familiar people.
- 7 months onwards- true emotional attachment to one person initially, although multiple attachments often form soon after words.

According to John Bowlby (who was influenced by the work of Lorenz and other ethologists), attachment formation in humans would also have survival values and natural selection could act to make this behavior pattern wide spread in the species.

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## 5.2 Review questions

1. The central nervous system comprises:
   a. the brain and spinal cord
   b. the brain and cranial nerves
   c. the spinal cord and spinal nerves
   d. the cranial nerves and spinal nerves
2. Reflex actions:
   a. are automatic
   b. always produce the same response to the same stimulus
   c. are actioned by reflex arcs of neurons
   d. all of the above
3. Which of the following statement about instinctive actions is not true:
   a. are innate
   b. are adaptive
   c. require some learning
   d. can sometimes be modified by experience
4. Instinctive behavior always:
   a. Require a key stimulus
   b. Show a fixed action pattern response
   c. Have an innate releasing mechanism
   d. All of the above
5. Example of circannual rhythms include:
   a. Hibernation
   b. Migration
   c. Reproduction in short day breeding animals
   d. All of the above

## 5.3. learned behavior

**Learned behavior** Is a behavior that is acquired through experience (such as trial and error) or by insight. It is the formation of new responses to existing stimuli through practice or reputation.

Most biologists would now define learning as *"the strengthening of existing responses or the formation of new responses to existing stimuli that occurs because of practice or repetition."*

Unlike innate behavior, learned behavior patterns are rarely fully functional the first time they are performed. At the very simplest level of learning, trial and error brings about an improvement in the effectiveness of the behavior pattern.

Table; 5.1. Differences between innate and learned behaviors

| Innate behavior | Learned behavior |
|---|---|
| Genetically determined and common to all members of species | The behavior is changed by or develops through, experience and may vary from individual to individual, experience and may vary from individual to individual |
| Behavior is fully functional at the first attempt | The animal develops the behavior through trial and error or by insight |
| There is, generally, no modification of the behavior | The behavior may be modified by new experiences |
| Adaptive behavior that has been retained as a result of natural selection | Behavior is learned in a different way by each member of the species and may not be adaptive |

There are many different kinds of learned behavior, including:

- Habituation
- Sensitization
- Insight learning
- Associative learning
  - ✓ Classical conditioning
  - ✓ Latent learning

➢ **Habituation:** - is a process which results in decreased responses to a stimulus after repeated exposure to that stimulus over a period of time.

- ✓ It is the fall or elimination of responses to frequently occurring stimuli that have no effect on the animals well being.
- ✓ It occurs when stimulus is harmless.

Habituation, in which a response to a stimulus becomes weaker as the stimulus is repeated more and more often. i.e.: learned behavior in which the response to a stimulus decreases with a repeated exposure.

> **Example**; we all have experiences noticing a quite strong smell on entering a room, but sometimes later we don't even notice that. There is any odour present.
> In this example, your sense of smell has demonstrated habituation. You have stopped responding to the odour even though it is still present.

*Ethologists* often rely on habituation in order to carry out their research effectively. After some times of being among the animals they are investigating, the animals become "habituated" to them and largely ignore them. The ethologist can then carry out their research assuming normal behavior by the animals.

- **Sensitization**: - is a period of high response to harmless stimuli.
  It is an increase in response occurring after harmful stimulus when a stimulus occurs after a harmful stimulus. i.e. there is an increase in response to a harmless stimulus, when that stimulus occur after a harmful stimulus.

  The strength and duration of the sensitized response depend on the extent of the initial sensitization.
  In higher animals, peripheral sensitization refers to sensitization those results from changes in neurons of the PNS.
  Central sensitization refers to the same process occurring in neurons of the CNS.
- **Associative learning:** - after some repetition of stimuli followed by the same sequence, a long term association is built up between the event and it result. This type of learning is called associative learning.
- **Classical conditioning**: - in classical conditioning a naturally occurring stimulus becomes associated with different stimulus, which now produces the same response. It was discovered by the Russian physiology *Ivan Pavlov*, who worked with dogs to develop this theory. The various stimuli and responses are:
  **The unconditional stimuli (US)**:- this "unconditionally" naturally and automatically triggers a response. For example, when you smell a favorite food, you immediately feel very hungry. The smell of the food is the unconditioned stimulus.
  **The unconditioned response (UR)**: -is the unlearned response that occurs naturally to the unconditioned stimulus. In the "feeling hungry" example, feeling hungry is the unconditioned response.
  **The conditioned stimuli (CS)**: - this natural stimulus does not initially produce the un conditioned response. But, after association with the unconditioned stimulus, it triggers the same response.

