GCE AL I BIOLOGY I UNIT 1 & 2

CHEMICAL AND CELLULAR BASIS OF LIFE

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UNIT 1

1.1.1. SCOPE AND IMPORTANCE OF BIOLOGY

1. SCOPE OF BIOLOGY

1. Biology is the **natural science** that studies **life** and **living organisms** on earth and may be beyond in the future.
2. It includes the study of various **aspects of living organisms** and their **interactions with the non-living components**.
3. Biology has three primary branches
   i. **Botany** (the study of plants)
   ii. **Zoology** (the study of animals)
   iii. **Microbiology** (the study of microorganisms)
4. Some areas of study in these branches:
   i. Cell Biology (studying cells)
   ii. Histology (studying tissues)
   iii. Anatomy (studying about gross structure of the body)
   iv. Physiology (studying function)
   v. Biochemistry (studying biological molecules)
   vi. Genetics (studying inheritance)
   vii. Ecology (studying environment)
5. **Interdisciplinary branches** – the relationship of Biology with other branches of science.
   a. Some common interdisciplinary branches – Biophysics, **Biochemistry**, Biometry and Bioinformatics. Psychology and Sociobiology are interdisciplinary branches involving Biology and Social Sciences.
6. **Applied branches** –use to apply the knowledge gained from different areas to be used for **welfare of man, animals and plants**.
   a. These include branches like **Agriculture, Animal husbandry, Aquaculture** etc.

ISSUES PERTAINING TO BIOLOGY

BIOLOGY

1 Diversity

1. Biodiversity generally refers to the **variety and variability of life on Earth.**
2. There are 8**.7 million eukaryotic species** on our planet give or take 1.3 million.

2 Human Body and how it Functions

1. can gain the knowledge about the **structure of the organs**.
2. organization of the human body and functions of different organ systems and the **relationship** between structure and functions.

3 Plant

1. The **primary producers** in the world.
2. **All the animals depend** directly or indirectly on plants.
3. Therefore understanding plant life is important.
4. As the time human population is increasing we need to increase the **productivity**.
5. Therefore understanding plant function and biology is important to produce **high yielding plants**, disease resistant plants, etc.

4 Natural resources and environment

1. Natural resources are sources of materials and energy found **naturally** which are used
2. These natural resources are **limited** on earth.
3. Due to the increase of growth rate of human population, **overuse** of natural resources is taking place.
4. It causes threat of **depletion** of natural resources.
5. Due to **over exploitation** of natural resources, various environmental problems arise such as; **pollution and Climate change**
6. Knowledge of Biology is useful to bring about **remedies** for the above problems.

5 Sustainable food production

1. Sustainable food production is the production of **sufficient amounts of food** for the human population using environmentally safe methods.
2. The current human population is about **7.5 billion** and

expected to be double in less than 40 years.

3. Therefore, for the **survival of human beings** sustainable food production is necessary.
4. To maintain sustainable food production following methods can be applied, which are based on **knowledge in biology**.
   a. Production of **high yielding** varieties of plants and animals.
   b. Production of **disease resistant** plants and animal varieties.
   c. Improve the **post harvest technological** methods.

6 Diseases and causes

1. To maintain **healthy human body** one should have the knowledge of causes of the diseases and their effects.
2. Some dangerous diseases which exist in current world **are non communicable diseases** such as cancers, heart diseases, diabetes, chronic renal diseases
3. And **communicable diseases** such as dengue, AIDS, etc.
4. Currently scientists are working on **prevention**, remedial measures and cures for such diseases.

7 Legal and ethical issues

1. Knowledge and application of biological concepts is important in solving some **legal issues**
2. such as parentage testing, in **criminal investigations** and to solve immigration disputes.
3. **DNA fingerprinting** is used in above circumstances.

1.1.2. Nature and organization of living world

Diversity of organisms–size, shape, form, habitat

1. Organisms are **diverse** based on **size, shape, form** and **habitats.**

2. Living organisms show a wide **range of variation** in size, shape, form and habitat.
3. Size **Bacteria** 0.25 µm 2 µm to **Giant Red Wood** 100m
4. Shape Organisms are diverse in shape, Ex: **Cylindrical** (earth worm), **streamline shape** (birds, fish)
5. Form **Unicellular** (Amoeba), **multicellular** (any plant or animal)
6. Habitat **Terrestrial** (Rat), **aquatic** (Fish), **arboreal** (Loris), aerial (Birds)

Characteristics of organisms

BIOLOGY

Order and organization

1. From **molecular level to biosphere** there is an **order and organization** in organisms to perform their biological activities efficiently.
2. Lower level components are organized in a methodical pattern in upper level to make it most efficient.e.g: **plant leaf and human eyes.**

Metabolism

1. The sum of **all chemical activities** taking place in an organism is its metabolism.
2. It includes **catabolic reactions and anabolic reactions.**

Growth and development

1. All organisms begin their life as a **single cell.**
2. During growth an irreversible increase in **dry mass occurs,** which is characterized only by the living.
3. **Irreversible changes** that occur during the life span of an organism is development.
4. Growth and development are two **consequent processes** that happen in the life span of organisms.

Irritability and coordination

1. Irritability is the **ability to respond** to stimuli from both internal and external environment.
2. **Movement** of organisms occurs as a result of irritability and coordination.
3. In animals this happens as a result of **coordinated efforts** of nervous, hormonal, muscular and skeletal systems

Adaptation

1. Adaptation is a peculiarity of structure- **anatomy, physiology or behavior**
2. that promotes the likely hood of an **organism's survival** and reproduction in a particular environment.
3. E.g: **Sunken stomata in Xerophytes,** Viviparity in some mangroves, Splayed out foot in camels.

Reproduction

1. Ability to **produce offspring** for continuous existence of species

Heredity & Evolution

1. Organisms have **genes** that **pass from one generation to the next**
2. control specific **physiological, morphological and behavioral** characters of organisms.
3. Ability of organisms to **change over time** as a result of genetic modification – **evolution**

OMG IT'S A RED HERRINGS

Hierarchical levels of organization of living things

Molecules
A molecule is an electrically neutral group of two or more atoms held together by chemical bonds.

Organelle
An **organelle** is a tiny cellular structure that performs specific functions within a cell.

Cells
is the basic structural, functional, and biological unit of all known organisms.

Tissues
it consists of a group of structurally and functionally similar cells

Organs
Organs are the body's recognizable structures (for example, the heart, lungs, liver, eyes, and stomach) that perform specific functions.

organ systems
An organ system is a group of organs that work together as a biological system to perform one or more functions. The 11 organ systems of the body are the **integumentary**, muscular, skeletal, nervous, circulatory, lymphatic, respiratory, endocrine, urinary/excretory, reproductive and digestive.

Organism
In biology, an organism is any individual entity that embodies the properties of life.

Populations
A **population** is the number of living people that live together in the same place.

Communities
an interacting group of various species in a common location.

Ecosystem
a biological community of interacting organisms and their physical environment.

Biosphere
the regions of the surface and atmosphere of the earth or another planet occupied by living organisms.

General Certificate of Education (A/L) Examination
2011 - August
Biology II - Three hours

PART A - Structured Essay

Answer all question on this paper itself
(Each question carries 10 marks)

1. (A) i. What are the major characteristics that distinguish living from non-living?

....

....

....

....

....

General Certificate of Education (A/L) Examination
2009 - August
Biology II - Three hours

PART A - Structured Essay

Answer all question on this paper itself
(Each question carries 10 marks)

1. *(A)* (i) All living organisms show few characteristics which collectively distinguish them from non-living matter. Indicate four such characteristics.

....

....

....

....

(ii) Write down the levels of organization of living matter in the correct order.

....

....

Unit 2

CHEMICAL AND CELLULAR BASIS OF LIFE

LESSON 1 COMPOSITION OF ELEMENTS IN LIVING MATTER

2.1.1 The elemental composition of living organims

1. **MATTER**- Any substance, which take a **space and has a mass**.
2. **ELEMENT** – An element is defined as a **matter**, which **cannot be broken down into simpler forms** by **any non-nuclear chemical reaction**. X
3. There are **118 elements** are known. There are **92 elements** are **naturally** present in the nature.
4. The rest were made in laboratories.
5. Out of the 92 elements around **25 -30 elements** are present in living organism
6. There are **4 basic elements** common in living organism: **carbon,_oxygen, nitrogen and hydrogen**.
7. The percentage of **oxygen** in the mass of living systems is **65 %.**
8. The percentage of **carbon** in the mass of living matter is **18 %**.
9. The percentage of **hydrogen** is **10 %**.
10. The percentage of **nitrogen** is **3 %**
11. The **source of oxygen and hydrogen** for organisms is mostly **water**.
12. Water composition is the most abundant in living thing (**around 70%)**
13. Elements are separated in to **macro elements** and **trace elements**
14. This classification is depending on their abundance in living matter.
15. Macro elements
16. Found **>0.01%** in the dry weight of an organism.
17. **C, H, O, N, P, S, Ca, K, Mg** are found as **macro elements** in ALL ORGANISMS 9-ELEMENTS
18. In some organisms e.g. Human **Na, Fe and Cl** (3) are also found as macro molecules. Human total macro elements – **12**
19. Princess Fiona Made Salt CHON Soup and Catered with Kidney beans.
20. **Plants** major elements
the macronutrients: nitrogen (N), phosphorus(P), potassium (K), cal

cium (Ca), sulfur(S), magnesium (Mg), carbon (C), oxygen(O), hydrogen (H) CHON Mg/Ca/S/P/K

21. **Trace** elements

22. Found less than **0.01%** in dry weight E.g **Si, V, Cr, Co, B, Mn, Zn, Cu, Mo,I,Al etc.**

2.1.2 the physical and chemical properties of water important for life

STRUCTURE OF A WATER MOLECULE

1. Water accounts for about **70%** of a cell's weight.
2. In each water molecule (H2O) the two H atoms are linked to the O atom by **covalent bonds**.
3. The two bonds are highly **polar**.
4. Because the **O is strongly attractive** for electrons.
5. Whereas the **H is only weakly attractive**.
6. Consequently, there is an **unequal distribution** of electrons in a water molecule.
7. **Positive charge on the two H atoms and of negative charge on the O**.
8. When a positively charged region of one water molecule (that is, one of its H atoms) comes close to a negatively charged region (that is, the O) of a second water molecule, the electrical attraction between them can result in a **weak bond called a <u>hydrogen bond</u>.**
9. **Each water molecule** can form **hydrogen bonds** through its two H atoms to two other water molecules.
10. Producing a **network** in which hydrogen bonds are being continually broken and formed.

PROPERTIES

MACROMOLECULES

1. Living cells contain four major types of small organic molecules.
2. The **sugars, the fatty acids, the amino acids, and the nucleotides**.
3. **Large organic compounds** called macromolecules
4. A very large molecule made up of small organic molecules – **monomers**.
5. The monomers may be the **same or slightly different**.
6. Only a **few monomers** can recombine to create macromolecules.
7. Macromolecules are formed by **dehydration reactions**.
8. **Water molecules are removed** from the formation of bonds dehydration reactions..
9. **Macromolecules Composition – 21%**
   a. **Carb – 10%, fat -8%, Pro -55%, Nucleic acid -27%**
10. **Water – 74%**
11. **Ions and small molecules 5%**

Carbohydrates

1. Carbohydrates = sugars and their polymers
2. **Most abundant** biological molecules on earth.
3. Product of **photosynthesis.**
4. Carbohydrates serve as **precursors** to all other biological molecules.
5. Oxidized to yield **energy**
6. Polymers have **structural functions**
7. **derivatives** found in other molecules

Monosaccharides

1. Generally have molecular formulas that are multiples of CH_2O
2. Names of monosaccharides generally end in "ose".
3. Depending on location of carbonyl group, sugars can be ketoses (fructose) or aldoses (glucose).
4. can be of varying length (3-7 carbons long).
5. Hexose sugars are most common.
6. some sugars vary only in spatial arrangements of their parts around an asymmetric carbon (e.g. glucose and galactose)
7. in aqueous solutions most sugars from ring structures
8. Monosaccharides serve as major nutrient source for cells.
9. Their carbon skeletons serve as raw material in the formation of other biological molecules.
10. consists of two monosaccharides joined by a glycosidic linkage
11. 2 glucoses make maltose
12. 1 glucose + 1 galactose = lactose
13. 1 glucose + 1 fructose = sucrose (table sugar)

POLYSACCHARIDES

1. macromolecules consisting of 100's or 1000's of monosaccharides linked together by glycosidic bonds.
2. Starch – Storage polysaccharide of **plants**
3. Water insoluble
4. consists entirely of glucose monomers
5. monomer linked by 1-4 alpha glycosidic linkages
6. amylose = unbranched starch
7. amylopectin = branched starch
8. most animals have enzymes which hydrolyze starch

Glycogen

1. **storage polysaccharide in animals** (liver and muscles)
2. also made of glucose monomers but is more extensively branched than starch
3. Both glycogen and starch polymers have a helical shape resulting from their 1-4 alpha glycosidic bonds.

Cellulose

1. major **STRUCTURAL component of plant cell walls** 2004
2. polymer of **ß- glucose**, but are linked by **1-4 beta glycosidic linkages** (as in cellobiose).
3. This difference gives cellulose **a different shape** and properties than starch and many cellulose molecules held together by **H-bonding** between hydroxyl group of glucose monomers, arranged in units called microfibrils.
4. enzymes that hydrolyze alpha bonds unable to hydrolyze beta bonds
5. very few organisms produce **cellulases,** enzymes that hydrolyze cellulose.

Chitin

1. structural polysaccharide made from glucose with a **nitrogen** containing group.
2. major component of **arthropod exoskeleton** and **fungal cell walls**. 2012
3. Long-chain polymer of **N-acetylglucosamine**, is a derivative of glucose.

Inulins

1. Inulins are a group of naturally occurring polysaccharides produced by many types of **plants** 2015
2. The inulins belong to a class of dietary fibers known as **fructans**.
3. Inulin is a heterogeneous collection of **fructose polymers**.

4. The degree of polymerization of standard inulin ranges from **2 to 60**.

Pectin

1. Water-soluble carbohydrate substances
2. Made of **galactouronic and galactopyranose** (2016)
3. Found in the **cell walls**
4. In the fruits of plants, pectin helps keep the walls of **adjacent cells joined together.**
5. Immature fruits contain the precursor substance **protopectin,** which is converted to **pectin** and becomes more water-soluble as ripening proceeds.
6. At this stage the pectin helps ripening fruits to remain firm and **retain their shape**.

LIPIDS

1. Consist of **C, H and O**
2. 3 important families of lipids are:

1. Triglycerides
2. Phospholipids
3. Steroids

Triglycerides - Includes fats and oils.

1. Large molecules (**not polymers**) constructed from two kinds of molecules
2. **Glycerol** (3 carbon alcohol with 3 OH groups) 2005
3. **Fatty acid** (long hydrocarbon with carboxyl group)
4. **3 fatty acids** joined to glycerol by ester linkage (bond between OH and carboxyl groups).
5. **Number of fatty acids** determines if its a mono-, di-, or triglyceride.
6. Triglycerides **differ** in the types of fatty acids attached. Do not have to be the same.
7. Saturated fats = hydrocarbon chains contain **maximum** number of bonded hydrogen atoms (i.e. **no double bonds**).
8. Usually **solid** at room temperature.
9. Unsaturated fats = one or more **double bonds** present in carbon skeleton.
10. Double bonds introduce **kinks** in hydrophobic tail and so these molecules do not **pack** as well and are usually **liquid at RT.**

Phospholipids

1. have only 2 fatty acids
2. Third OH group of glycerol bonded to a phosphate group
3. Phospholipids in water spontaneously assemble into micelles and phospholipid bilayers (and liposomes).
4. In these structures, the nonpolar, hydrophobic tails are tucked away from contact with water, and the polar, hydrophilic heads of the phospholipids are facing the aqueous environment.
5. Cell membranes are made of phospholipids and are also bilayers.

Steroids

1. Characterized by carbon skeleton consisting of 4 interconnected rings
2. Cholesterol is a precursor of all steroid hormones (e.g. sex hormones).
3. present in cell membranes

Biological importance

1. Structure and shape cell membrane /body
2. Energy
3. Sex hormones
4. Insulation
5. Protection of internal organ

Proteins

Functions

i. **H**ormones - insulin
ii. **A**nti-body (defense) immunity
iii. **M**ovements cytoskeleton
iv. **S**torage albumin
v. **T**ransport membrane proteins
vi. **E**nzymes amylase
vii. **R**eceptor - regulation

HAMSTER

1. Each protein has a unique **3-D** conformation and therefore often a unique function.
2. Proteins are polymers formed by monomers called **amino acids**
3. Amino acids consist of an **asymmetric carbon** bonded to 4 different covalent partners (2003)
4. Different amino acids differ in their **R-group**.
5. R-group determines **physical and chemical characteristics** of a particular amino acid.
6. R-groups can be **nonpolar, polar, or electrically charged** (i.e. ionic).
7. Amino acids can be covalently linked through **condensation** reactions to form polymers.
8. This covalent linkage is called a peptide bond.
9. All polypeptide chains have a polarity: **N-terminus and carboxy-terminus**.

Levels of protein structure

When cells make a polypeptide, the chain folds spontaneously to assume the functional conformation of that protein.

Primary structure

Order of amino acids along a chain

Secondary structure

alpha helix: coil held together by H-bonding between every 4 a.a.

pleated sheet: chain folds back in parallel or antiparallel orientation, and H-bonds between parallel regions hold structure together.

Tertiary structure

Overall 3-D shape of protein

H-bonds, ionic interactions, Hydrophobic interactions, and disulfide bridges of side chains also involved in stabilizing the tertiary structure.

Heat breaks disulfide bonds. 2007

Quaternary structure

Some proteins consist of two or more polypeptide chains.