**The conditioned response (CR)**: - the conditioned response is the response to that previously neutral stimulus (which is the same as the unconditioned response to the unconditioned stimulus).

If the pairing of conditioned stimulus with the unconditioned stimulus is not maintained, then the conditioned response diminishes and eventually is lost this is called **extinction**.

**Extinction** is the decreasing or dying out of a behavioral response created by conditioning, because of a lack of reinforcement.

Extinction – the eventual loss of the conditioned response when the CS is not again associated with the US any longer.

The CS is a signal to the animal that US is about to appear.

Benefit to man and animals;

- Has an adaptive function. That is, it helps to prepare animals for important events.
- The CS must always come first before the US.
- If the CS is not followed by the US there will be a loss of response(extinction)

## What is Operant conditioning?

In operant conditioning the animal takes an action (operates) to gain a reward or to avoid punishment.

When behaviors have favorable consequences, the probability that the act will be repeated is increased.

A behavior is strengthened or weakened as the result of the consequences (operants) of the behavior. Reward will strengthen/ reinforce behavior and punishment will weaken or extinct the behavior.

Operant conditioning can modify more complex, voluntary behaviors by the animal/ person learning to associate the behavior with certain specific consequences. It modifies behavior through reinforcement or punishment.

The term operant conditioning was first used by B.F. Skinner, a behaviorist psychologist who carried out a great deal of pioneering research in this area.

Reinforcement→ increased

Behavior → consequences→ likely hood of repetition

Punishment→ decreased

Skinner identified three types of responses that he called operants that can follow behavior

- **Neutral operants-** responses from the environment that neither increases nor decreases the probability of a behavior being repeated.
- **Reinforcers-** responses from the environment that increase the probability of behavior being repeated. Reinforcers can be either positive or negative.
- **Punishers-** responses from the environment that decreases the likelihood of a behavior being repeated.

Skinner carried out much of his research on rats and other animals using the Skinner box.

Animal trainers use a technique called shaping, which is based on operant conditioning, to train animals to perform in specific ways.

Animals can be thought new things and sometime a very complex act in order to receive a reward.

Specific examples where shaping is used include;-

- Training guide dogs for the blind
- Training horses to show different acts
- Training dolphins and killer whales at marine parks
- Training zoo animals

Both classical and operant conditionings are sometimes referred to as **associative learning** because the animals learn to modify their behavior as a result of either associating particular behavior patterns with operant responses.

## What is latent learning?

The word “latent” means “hidden”-so we are talking about hidden learning or learning that is not apparent as it takes place. Latent learning happens when the brain acquires knowledge at a certain time without reinforcement, but does not use it until later, at a time when that knowledge is needed.

It could be defined as the association of stimuli or situations without reward. There are situations in which animals learn without any obvious reward. For example, if a rat that is neither hungry nor thirsty is placed in a maze that holds no reward, the rat will still investigate the path. Having been permitted to explore the maze, the rat will run the maze in fewer trials than inexperienced rats when food is finally offered as reinforcement. This shows that the rat learned some of the characteristics of the maze during its unrewarded exploration even though the knowledge was not put into immediate use i.e. it was latent.

**Example- 2.** One teacher drives another to school every day. Then one day the driver is ill. The other teacher drives himself to school without getting lost. He learned the route to the school without reinforcement but never had to use it until the usual driver was ill. This is an example of latent learning.

## What is insight learning?

Insight learning involves finding solution to problems that are **not** based on actual experience (as with trial and error) but on trials occurring mentally.

Insight learning is most *prevalent in the higher primate* particularly human beings. Insight is the ability to respond correctly the first time to a situation different from any previously encountered experience.

Through insight an animal is able *to adapt to new situation* due to prior learning experience in other situations and in effect solve the new problem mentally without the necessity of trial and error.

One might have puzzled over a problem for several days or weeks and suddenly the answer flashes into your mind. This is called insight learning.

It is characterized by its *suddenness*. It seems to occur so quickly to be the result of a trial and error process. Much of the pioneering research on insight learning was carried out by *Wolfgang Kohler* working with chimpanzee (particularly called *sultan*).

**Example 1.** A hungry chimpanzee released in a room with various boxes scattered around the floor and a bunch of bananas hanging from the ceiling above his reach. The chimpanzee will often survey the situation for a short time and then begin gathering the boxes and pilling them on top of each other under the bunch of bananas. He can then climbs on top of the boxes and reach the bananas.