Quaternary structure is the overall protein structure that results from the aggregation of these polypeptide units

e.g. collagen = triple helix (3 subunits) **(2011/ collagen is protein). most abundant protein in the body 30% of total protein**

Nucleic acids

1. Nucleic acid polymers (**DNA and RNA**) consist of joining together of monomers called **nucleotides**.
2. DNA consists of 2 chains of nucleotides that spiral an imaginary axis to form a double helix
3. Strands kept together by H-bonding between complementary bases on each strand (A-T, and C-G).
4. All nucleotides composed of
   a. phosphate group
   b. pentose sugar
   c. nitrogenous base
5. Different nucleotides differ in their nitrogenous base.
6. There are two families of nitrogenous base
7. Pirimidines: cytosine (C), thymine (T), uracyl (U)
8. Purines: adenine (A), guanine (G)
9. nucleotides are joined by covalent bonds called phosphodiester linkages, between phosphate of one nucleotide and the sugar of next monomer.
10. DNA backbone is a phosphate.
11. encodes information and protein synthesis

RNA

1. RNA (Ribonucleic Acid) is a polynucleotide, similar to DNA, one of whose roles is protein synthesis. RNA is structurally different from DNA, in thatIt is usually single stranded.
2. It contains the Nitrogenous Base Uracil instead of Thymine.
3. Its Nucleotides contain Ribose sugar, as opposed to Deoxyribose sugar.
4. DNA contains Genes, which code for specific Polypeptide Chains.
5. RNA reads the instructions (Transcription) and assembles the Polypeptide Chain (Translation).
6. During Transcription, the DNA molecule 'opens up', exposing the gene to be read. Free RNA nucleotides, which are complementary using the base paring rules C-G and A-U (since Uracil is similar to Thymine) bond to the exposed bases on the Template Strand.
7. The RNA backbone then forms creating an mRNA (messenger RNA) molecule which is identical to the Coding Stand (opposite to the Template Strand). The mRNA then 'peels away' from the DNA strand.
8. The mRNA strand leaves the nucleus through a nuclear pore and attaches to a Ribosome, which is composed of rRNA (ribosomal RNA).
9. tRNA (Transfer RNA) carries amino acids.
10. When the tRNA carrying the correct amino acid in the sequence collides with the Ribosome, the amino acid joins with the previous amino acid, forming a Peptide Bond.
11. This produces a polypeptide chain, whose Primary Structure is dictated by the sequence of bases in the gene. Primary Structure gives rise to Secondary and Tertiary Structures.

Adenosine Triphosphate (or ATP)

1. The phosphates in this molecule can supply energy to substrates in our cells.
2. Enzymes exist in our cells that can remove a phosphate from ATP and attach it to a different molecule-usually a protein
3. When this happens, we say that the protein has been phosphorylated.

MICROSCOPE

2.2.1 Elaborates on the contribution of microscopes to the expansion of knowledge on cells and cellular organization.

1. Zacharias Janssen -1590s
2. Galileo Galilei soon improved upon the compound microscope design in 1609
3. Dutch scientist Antoine van Leeuwenhoek designed high-powered single lens microscopes in the 1670s.

TWO WORDS

4. **Magnification** is how large the image is compared to real life
5. **Resolution** is defined as the ability to distinguish between two points that are close together

LIGHT MICROSCOPE

1. Very common
2. inexpensive,
3. requires minimal user training
4. and yields good results
5. A number of lenses are used to produce an image
6. Image viewed directly through eyepiece
7. Light passes from bulb under the stage, through condenser lense, then through specimen
8. Beam of light then focused through objective lens, then through eyepiece lens
9. Four different objective lenses (x10, x40, x100) allow for specimen to be viewed at different magnifications
10. Eyepiece lens magnifies image again, usually (x5 and x10)
11. Total magnification is given by multiplying the magnification of the 2 lenses
12. Magnification possible with light microscope: up to 1500x
13. Magnification Up to 1500x in total
14. Resolution 200 nm
15. Limited by the wavelength of visible light
16. Specimen Preparation
17. Staining - Applying a coloured stain to the sample which binds to certain chemicals/structures, improving their visibility
18. Acetic orcein stains DNA dark red
19. Gentian violet stains bacterial cell walls
20. Sectioning - Specimen is embedded in wax to preserve structure of sample cell walls while cutting them into a thin slice
21. To correctly use a light microscope, you also need to calibrate the eye piece graticule using the stage micrometer - this step allows you to measure the size of cells and structures that you are observing.
22. To do this, align the stage micrometer (a microscope slide with a scale on it) with the eye piece graticule, then use the reading from the scales to calculate the calibration factor from the objective lens.

ELECTRON MICROSCOPE

1. A Transmission Electron Microscope (TEM) emits an electron beam through a very thin prepared sample.
2. Electrons penetrate the denser parts of the sample with greater difficulty and this gives the contrast in the 2D image produced.
3. A Scanning Electron Microscope (SEM) emits an electron beam directly onto a sample such that none of the electrons penetrate it. Instead, they bounce off the sample and are received on a sensor, producing a 3D image.
4. Magnification
5. TEM: Up to x 500, 000
6. SEM: Up to x 100, 000
7. Resolution- 0.1 nm
8. 2000 x times more than light microscope
9. Produces detailed images
10. Specimen Preparation
11. Specimen needs to be prepared correctly
12. Fixed to make it firm
13. Dehydrated and embedded in resin
14. Stained using metal salts or metal particles
15. Mounted on a copper grid
16. Placed in a vacuum
17. Staining - Specimens are stained with metal salts or particles
18. This causes electrons to scatter differently, giving contrast
19. Magnification - The degree to which the size of an image is larger than the object itself
20. Resolution - The degree to which it is possible to distinguish between two points on an object that are very close together
21. The higher the resolution, the greater the detail that you can see

2.2.2 Describes the historical background of cell and analyses the structure and functions of the sub cellular units

Cell theory

1. The first man to witness a live cell under a microscope was **Antony van Leeuwenhoek**
2. The cell was discovered by **Robert Hooke in 1665**.
3. Hooke's description of these cells was published in **Micrographia**
4. **Matthias Schleiden** - wrote Contributions to Phytogenesis (**1838**), in which he stated that the different parts of the **plant** organism are composed of cells or derivatives of cells.
5. In **1839 Theodor Schwann** (1810-1882) published a monograph that declared all **animals** and plants are made from one single fundamental unit.
6. In **1858**, **Rudolf Virchow** concluded that all **cells come from pre-existing** cells, thus completing the classical cell theory
7. **Cell Theory** is one of the basic principles of biology.
8. Credit for the formulation of this theory is given to German scientists Theodor Schwann, Matthias Schleiden, and Rudolph Virchow.

9. **The Cell Theory states:**

a. **All living** organisms are composed of cells.
b. The cell is the **basic structural & functional unit of life**.
c. Cells arise from **pre-existing cells**.

10. The cell theory is a widely accepted explanation of the relationship between cells and living things.

THE CELL

1. The **cell membrane** makes the boundary of the cell. There is a basic cell structure that is present in many but not all living cells: the **nucleus**.
2. The nucleus of a cell is a structure in the **cytoplasm** that is surrounded by a membrane (the nuclear membrane)
3. and contains, and protects, most of the cell's DNA.
4. Based on whether they have a nucleus, there are two basic types of cells:

   a. prokaryotic cells and

   b. eukaryotic cells.

PROKARYOTES AND EUKARYOTES

PROKARYOTIC CELL

1. Prokaryotic cells are cells without a **nucleus.**
2. The **DNA** in prokaryotic cells is in the cytoplasm.
3. Prokaryotic cells are **single-celled** organisms, such as bacteria.

EUKARYOTIC CELL

1. Eukaryotic cells are cells that contain a **nucleus.**
2. A typical eukaryotic cell is shown in Figure below.
3. Eukaryotic cells are usually **larger** than prokaryotic cells, and they are found mainly in **multicellular organisms**.
4. Eukaryotic cells also contain other **organelles** besides the nucleus.

The structure and functions of the sub cellular units

CELL WALL

BACTERIA CELL WALL

1. Gram-positive bacteria stain violet by Gram staining due the presence of **peptidoglycan** in their cell wall.
2. Peptidoglycans are attached to negatively-charged lipoteichoic acid monomers important for cell direction and adherence.
3. Lipoteichoic acids are covalently linked to lipids within the cytoplasmic membrane, thus connecting the peptidoglycans to the cell cytoplasm.
4. The outer membrane of Gram-negative bacteria contains **lipopolysaccharides**, proteins, and phospholipids.
5. The lipopolysaccharide component acts as a **virulence factor** and causes disease in animals.