**Example 2**. A chimpanzee choosing a long stick over a short one to retrieve food from outside a cage.

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## 5.3. Review questions

1. Which of the following statements about learned behavior is not true?
   a. Fully functional the first time it is performed
   b. Acquired anew by each member of the species
   c. Modified by experience
   d. Developed by trial and error or insight
2. In Pavlov's experiment on the classical conditioning of dogs, the ringing of the bell represents:
   a. The conditioned stimulus
   b. The conditioned response
   c. The unconditioned response
   d. The unconditioned stimulus
3. Which of the following are not examples of learned behavior?
   a. Classical conditioning
   b. Operant learning
   c. Innate behavior
   d. Insight learning
4. Insight learning involves;
   a. Trial and error
   b. Innate behavior
   c. Operant conditioning
   d. None of the above
5. Latent learning is different from learning through operant conditioning because it:
   a. is a kind of innate behavior
   b. does not require any input from the environment
   c. does not require reinforcement
   d. is a kind of insight learning

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## 5.4. Examples of behavior patterns

- Courtship behavior
- Territorial behavior
- Social behavior

### 1. Courtship behavior

**Courtship behavior;-**Is an activity that precedes and result in mating and reproduction. It allows members of a species to recognized each other and prevent or reduces attempts at interbreeding between different species.

Courtship may involve a *few chemical, visual, auditory stimuli* or it may be a complex series of act by two or more individuals using several methods of communication.

Elaborate courtship rituals can also help to strengthen already established pair bonds. These may last through the time it takes to rear the young and in some cases even longer. Methods of communication that are used to attract mates include;

- Secretion of *sex pheromones*- this is used by some female insects to attract males from a distance.
  **Pheromones;-** are chemicals secreted by one animal, usually the female, to produce a behavioral response in another.
- The use of *touch* by painted turtles.
- The *courtship songs of frogs* heard on spring nights (courtship vocalizations).
- The *songs of humpback whale* under the sea which can be heard hundreds of miles away.

In most animals courtship behavior is innate and consists of a preprogrammed set of FAP in response to a key stimulus. Despite being innate, the FAPs are often complex behaviors with the FAP in one animal serving as a stimulus for another FAP in the other animal. This interaction of FAP continues until courtship is successful.

Note that there are many different pheromones including;

- **Alarm pheromones** that are secreted by animals when attacked and produce the response of flight or aggression by others of the same species.
- **Releaser pheromones** that are volatile and can attract a mate from a distance two miles or more.
- **Territorial pheromones** that are used to mark the boundaries of a territory by the owner; dog urine contains a power full territorial pheromone.
- **Sex pheromones** that signal the availability of a female for mating.

## 1. Territorial behavior

**Territory** is an area that an animas reserves for itself so as to exclude other members of the same species. It is any space that an animal defends against intruders of the same species.

Territorial behavior is any behavior that is used to defend an area that gives access to;

- Good foraging
- Increased mating chances
- A den (the hidden home of certain wild animals) or similar mating site
- Reduce vulnerability to predators

Territorial behavior is found in nearly every species of animals. Even humans possessing territory gives the holder areas to forage for food and so increase the chances of attracting a mate. Animals that do not have a territory of their own may contest with the owner for a territory that is already occupied. Such contests are called **conspecific** (same species) **conflict**.

Conspecific conflicts usually involve ritualistic displays and rarely involve fighting. Territorial animals usually defend areas that contain one or more of;

- ✓ a nest,
- ✓ a den or mating site,
- ✓ Sufficient food for themselves and their young..

**Ritual fighting**- is fighting behavior in which the act of fighting are displayed without any physical contact.

Males are usually the territorial sex. But in some species (fiddler crabs) females maintain a territory also.

Residents of a territory are difficult to dislodge as they are often older and more experienced.

Defense treat displace may be;

- ✓ visual (color of feathers or fur),
- ✓ auditory (bird's song) or
- ✓ Olfactory (deposition of scent marks).

The resident animal usually holds on to his/her territory only by expending considerable time and effort in its defense.

**Example;-**Sunbirds can use up to 13,000 kilo joules per hour patrolling and defending their territory. This is more than the recommended daily energy intake for an average adult human male.

The Ethiopian wolf (*Canis simensis)* is a social animal. The wolves leave and hunt in packs as a result they maintain a group territory by marking with urine containing pheromones.

## Defending territories

Some animals defend their territory by fighting those who try to invade it. But, this is the exception rather than the rule. Fighting uses up a large amount of energy and can result injury or death. So fighting is the "last resort". Marking a territory usually "warns off" intruders. Animals that do not mark territories use treats from one or more of vocalization, smells and visual displays.

**Example**, the songs of birds and the loud calls of monkeys are warnings to intruders.

**1.**  **2.** 

Figure -1. a younger male zebra challenges the older resident male.

Figure -2. a male robin threathing an intruder by using vocalization and by exaggerating.

## 2. Social behavior

Social behavior *is the set of interactions that occur between one or more individuals of the same species that modify the behavior of individuals of the same species in a way that is usually beneficial to the group as a whole.*

It has survival value to the species as the whole. It is found in wide variety of animals including some invertebrates, fishes, birds, and mammals.

**Benefits of social behavior-** It allows animals to;

- Form stable groups in which intra specific aggressions is reduced. Some times as a result of hierarchies being established.
- Improves the effectiveness of reproduction and or parenting through court ship behavior and pair bond formation.
- Forage more efficiently especially if food sources are localized.

- Protect them against attack more effectively. For example, baboons cooperate to fight off a leopard which will be extremely difficult for a single baboon.
  Example -2. Fish and birds moving in groups are more difficult for a predator to attack
- Increase the chance of surviving extreme conditions. **Example**;-Some birds such as penguins huddle together in very cold weathers to reduce the overall surface area to volume ratio and can reduce heat loss by up to 50%.
- Communicate across long distance.

## Social behavior in bees

Honey bees and bumble bees and other species of insect exhibit ***eusociality.*** *eusociality* has three main features;-

- there is cooperation in caring for the offspring; as a consequences, many individuals are caring for offspring that are not their own.
- there are usually several generations in the colony so that it will sustain for longer and allow offspring to assist parents, and
- there is divisions of labour- not every individual in the group is reproductively active; in the case of bees, for example, the queen is the only reproductively active females with the male drones also being active, the female worker bees are more or less sterile.

**Honey bees** nest in large cavities such as a hollowed out trees or other enclosed spaces. They also use man made beehives. Honey bees build vertical sheets of hexagonal honeycomb from wax secreted by glands in their abdomens in which they store honey and pollen. An individual hexagon (cell) can be used as a home for a single developing bee larva.

There are 3 different casts of bees in a nest;

- **the queen**- the only truly reproductively active female (first caste).
  Responsible for laying all the eggs.
- **workers**- non reproductively active females (second cases)
  Take care of larva, build and cleans nest and forage .
- **drones**- reproductively active males ( third caste)
  Leave the nest to mate then die.

The queen secretes powerful pheromones within the nest that control the behavior of the workers at different stages of their development. She may also make aggressive attacks on maturing worker bees.

If the queen does not produce these pheromones or if she produces too few eggs, then the structure of the nest breaks down. She may be attacked by mature workers, one of whom will replace her.

A honey bee colony may last for several years, with the male drones being driven out of the nest over winter to preserve resources for the workers and the queen. At the end of the colon y cycle

the queen, the drones and most workers will die, leaving just a few large workers who will assume the status of queens and the following spring fly away to establish their own colonies.

## The role of worker bees at different stages of development

- A newly emerged worker acts as a **nurse,** feeding and caring for the eggs and larva and cleans out dirty honey comb.
- After a few days it becomes a **builder**, making new wax cells for the eggs and larva to develop in, and receives food from incoming foragers.
- After about 2 weeks it becomes a **soldier** and acts as a guard to the hive, keeping out strange and unwanted bees from other hives and also from invading pests. It also removes corpses.
- After about 3 weeks the worker bees finally become **food gatherer** and goes off in search of nectar pollen and water for the hive. A worker bee dies at 5-7 weeks

## Communication in worker bees

Worker bees communicate with each other in a very special way to convey information about the source of nectar (food). They do this not by sound or speech but by *special dances* on the upright walls of the honey comb.

**Example;** If a worker discovers food nearer than about one hundred meters, she will do a "**round dance".** If the food is more than about 100 meters away, the worker will do a tail-wagging dance **(wag-dance).** This type of dance is used to inform other workers about that *direction and distance* of the food source.

The dance takes the form of a "figure eight" on the vertical face of the honey comb. If the food is directly between the hive and the sun the bees will do a vertical dance on the honey comb.