PLANT CELL WALL

1. Made up of **cellulose and pectin**, **hemicellulose, lignin, suberin**.
2. The cell wall is differentiated into **middle lamella**, **primary cell wall, secondary cell wall**
3. Primary cell wall is the **fist cell wall** laid down by the protoplast inner to the middle lamella.
4. The primary wall is thin and elastic and composed of **cellulose**, hemicellulose, pectic substances, lipids, proteins, some miner als and water.
5. Middle lamella is present between **two adjacent cells**
6. This layer is present outside the primary cell wall and is composed of **calcium and magnesium pectate**.
7. It **holds** the adjacent cells together like the cement holds the bricks.
8. Secondary cell wall is formed towards inner side primary wall and is made of several layers of **cellulose, hemicellulose**.
9. Deposition of **lignin and suberin** takes place after the primary wall is fully formed. The wall is thick and nonelastic and provide additional strength.
10. Cell wall has **pits** through which cytoplasm of adjoining cells join through- **plasmodesmata**.

PLASMA MEMBRANE

1. **Outer limit** of protoplasm.
2. Biological Membranes are very small (**7-10nm**). .
3. the **Fluid Mosaic Model** is generally acceptable as describing how membranes are arranged.
4. The Fluid Mosaic Model states that membranes are composed of a **Phospholipid Bilayer** with various **protein molecules** floating around within it.
5. The 'Fluid' part represents how some parts of the membrane can **move** around freely, if they are not attached to other parts of the cell.
6. The 'mosaic' part illustrates the **'patchwork' of proteins** that is found in the Phospholipid Bilayer.
7. Some proteins in the membrane are called '**Intrinsic**'.
8. This means that they **completely span** the Bilayer.
9. Others are called '**Extrinsic**' – they are **partly embedded** in the Bilayer.
10. Other membranes in the cell also have the same structure.
11. the functions of plasma membrane
    a. Boundary of cell.
    b. Osmotic balance within the cell.
    c. Regulates the exit of waste materials
    d. Exchange.
    e. Activities between cells/ identification of cells.
    f. Signal

BOREAS
God of the wind

Nucleus

1. **Double membrane** enclosed organelle found in eukaryotic cell
2. The membrane a nuclear membrane, also known as the **nuclear envelope,** is the lipid bilayer membrane
3. which **surrounds the genetic material** and **nucleolus** in eukaryotic cells
4. It has an **outer membrane**
5. It has an **inner membrane**
6. The **nuclear pore** is a protein-lined channel in the nuclear envelope that regulates the transportation of molecules between the nucleus and the cytoplasm
7. **Neucleoplasm** is one of the types of protoplasm
8. **Nucleolus** is usually is the center of the nucleus .
9. it is composed of protein and nucleic acid. It **synthesized rRNA** and assemble ribosomes.
10. nucleolus disappears when cell divided.
11. Chromosomes - **a thread-like structure** of **nucleic acids and protein** found in the nucleus of most living cells, carrying

genetic information in the form of genes.
12. Stores genetic information of the cell.

Ribosomes

1. They are present in both **eukaryotic and prokaryotic** cell.
2. Has **no membrane** (EXAM2010)
3. Some ribosome attached to the **endoplasmic reticulum** and some float **freely** in the cytoplasm.
4. Ribosome also located in **mitochondria** and **chloroplast** (EXAM2008)
5. Ribosomes are a cell structures that **makes protein**.
6. Consists of a **large and a small sub** unit composed of r-RNA and protein.
7. Prokaryotic ribosomes are **70S** (S FOR SWEDBURG) particle

units with 30S and 50S subunits

8. Eukaryotic ribosomes are **80S** units with 40S and 60S subunits.

Endoplasmic reticulum

1. **SINGLE membrane**
2. Endoplasmic means **within the plasm'** and reticulum means **network**.
3. Network of internal membranes forming flattened or tubular sacs
4. Continuous with the **outer membrane of nuclear envelope**
5. Two types of ER: **Rough ER and Smooth ER**
6. Rough Endoplasmic Reticulum:
    a. The rough endoplasmic reticulum (RER) is dotted with **ribosomes**, thus it is called as rough.
    b. The RER endoplasmic reticulum is especially prominent in cells synthesizing proteins.
7. Smooth Endoplasmic Reticulum:

a. The smooth endoplasmic reticulum (SER) **lacks ribosomes**.

b. The smooth ER is especially abundant in **mammalian liver and gonad cells**

Function of Rough Endoplasmic Reticulum:

c. The prime function of rough endoplasmic reticulum is the **production and processing of specific proteins** at ribosomal sites that are later exported.

d. the proteins are folded into **three dimensional shapes** and carbohydrates are added.

e. One of the functions of rough endoplasmic reticulum include **transportation** of the ready proteins to the sites where they are required.

Function of Smooth Endoplasmic Reticulum:

f. Smooth Endoplasmic Reticulum (SER) is mainly concerned with the synthesis of **carbohydrate and lipids**, and sometimes, with their metabolism.

g. **Steroid hormones** are produced in SER present in the adrenal and endocrine glands.

h. SER also produces **cholesterol** and membrane phospholipids, which are used for membrane formation.

i. One of the most important functions of Smooth Endoplasmic Reticulum (SER) is to **detoxify the body from metabolic wastes and drugs**

j. protein transportation

Golgi complex

1. Stacks of flattened vesicles or Golgi bodies
2. Inner and outer surfaces can be identified
3. found within the cytoplasm of both plant and animal cell.
4. The Golgi composed of stacks of SINGLE membrane bound structure,
5. flattened sacks, called cisternae(singular-cisterna).
6. These are associated with endoplasmic reticulum (ER) and modify products made by ER.
7. These faces are characterized by unique morphology and biochemistry.
8. In mammalian cell typically contains 40-100 stacks
9. This collection of cisternae is broken down into cis medial and trans compartments.
10. In plant cell individuals stack is sometimes called a dictyosome.
11. Each cisternae comprises, a flat membrane enclosed disc that includes special Golgi
12. enzymes which help to modify cargo proteins that travels through it.
13. Number of Golgi stacks correlates with how active the cell is in secreting proteins.

a. major collection and dispatch station of protein products Received from the endoplasmic reticulum.
b. package materials to be transported out if the cell.
c. Lipids and proteins modification
d. creation of lysosomes.
e. secretes mucus

LYSOSOMES

1. SINGLE Membrane bounded vesicles contributing to digestive activity
2. The outer surface is formed by a single membrane, a phospholipid bilayer that can fuse with some other membrane bound organelles.
3. A single Lysosome contains many enzyme molecules.
4. The enzyme contained within Lysosome is known collectively as acid hydrolase and works best in acidic environment,
5. Break down digestion of materials from inside the cell (autophagy).
6. That is by fusing with vacuoles from inside the cell.
7. This could include digesting organelles, so that useful chemicals locked up in their structure which can be reused by the cell.
8. Break down digestion of materials from outside the cell (heterophagy).
9. That is by fusing with vacuoles from outside the cell.
10. This could include breaking down material taken in by phagocytes, which include many type of white blood cells.
11. Recycle the products of biochemical reactions.
12. Those have taken place in the cell by endocytosis.
13. Completely breakdown cells that have died (autolysis).

MICROBODEIS
PEROXISOMES AND GLYOXYSOMES

1. SINGLE membrane
2. Peroxisomes are about the size of lysosomes (0.5 1.5 m) and like them are enclosed by a single membrane.
3. They also resemble lysosomes in being filled with enzymes.
4. In humans, new peroxisomes are formed by the fusion of vesicles released by the endoplasmic reticulum with vesicles released by mitochondria.
5. Once formed, peroxisomes can then increase their number by growth and division.
6. The enzymes and other proteins destined for peroxisomes are synthesized in the cytosol.
7. Some of the functions of the peroxisomes in the human liver:

a. Oxidation of excess fatty acids (Fat to carbo)
b. Breakdown of hydrogen peroxide (H2O2),
c. synthesis of cholesterol.
d. synthesis of bile acids.
e. Participates in the synthesis of the lipids used to make myelin.

8. Glyoxysomes are specialized peroxisomes found in plants

As in all peroxisomes, in glyoxysomes the fatty acids are oxidized to acetyl-CoA by peroxisomal β-oxidation enzymes.
When the fatty acids are oxidized hydrogen peroxide (H_2O_2) is produced as oxygen (O_2) is consumed.
Thus the seeds need oxygen to germinate. Besides peroxisomal functions, glyoxysomes possess additionally the key enzymes of glyoxylate cycle (isocitrate lyase and malate synthase) which accomplish the glyoxylate cycle bypass

Also involved in photorespiration in plants **Details are coming up**

Mitochondria

1. Mitochondria are the powerhouse of cells.
2. Main place of producing ATP.
3. Its length is 3 to 4 micrometer & its diameter is 0.5 to 1 micrometer.
4. Most of the **cellular respiration** takes place in mitochondria.
5. Mitochondria have tow membrane are as follows:
a. (i) Outer Membrane
b. (ii) Inner Membrane
6. There is a space between the inner membrane & outer membrane -inter membrane space.
7. Outer Membrane:- The outer membrane covers the mitochondria.
8. Inner Membrane:- The inner membrane of mitochondria are in folding or fingre like folding- Cristae.
The electron transport system is a series of protein imbedded on the cristae of mitochondria.Cristae:
9. These cristae are important because they make more surface area where chemical reaction can take space.
10. The molecules & some of the enzymes responsible for making ATP are located in & on the folds of these inner membrane.
11. Matrix:
12. a.The area inside the cristae is called the matrix.
13. b.The matrix is a fluid that has water & proteins (enzymes) all mixed together here's where the rest of the enzymes that make ATP come from.
a. The Krebs cycle occurs in the matrix while electron takes place on the cristae. A typical plant cell e.g. palisade cell might contain as many as 50 chloroplasts.