Information about the nectar is conveyed in two ways;

- The angle of dance away from the vertical corresponds with the angle of the nectar from the sun.
- The length of the straight-run of the dance is proportional to the distance from the nest.

If the food is on the other side of the hive but still in line with sun the bees will reverse the direction of the central waggle. A tail wagging dance lines at angle to the vertical means that the food is at angle between the hive and the sun.

These dances are inborn and instinctive.

There are various modifications of the tail wagging (the wag-dance).

Recent research shows that the foraging bees also used **sound** to inform other bees about the distance of the source and perhaps to help to **recruit** these other workers. The time for which they produce their sounds is directly correlated with the distance to the nectar source.

## Review question

1. Which of the following statements concerning courtship behavior is true?
   a. It precedes and can result in mating behavior
   b. It allows members of a species to recognize each other
   c. It prevents attempts at inbreeding between different species
   d. All of the above
2. Worker bees are:
   a. Sterile males
   b. Fertile male
   c. Fertile female
   d. Sterile females
3. Communication within a honey bee nest take the form of:
   a. Pheromones secreted by the queen
   b. Sound produced by returning foragers
   c. Wag dance
   d. All of the above
4. Which of the following is not true of social behavior? social behavior is likely to:
   a. Reduce the risk of intra-specific aggression
   b. Reduce the danger from predators
   c. Reduce foraging efficiency
   d. Reduce the risk from extreme conditions
5. Which of the following is not a feature of eusociality?
   a. The presence of several generations in the colony
   b. Cooperative foraging
   c. Cooperative caring for the young
   d. Division o labour

**----THE END----**

## Summary questions on unit 5

1. Which one of the following is not true about innate behavior?
   a. can be improved by trial and error
   b. common to all members of the species
   c. present at birth or on the hatching
   d. do not have to be learned
2. To which one of the following classes of stimuli do pheromones belong?
   a. Auditory b. small c. visual d. touch
3. If someone suddenly removes his/her hand from a very hot object, which of the following type of behavior is manifested?
   a. Reflex action b. imprinting c. learned behavior d. insight learning
4. Which of the following is responsible for the bending of a young plant towards a unidirectional source of light?
   a. Reduce photosynthesis on dark side
   b. Faster growth rate on darker side
   c. Reduce auxin concentration on dark side
   d. Increased rate of cell division on light
5. Which of the following is learned behavior?
   a. Suckling of the new born at mother's breast
   b. Salivation by conditioned dogs at the sound of a bell
   c. Withdrawal of hands suddenly form hot object
   d. Blinking of the eyes when something get in to them
6. Which of the following behavioral biologist is known for his study about imprinting behavior in animals?
   a. W. Kohler b. B .F. Skinner c. Ivan Pavlov d. Konrad Lorenz
7. Baby ostrich tend to follow the first moving object that they see as they hatch out of the egg. What kind of animal behavior does this demonstrate?
   a. Positive taxis c. positive kinesis
   b. Innate behavior d. learned behavior
8. Which type of animal behavior happens without learning?
   a. Innate b. latent c. insight d. conditioned
9. A reflex action that involves internal organ such as the heart in referred to as----------.
   a. somatic reflex c. spinal cord reflex
   b. external reflex d. autonomic reflex
10. Which of the following organs serves as a coordinating system in a reflex action?
    a. Spinal cord b. sense organ c. nerve cell d. muscle
11. Which one of the following is not grouped under genetically pre programmed patterns of behavior?
    a. Reflex action in human c. conditioned behavior
    b. Orientation behavior d. instinctive behavior
12. If actively growing potted seedling is kept horizontally, which of the following would eventually happen to the seedling?
    a. The shoot would bend upward
    b. The root would bend upward
    c. The seeding would stop growing

**d.** The seeding would grow horizontally

13. In which of the following way does learned behavior differ from innate behavior?
    a. Adaptive in nature
    b. Genetically determined
    c. Modified by new experiences
    d. Functional at the first attempt
14. Which of the following forms of learning is mainly used in shaping animal behavior?
    a. Classical conditioning
    b. Latent learning
    c. Operant conditioning
    d. Insight learning
15. Which one of the following about biological clocks is **not** true?
    a. Control circadian rhythm
    b. Are the result of divergent evolution
    c. Control circannual rhythm
    d. All
16. If a chimpanzee piles up boxes, and climbs on it to reach a bunch of banana hanging from a ceiling, which behavior is manifested?
    a. Operant conditioning
    b. Trial and error
    c. Latent learning
    d. Insight learning
17. Which animal behavior pattern is best illustrated by the famous Pavlov's dog?
    a. Habituation b. latent learning c. associative learning d. instinctive behavior
18. "Skinner box" is used for experiments in ;-
    a. Classical conditioning c. migration
    b. taxis d. operant conditioning
19. what is the survival value of a social behavior in which some birds move in large group?
    a. protection of territory
    b. displaying court ship activity
    c. technique for trapping prey
    d. protection from predators
20. One of the following is **not** true about operant conditioning?
    a. It is concerned with learnt behavior
    b. It is based on reward and punishment
    c. It is based on innate behavior
    d. It is based on consequence of actions
21. Which of the following do bees use to inform other bees about the location and distance of source of nectar they discover?
    a. Pheromones c. Waggle dance
    b. Buzzing noise d. Vibration of wings

22. Which one of the following is not classified as learned behavior?
    a. Insight  b. innate  c. latent  d. conditioned
23. The fissile hominid *Lucy* belongs to the genus;
    *a. Afarensis  b. Homo  c. Australopeithicus  d. Ardipithecus*
24. What do we call the learned behavior if a mouse that have just escaped from the mouth of a cat jumped violently at a slight touch by trivial object?
    a. Latent learning
    b. Sensitization
    c. Conditioning
    d. Imprinting
25. Which of the following is the correct route that connects a stimulus and a response?
    a. Receptor- coordinator- effector  c. receptor-effector- coordinator
    b. Coordinator –receptor –effector  d. effetor – receptor – coordinator
26. To what kind of animal behavior can the spinning of a web by a spider be classified?
    a. Learned behavior
    b. Experimental behavior
    c. Instinctive behavior
    d. Accidental behavior
27. Which group of the Ethiopian wolves contributes mainly to territory marking with their urine containing pheromones?
    a. The adult male and female
    b. The adult male and young female
    c. The young male and adult females
    d. Sub adult male female
28. Which one of the following types of pheromones are used to mark the boundary of territory by the owner dog urine?
    a. Sex pheromones
    b. Releaser pheromones
    c. Territorial pheromones
    d. Alarm pheromones
29. Possessing a territory give the holder?
    a. Access to good foraging
    b. Access to increase mating chance
    c. Reduced vulnerability to predators
    d. All
30. Suppose when you first enter a room you notice unpleasant smell which you eventually forget about it presence, what is this behavior called?
    a. Latent learning
    b. Insight learning

c. Habituation
d. Operant conditioning

31. What does an ethologist study?
    a. Insect diets  c. fossil fuel
    b. Soil type  d. animal behavior
32. Which hormones promote human sleep fullness in darkness and controls sleep-wake cycle?
    a. Insulin  c. melatonin
    b. adrenaline  d. thyroxin
33. Which one of the following is an example of an orentational innate behavior?
    a. kinesis in woodlice  c. sudden withdrawal of limb from hot object
    b. blinking of the eyes  d. nest building by weaver bird
34. In Pavlov's experiment on the classical conditioning of dogs, what does the reaction of the dog to the sound of bell represent?
    a. the conditioned stimulus
    b. the conditioned response
    c. reproductive functions
    d. the unconditioned stimuli
35. Behavior that is repeated on a daily basis is referred to as;-----
    a. lunar  b. circadian  c. circannual  d. seasonal
36. In which of activity of the honey bee colony are worker bees involved?
    a. laying eggs
    b. serving a queen
    c. reproductive functions
    d. taking care of larva

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## ANSWER KEY ON UNIT 5 REVIEW QUESTIONS

| No | 5.1 | 5.2 | 5.3 | 5.4 |
|---|---|---|---|---|
| 1 | D | A | A | D |
| 2 | C | D | A | D |
| 3 | D | C | C | D |
| 4 | C | D | D | C |
| 5 | D | D | C | B |

ANSWER KEY ON UNIT 5 SUMMARY QUESTIONS

| | | | |
|---|---|---|---|
| 1. B | 11. C | 21. C | 31. D |
| 2. B | 12. A | 22. B | 32. C |
| 3. A | 13. C | 23. C | 33. A |
| 4. B | 14. C | 24. B | 34. B |
| 5. B | 15. B | 25. A | 35. B |
| 6. D | 16. D | 26. C | 36. D |
| 7. B | 17. C | 27. A | |
| 8. A | 18. D | 28. C | |
| 9. D | 19. D | 29. D | |
| 10. A | 20. C | 30. C | |

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**----------THE END----------**