Chloroplasts

1. The chloroplast is made up of 3 types of membrane:
2. A smooth outer membrane which is freely permeable to molecules.
3. A smooth inner membrane which contains many transporters
4. A system of thylakoid membranes
5. Thylakoids
6. The thylakoid membranes enclose a lumen: a system of vesicles (that may all interconnected).
7. At various places within the chloroplast these are stacked in arrays called grana (resembling a
8. stack of coins).
9. Four types of protein assemblies are embedded in the thylakoid membranes:
10. Photosystem I which includes chlorophyll and carotenoid molecules
11. Photosystem II which also contains chlorophyll and carotenoid molecules
12. Cytochromes b and f
13. ATP synthase
14. These carry out the so-called light reactions of photosynthesis.
15. The thylakoid membranes are surrounded by a fluid stroma.
16. The stroma contains: all the enzymes, e.g., RUBISCO, needed to carry out the "dark" reactions
17. of photosynthesis: that is, the conversion of CO_2 into organic molecules like glucose.

CYTOSKELETON

1. Cells contain elaborate arrays of protein fibers that serve such functions as:
   i. establishing cell SHAPE
   ii. providing mechanical STRENGTH
   iii. LOCOMOTION
   iv. chromosome separation in mitosis and meiosis
   v. intracellular TRANSPORT of organelles
2. The cytoskeleton is made up of three kinds of protein filaments:
   i. Actin filaments (also called microfilaments)
   ii. Intermediate filaments
   iii. Microtubules

AMI

3. Actin Filaments
   i. Monomers of the protein actin polymerize to form long, thin fibers.
   ii. These are about 8 nm in diameter and, being the thinnest of the cytoskeletal filaments,

   b. Intermediate Filaments
   i. These cytoplasmic fibers average 10 nm in diameter "intermediate" in size).
   ii. There are several types of intermediate filament, each constructed from one or more proteins characteristic of it.
   iii. keratins are found in epithelial cells and also form hair and nails;
   iv. nuclear lamins form a meshwork that stabilizes the inner membrane of the nuclear envelope;
   v. neurofilaments strengthen the long axons of neurons;
4. Microtubules
   i. Microtubules are straight, hollow cylinders whose wall is made up of a ring of 13 "protofilaments"; have a diameter of about 25 nm;
   ii. are variable in length but can grow 1000 times as long as they are wide;
   iii. are built by the assembly of dimers of alpha tubulin and beta tubulin;
   iv. are found in both animal and plant cells. In plant cells, microtubules are created at many sites scattered through the cell. In animal cells, the microtubules

originate at the centrosome.

CILIA AND FLAGELLA

1. These whip-like appendages extend from the surface of many types of cells.
2. If there are many of them, they are called cilia;
3. if only one, or a few, they are flagella.
4. Flagella also tend to be longer than cilia but are otherwise similar in construction.
5. Function

a. Cilia and flagella move liquid past the surface of the cell.
b. For single cells, such as sperm, this enables them to swim.
c. For cells anchored in a tissue, like the respiratory epithelium
d. This moves liquid over the surface of the cell

6. Structure

a. Both flagella and cilia have a 9 + 2 arrangement of microtubules.
b. This arrangement refers to the 9 fused pairs of microtubules on the outside of a cylinder, and the 2 unfused microtubules in the center.
c. Dynein "arms" attached to the microtubules serve as the molecular motors.
d. The entire assembly is sheathed in a membrane that is an extension of the plasma membrane.
e. *Cilia are short and there are usually many (hundreds) cilia per cell. On the other hand, flagella are longer and there are fewer flagella per cell (usually one to*

eight). Though eukaryotic flagella and motile cilia are structurally identical, the beating pattern of the two organelles can be different

CENTRIOLES

1. The centrioles are cylindrical shaped cellular organelles.
2. They are found in most of the eukaryotic cells.
3. The centrioles are made of groups of microtubules,
4. these microtubules are arranged in a pattern of 9+0.
5. A few groups have since lost their centrioles:
   a. Fungi
   b. Plants (**EXAM 2001**)
6. In higher animal cells the centrioles form the mitotic poles.
7. The centrioles function as the microtubule organizing center,
8. The centrioles may produce flagella or cilia.
9. The Centrosome is located in the cytoplasm usually close to the nucleus.
10. It consists of two centrioles oriented at right angles to each other
11. flagellum. 1-axoneme, 2-cell membrane, 3-IFT (Intraflagellar transport), 4-Basal body, 5-Cross section of flagellum, 6-Triplets of microtubules of **basal body** (**2000EXAM**).

VACULOES

1. Vacuoles are enclosed by a single membrane.
2. Young plant cells often contain many small vacuoles, but as the cells mature, these unite to form a large central vacuole.
3. Vacuoles serve several functions,
   a. storing foods (e.g., proteins in seeds)
   b. storing wastes
   c. storing malic acid in CAM plants
   d. storing various ions (e.g., calcium, sodium, iron) which, among other functions, helps to
   e. Maintain turgor in the cell.
4. Plant cells avoid bursting in hypotonic surroundings by their strong cell walls.
5. These allow the build-up of turgor within the cell.
6. Loss of turgor causes wilting.

Cell junctions

1. Three kinds of junctions occur in vertebrates:
    a. Tight junctions
    b. Adherens junctions
    c. Gap junctions
    d. Plasmodesmata
2. TGAP

3. Tight Junctions

a. Epithelia cells -provide the interface between cells lumen
b. Lumen side is called apical surface.
c. The rest of is the baso-lateral surface.
d. Tight junctions seal adjacent epithelial cells
e. Found just beneath their apical surface.
f. functions:
g. Restrict molecules and ions through the space between cells.
h. They block the movement of integral membrane protein between the apical and basolateral surfaces of the cell.

4. Adherens Junctions

a. Adherens junctions provide strong mechanical attachments between adjacent cells.
b. They hold cardiac muscle cells tightly together as the heart expands and contracts.
c. Adherens junctions are built from a protein called cadherins

5. Gap Junctions

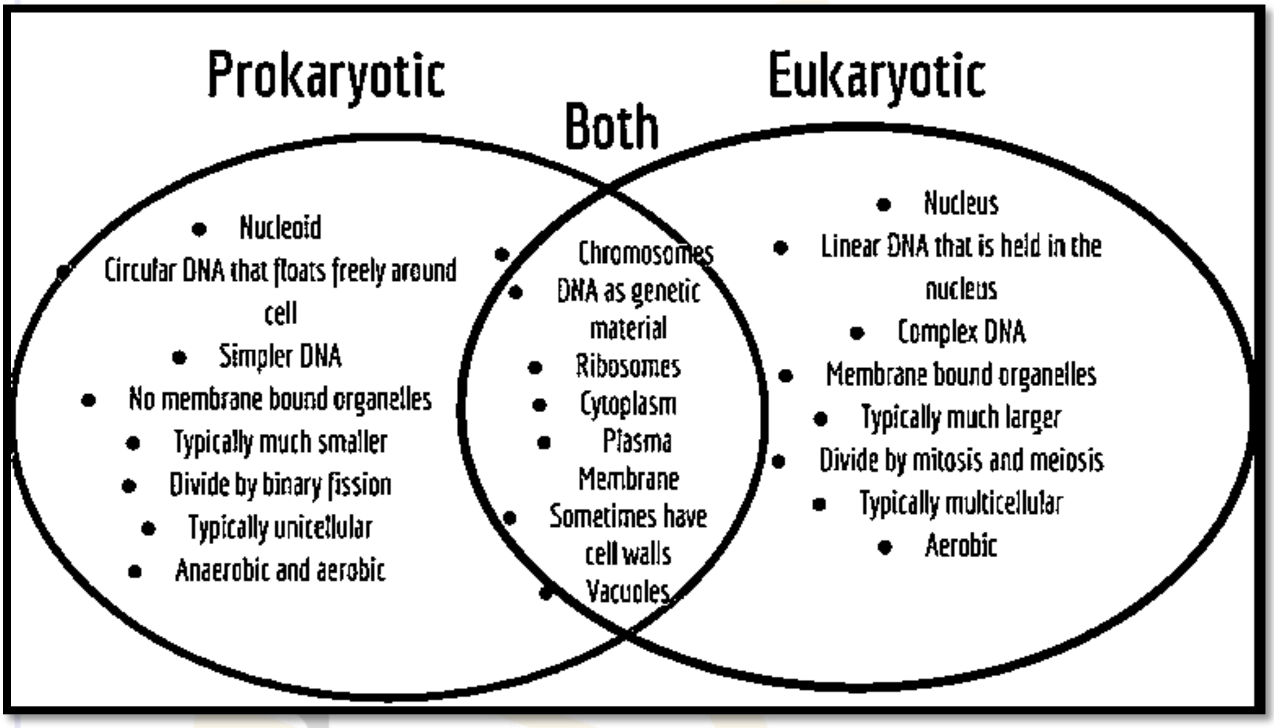
a. Gap junctions are intercellular channels
b. They are some 1.5 2.0 nm in diameter.
c. These permit the free passage between the cells of ions and small
d. They are cylinders constructed from 6 copies of transmembrane proteins called connexins.

6. Plasmodesmata
    a. Although each plant cell is encased in a box like cell wall, it turns out that communication between cells is just as easy, if not easier, than between animal cells.
    b. Fine strands of cytoplasm, called plasmodesmata, extend through pores in the cell wall connecting the cytoplasm of each cell with that of its neighbors.
    c. Plasmodesmata provide an easy route for the movement of ions, small molecules like sugars and amino acids, and even macromolecules like RNA and proteins, between cells.
    d. Plasmodesmata are sheathed by a plasma membrane that is simply an extension of the plasma membrane of the adjoining cells.
    e. This raises the intriguing question of whether a plant

tissue is really made up of separate cells or is, instead, a syncytium: a single, multinucleated cell distributed throughout hundreds of tiny compartments!

PROKARYOTES AND EUKARYOTES

PROKARYOTIC CELL



CELL CYCLE AND CELL DIVISION

The series of events in which a **cell doubles its genome**, synthesizes the **other constituents** of the cell and eventually **divides into two daughter cells** is termed cell cycle.

G1 (Gap1) = growth and new organelles
S = synthesis of DNA
G2 = preparation for cell division
G0 = Cell cycle arrest
Mitosis = nuclear division

1. Interphase

1. Interphase is the stage where a cell is not dividing and a cell spends the vast majority of its time in this stage
2. Chromosomes are elongated and the cell goes about its daily functions
3. Towards the end of interphase the cell organelles and DNA are replicated
4. The DNA is replicated and condenses into duplicated chromosomes which are held together by centromeres

2. Mitosis

Mitosis is nuclear division that leads to the formation of two identical daughter cells

Stages:
Stage 1: Prophase
Stage 2: Prometaphase
Stage 3: Metaphase
Stage 4: Anaphase
Stage 5: Telophase

Stage 1: Prophase
The **nuclear membrane** begins to disappear and **spindle fibres** begin to appear from the centrioles:
very thick and dense chromosomes.
the chromosomes are still enclosed in the cell nucleus within the nuclear envelope.
The chromosomes also contain a centromere, which is necessary in later phases for attachment to microtubules for migration.

Prometaphase
breakdown of the nuclear envelope into small vesicles.
Kinetochores also become fully matured on the centromeres of the chromosomes.
The disruption of the nuclear envelope allows for the mitotic spindles to gain access to the mature kinetochores.

Stage 5: Telophase
The chromosomes at each pole begin to unravel and lengthen; **spindle fibres** disappear; and the nuclear **membranes reform** at each pole:

Cell Division (Cytokinesis)

Cell division occurs immediately after mitosis and involves formation of cleavage furrow (in animals cells) or cell plate (in plant cells) prior to cell splitting

Meiosis:

1. Meiosis is nuclear division whereby four new daughter cells are produced each with half the number of chromosomes as the parent cell
2. As a cell prepares to enter meiosis, each of its chromosomes has duplicated in the synthesis stage (S) of the cell cycle, as in mitosis.
3. Each chromosome thus consists of two sister chromatids.

Meiosis I

At the beginning of meiosis I, a human cell contains 46 chromosomes, or 92 chromatids (the same number as during mitosis).

Meiosis I

The nuclear membrane begins to disappear and spindle fibres begin to appear from the centrioles:

An important difference

Synapsis

1. homologous chromosomes join to form a tetrad (the combination of four chromatids).

Crossing over

2. segments of DNA from one chromatid in pass to another chromatid in the tetrad.
3. They result in a genetically new chromatid.
4. Crossing over is an important driving force of evolution.

STAGES OF PROPHASE I

Prophase I

In most higher organisms, prophase 1 can last several days. During prophase, I chromosomes pair, condense and crossing over occurs between non-sister chromatids. It is separated into 5 different stages. Similar to mitosis, centrioles move to opposite poles and spindle fibres start to form.

Metaphase I

- The replicated chromosomes line up along the equator of the cell held in place by spindle fibres.

Anaphase I

- The spindle fibres begin to contract pulling one chromosome from each pair to each pole.

Telophase I

- The chromosomes at each pole begin to unravel and lengthen; spindle fibres disappear; and the nuclear membranes reform at each pole.

Meiosis II

Prophase II

- The nuclear membrane begins to disappear and spindle fibres begin to appear from the centrioles.

Metaphase II

- The replicated chromosomes line up along the equator of the cell held in place by spindle fibres.

Anaphase II

- The spindle fibres begin to contract pulling one chromosome from each pair to each pole.

Telophase II

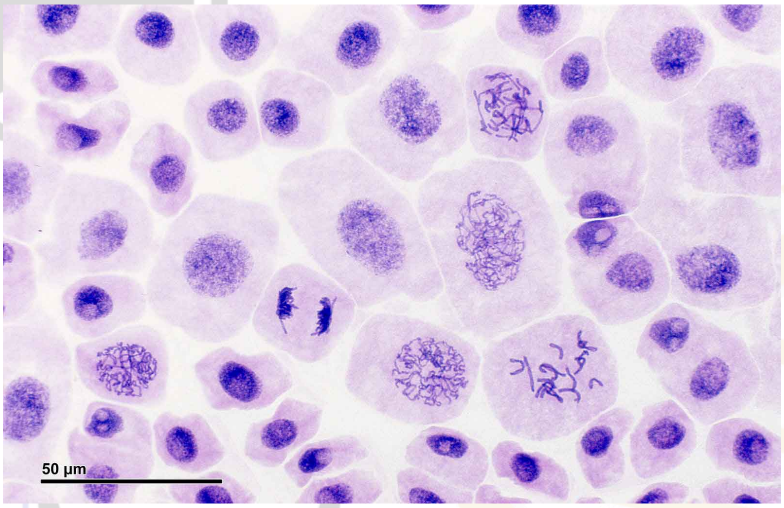
- The chromosomes at each pole begin to unravel and lengthen; spindle fibres disappear; and the nuclear membranes reform at each pole.

The cells that enter meiosis II are the ones made in meiosis I. These cells are haploid—have just one chromosome from each homologue pair—but their chromosomes still consist of two sister chromatids.

1. During meiosis II, each cell containing 46 chromatids yields two cells, each with 23 chromosomes.
2. Each of the four cells is haploid; that is, each cell contains a single set of chromosomes.
3. The 23 chromosomes in the four cells from meiosis are not identical because crossing over has taken place in prophase I.
4. The crossing over yields genetic variation so that each of the four resulting cells from meiosis differs from the other three.
5. Thus, meiosis provides a mechanism for producing variations in

the chromosomes.

6. Also, it accounts for the formation of four haploid cells from a single diploid cell.



Mitosis of onion root tip (2004) **EXAM2000**

Key differences which distinguish the two processes:

1. Division   Mitosis involves only one cell division, but meiosis requires two cell divisions
2. Independent assortment   Homologous pairs are randomly separated into separate cells in meiosis, but not mitosis
3. Synapsis   Homologous pairs form bivalents in meiosis, but not mitosis
4. Crossing over   Non-sister chromatids of homologous pairs may exchange genetic material in meiosis, but not mitosis
5. Outcome   Mitosis results in the formation of two daughter cells, while meiosis produces four daughter cells
6. Ploidy   Daughter cells produced by mitosis are diploid, while daughter cells produced by meiosis are haploid
7. Use   Mitosis is used to clone body cells, while meiosis is used to generate sex cells (gametes)
8. Genetics   Cells produced by mitosis are genetically identical (clones), while cells produced by meiosis are genetically distinct

Mnemonic: **Disco Pug**

•

ENZYMES

1. Enzymes are Biological Catalysts.
2. They **increase** the rate of **Metabolic reactions**.
3. Almost all Biological Reactions involve Enzymes.
4. All enzymes are **Globular Proteins** with a **specific Tertiary Shape**.
5. They are usually **specific** to only one reaction.
6. The part of the Enzyme that acts a **Catalyst** is called the **Active Site**.
7. The rest of the Enzyme is **much larger** and is involved in **maintaining the specific shape** of of the Enzyme.

8. When a reaction involving an Enzyme occurs, a **Substrate** is turned into a **Product**.
9. The Substrate can be one or more molecules.
10. The **Active Site** of an Enzyme is **Complementary** to the Substrate it catalyses.
11. Most **reactions** in a cell require **very high temperatures** to get going, which would **destroy** the cell.
12. Enzymes work by lowering the **Activation Energy** of a reaction.
13. The Activation Energy of a reaction is lowered by putting **stress** on the **bonds** within a molecule, or by **holding molecules close** together.
14. This **increases** the **likelihood** of a reaction, and so **lowers** the **energy** required to begin it.

The Lock-and-key Hypothesis 1894 by Emil Fischer

a. The **Lock-and-key Hypothesis** is a **model** of how Enzymes **catalyse** Substrate reactions.
b. It states that the **shape** of the **Active Sites** of Enzymes are **exactly Complementary** to the **shape** of the Substrate.
c. When a substrate molecule **collides** with an enzyme whose Active Site shape is complementary, the substrate will **fit** into the **Active Site** and an **Enzyme-Substrate Complex** will form.
d. The enzyme will **catalyse** the reaction, and the **products**, together with the enzyme, will form an **Enzyme-Product Complex**.
e. According to this model, it is possible for an enzyme to catalyse a reverse reaction.

The Induced-Fit Hypothesis Daniel Koshland in 1958

f. A more recent model, which is backed up by evidence, and is widely accepted as describing the way enzymes work, is the Induced-Fit Hypothesis.

g. It states that the shape of Active Sites are not exactly Complementary, but change shape in the presence of a specific substrate to become Complementary.

h. When a substrate molecule collides with an enzyme, if its composition is specifically correct, the shape of the enzyme's Active Site will change so that the substrate fits into it and an Enzyme-Substrate Complex can form.

i. The reaction is then catalysed and an Enzyme-Product Complex forms.

Factors affecting enzyme activity

TEMPERATURE

15. temperature – increase in heat leads to increase in random molecular mov't
16. Higher temperature adds stress to bonds
17. rate increases w/ temperature up until optimum temperature
18. proteins denature above the optimum temperature

pH

19. pH – controls balance between positively/negatively charged amino acids
20. ionic interactions hold enzymes together
21. optimum pH – ranges from 6 to 8
22. ionic interactions dependent on hydrogen ion concentration

ENZYME/ SUBSTRATE CONCENTRATION

1. Changing the **Enzyme** and **Substrate concentrations** affect the **rate** of reaction of an enzyme-catalysed reaction. **Controlling** these factors in a **cell** is one way that an organism **regulates** its **enzyme activity** and so its **Metabolism**.

2. Changing the **concentration** of a **substance only** affects the rate of reaction if it is the **limiting factor**: that is, it the **factor** that is **stopping** a reaction from preceding at a **higher rate**.

3. If it is **the limiting factor**, **increasing concentration** will **increase** the **rate** of reaction up to a **point**, after which any **increase** will **not affect** the rate of reaction. This is because it will **no longer** be the **limiting factor** and **another factor** will be **limiting** the **maximum rate** of reaction.

4. As a **reaction proceeds**, the **rate of reaction** will **decrease**, since the **Substrate** will get **used up**. The **highest rate** of reaction, known as the **Initial Reaction Rate** is the **maximum reaction rate** for an **enzyme** in an **experimental situation**.
5. Substrate Concentration

6. **Increasing Substrate Concentration** increases the **rate** of reaction. This is because **more substrate molecules** will be **colliding** with **enzyme molecules**, so **more product** will be formed.

7. However, after a **certain concentration**, any **increase** will have **no effect** on the **rate** of reaction, since Substrate Concentration will **no longer** be the **limiting factor**. The **enzymes** will effectively become **saturated**, and will be working at their **maximum possible rate**.

Enzyme Concentration

1. **Increasing Enzyme Concentration** will **increase** the **rate** of reaction, as **more enzymes** will be **colliding** with **substrate** molecules.
2. However, this too will only have an effect up to a **certain concentration**, where the Enzyme Concentration
3. is **no longer** the **limiting factor**.

INHIBITORS

23. inhibitor - substance that binds to an enzyme and decreases its activity
24. feedback inhibition - end product of biochemical pathway acts as

inhibitor of an earlier reaction on the pathway

25. **competitive inhibitor** – competes with substrates for same active site

26. **noncompetitive inhibitor** – binds to enzyme in a location other than the active site; changes the enzyme's shape so that the substrate won't fit

Enzyme cofactor

27. additional chemical components that assist enzyme function

coenzyme

a. coenzyme – nonprotein organic molecule
b. loosely bound to apoenzyme by non-covalent bond.
c. Examples : vitamins or compound derived from vitamins.

Prosthetic group

d. Prosthetic group The non-protein component,
e. tightly bound to the apoenzyme by covalent bonds is called a Prosthetic group.
f. serves as an electron acceptor and transfers electrons to substrates in another reaction
g. nicotinamide adenine dinucleotide (NAD+) – made of NMP and AMP bonded together
h. AMP acts as core
i. becomes NADH when reduced, can now supply 2 electrons and a proton for other reactions
j. A coenzyme that is very tightly bound and will not be released is called a prosthetic group.
k. Prosthetic groups are non-peptide (non-protein) compounds that mostly attach to proteins and assist them in different ways.
l. They can be inorganic (like metals) or organic (carbon-containing) and bind tightly to their target.
m. Prosthetic groups can bind via covalent (electron-sharing) or non-covalent bonds.

PHOTOSYNTHESIS

1. Begins the carbon cycle by **fixing CO2**
2. It has **2 major parts**:

1. the light reactions and

2. **the "dark" reactions**

3. The equation for photosynthesis is:

a. Energy + 6 CO_2 + 12 H_2O $\rightarrow$ $C_6H_{12}O_6$ + 6 H_2O + 6 O_2

4. Three kingdoms can do: Monera (cyanobacteria) Protista (algae) Plants
5. The light reactions of photosynthesis convert sunlight energy into the potential chemical energy (glucose).
6. The light reactions occur **on thylakoid membranes** in plants
7. Chlorophyll molecules contain an atom of **Mg** (magnesium metal) which loses electrons and becomes oxidized by light.
8. The electrons are accepted by an adjacent electron transport chain.

PHOTOSYSTEM

9. **Photosynthetic pigments, such as chlorophyll a, chlorophyll b, and carotenoids, are light-harvesting molecules found in the thylakoid membranes of chloroplasts.**
10. **When a pigment absorbs a photon, it is raised to an excited state, meaning that one of its electrons is boosted to a higher-energy orbital.**
11. **Most of the pigments in a photosystem act as an energy funnel, passing energy inward to a main reaction center.**
12. There are 2 photosystems:

1. Photosystem I (P700, cyclic)

2. photosystem II (P680 - noncyclic

13. After chlorophyll has lost electrons, enzyme X splits water (photolysis) releasing electrons to reduce chlorophyll.
14. Two H^+ ions made available by photolysis are pumped **into the**

$$2\ H_2O \rightleftharpoons O_2 + 4\ H^+ + 4\ e^-$$

thylakoid lumen.

15. Electrons do not stop until they pass through photosystem I and finally reduce $NADP^+$ to $NADPH_2$.
16. Photosystem I (P700 - cyclic)
17. Photosystem I can act on its own, sending electrons to FD (ferrodoxin) and back to P700 to pump H^+ and make ATP.

PS II REACTION (P680)

1. Pigments absorb light as a source of energy for photosynthesis
2. This creates an e- deficiency in PSII.
3. This deficiency is filled by a molecule called Z protein
4. This enzyme is somehow stimulated by the loss of e- in photo II to split two molecules of water.
5. The e- from this reaction are then released to the waiting e- hungry Photosystem IThis step also releases H^+ in to the thylakoid space helping to create a proton gradient.
6. O_2 is also released in this step.
7. In a process called non-cyclic photophosphorylation (the "standard" form of the light-dependent reactions), electrons are removed from water and passed through PSII and PSI before ending up in NADPH.
8. This process requires light to be absorbed twice, once in each photosystem, and it makes ATP
9. In the process of photosynthesis, the phosphorylation of ADP to form ATP using the energy of sunlight is called **photophosphorylation**.
10. **ATP PRODUCED BUT NOT FROM GLUCOSE | O_2 IS NOT NEEDED | EXAM2014**

PS I REACTION (P700)

1. Light absorption in PSI. The electron arrives at photosystem I and joins the P700 special pair of chlorophylls in the reaction center.
2. When light energy is absorbed by pigments and passed inward to the reaction center
3. the electron in P700 is boosted to a very high energy level and transferred to an acceptor molecule.
4. The special pair's missing electron is replaced by a new electron from PSII (arriving via the electron transport chain).

NADPH formation

1. The high-energy electron travels down a short second leg of the electron transport chain.
2. At the end of the chain, the electron is passed to NADP ++start superscript, plus, end superscript (along with a second electron from the same pathway) to make NADPH

ICPT

The Dark Reactions (Light Independent)

a. They can occur with or without light.
b. They occur in the **stroma of chloroplasts.**
c. The dark reaction requires **ATP and NADPH** -- products of the light reaction.
d. In addition the dark reaction requires CO_2, RuBP (a 5-carbon sugar called ribulose bisphosphate), and rubisco (the most plentiful enzyme on earth.

> The **absorption spectrum** indicates the *wavelengths of light absorbed* by each pigment (e.g. chlorophyll)
>
> The **action spectrum** indicates the *overall rate of photosynthesis* at each wavelength of light

•

DARK CYCLE (CALVIN CYCLE)

1. CO2 combines with ribulose-1,5-bisphosphate (RuBP).
2. Makes 2 times **3-phosphoglyceric acid (3-PGA).**
3. This reaction is catalyzed by the enzyme **RuBP carboxylase/oxygenase, or RUBISCO**
4. 3-PGA makes **1-3 bisphosphoglycerate**
5. 1-3 bis phosphoglycerate makes **glyceraldehyde-3-phosphate**
6. **Glucose is made** from glyceraldehyde-3-phosphate

HILL REACTION (FOR CAMBRIDGE SYLLABUS)

A respiratory process in many higher plants by which they take up oxygen in the light and give out some carbon dioxide, contrary to the general pattern of photosynthesis.

FACTORS AFFECTING PHOTOSYNTHESIS

Light

1. It is one of the major factors affecting photosynthesis.
2. Photosynthesis cannot occur in the dark and the source of light for the plants is sunlight.
3. Three attributes of light are important for photosynthesis:

Carbon Dioxide Concentration

4. The atmosphere contains 0.03% of carbon dioxide amidst other gases.
5. Plants take in carbon dioxide from the air.
6. But, since the amount of CO2 in the air is very less, it acts as a limiting factor for photosynthesis.
7. Experiments have been performed to study the rate of photosynthesis on increasing the concentration of CO2 in the atmosphere.

Temperature

1. It is commonly seen with all biological and biochemical processes that they occur best in a certain optimum range of temperature.
2. This holds true for photosynthesis as well.
3. It is observed that, when CO2 and light are not limiting factors, the rate of photosynthesis increases with increase in temperatures till the optimum level for that plant.
4. Beyond the optimum levels on both sides of the normal range, the enzymes are deactivated or destroyed and photosynthesis stops.

Water

1. Water is considered as one of the most important factors affecting photosynthesis.
2. When there is a reduced water intake or availability, the stomata begin to close to avoid loss of any water during transpiration.
3. With the stomata closing down the CO2 intake also stops which affects photosynthesis.
4. Therefore, the effect of water on photosynthesis is more indirect than direct.

Oxygen

1. Optimum levels of oxygen are favourable for photosynthesis.
2. Oxygen is needed for photorespiration in C3 plants and the by-product of photorespiration is CO2 which is essential for photosynthesis.
3. Also, the energy generated during the oxygen respiration is needed for the process of photosynthesis as well. However, an increase in the oxygen levels beyond the optimum for the plant leads to inhibition of photosynthesis.

This principle states that when a process is governed by more than one factor, the rate of the process is governed by that factor **which is closest to its minimum value.**

C3 PLANTS

1. The first step of the Calvin cycle is the fixation of carbon dioxide by rubisco.
2. Plants that use only this "standard" mechanism of carbon fixation are called C3 plants
3. About 85% percent of the plant species on the planet are C3 plants, including rice, wheat, soybeans and all trees.

C3 PLANTS PHOTORESPIRATION

1. Because **oxygen acts as a competitive inhibitor for Rubisco**, photosynthesis in C3 plants is reduced in the presence of oxygen
2. C3 plants are less efficient in hot and dry regions, as **stomata must remain closed** to prevent excessive water loss
3. When stomata are closed, O2 cannot diffuse out of the leaf, increasing O2 concentration relative to CO2
4. In these hot and arid conditions, other types of plants have evolved to limit the exposure of Rubisco to oxygen

C4 PLANTS

1. C4 and CAM (Crassulacean acid metabolism) plants uses the enzyme **PEP carboxylase** to combine CO2 to a 3C compound (PEP) and make a 4C compound
2. **PEP carboxylase has a higher affinity for CO2** than Rubisco and doesn t bind to oxygen at all.
3. These plants can then transfer the CO2 (stored in the 4C compound) to regions with low oxygen concentrations
4. In the C4 pathway, carbon dioxide is **physically separated from oxygen** in order to improve CO2 binding to Rubisco
5. The CO2 is converted to a 4C compound and then sequestered to a deeper tissue layer where less oxygen is present
6. In this deeper tissue layer, the CO2 is released and can enter the Calvin cycle without competition from oxygen

CAM PATHWAY

1. In the CAM pathway, carbon dioxide reserves are created (temporal isolation) in order to improve CO2 binding to Rubisco
2. CAM plants are adapted to arid environments
3. Water loss is high and stomata must remain closed during the day
4. The CO2 is converted into a 4C compound during the night, when stomata are open and CO2 is able to diffuse into the leaf
5. This allows reserves of CO2 to be created for use during the day, when stomata are closed and O2 cannot be released

ENERGY RELATIONSHIPS IN METABOLIC

1. **Respiration** is the oxidation of **energy-containing organic molecules**.
2. The energy released from this process is used to combine ADP with inorganic phosphate to make **ATP**.
3. Most cells use carbohydrate, usually **glucose**, as their fuel.
4. Respiration may be **aerobic or anaerobic**
5. In aerobic respiration, **oxygen is involved**, and the substrate is oxidised completely, releasing much of the energy that it contains.
6. In anaerobic respiration, **oxygen is not involved**, and the substrate
7. Respiration of glucose has **4 main stages**:

a. **Glycolysis** in the cytoplasm (cytosol) of the cell
b. the **Link reaction** in the matrix of a mitochondrion
c. the **Krebs cycle** in the matrix of a mitochondrion
d. **Oxidative phosphorylation** on the inner mitochondrial membrane.

GLYCOLYSIS

1. Glycolysis (the breakdown of glucose) is the first stage of respiration.
2. It takes place in the **cytoplasm and does not require oxygen.**
3. It begins with the 6-carbon ring-shaped structure of a single glucose molecule and ends with 2 molecules of a 3-carbon sugar called pyruvate and a net gain of 2 ATP.
4. A glucose is phosphorylated, using phosphate from 2 molecules of ATP, to give hexose bisphosphate.
5. This phosphorylation converts an energy-rich but unreactive molecule into one that is much more reactive, the chemical potential energy of which can be trapped more efficiently.
6. The hexose bisphosphate is split into 2 triose phosphate molecules.
   Hydrogen atoms and phosphate groups are removed from the triose phosphate (by the coenzyme NAD).
7. The removal of hydrogens is an oxidation reaction, so triose phosphate is oxidised to 2 molecules of pyruvate (pyruvic acid).
8. During this step, the phosphate groups from the triose phosphates are added to ADP to produce a small yield of ATP.
9. Overall, 2 molecules of ATP are used and 4 are made during glycolysis of one glucose molecule, making a net gain of 2 ATPs per glucose.
10. The pyruvic acid is then converted to either lactic acid or alcohol and carbon dioxide without the production of any more ATP.
11. The pyruvate formed in glycolysis is still energy-rich.
12. It passes next to the link reaction.
13. This reaction and all subsequent stages of respiration occur inside a mitochondrion, and can only occur in the presence of free oxygen.
14. Respiration requiring free oxygen is aerobic respiration.
15. Pyruvate is transported into the mitochondrial matrix by a membrane transport protein, which exchanges it for OH in the matrix.
16. If the cell cannot catabolize the pyruvate molecules further, it will harvest only 2 ATP molecules from 1 molecule of glucose.
17. For example, mature mammalian red blood cells are only capable of glycolysis, which is their sole source of ATP.
18. If glycolysis is interrupted, these cells would eventually die.
19. Since glycolysis occurs in the cytosol and electrons on NADH must be transported to mitochondria, there are different mechanisms for the transport with different efficiency.
20. One mechanism transports 2e from cytosolic NADH to mitochondrial NADH.
21. This mechanism is efficient but slow. However, another mechanism transports 2e from cytosolic NADH to mitochondrial FADH2.
22. This mechanism is less efficient but faster because obviously FADH2 produces less ATP/mole than NADH.

23. Glycolysis happens in the cytoplasm and the mitochondrial membrane is impermeable to NADH.
24. So the electrons have to be transported to the electron transport chain by means of another pathway called a shuttle.
25. There are two different shuttles.
26. One of them shuttles the electrons to the first complex which means 1 NADH = 2.6 ATP
But the other one shuttles the electrons to the third complex which means 1 NADH = 1.5 ATP (or 1.6 ATP by OCR standards)

ANAEROBIC RESPIRATION

1. Does not use oxygen.
2. The Krebs cycle and the link reaction therefore come to a halt.
3. Oxidative phosphorylation cannot take place
4. Glycolysis, however, can still continue
5. Pyruvate produced at the end of it can be removed
6. Reduced NAD (NADH) can be converted back to NAD+.
7. Acetaldehyde to ethanol (NADH → NAD+) FINAL ELECTRON ACCEPTOR Acetaldehyde 2012
8. FINAL ELECTRON ACCEPTOR Acetaldehyde **EXAM2012**
9.
10. Pyruvate to lactate (NADH → NAD+) FINAL ELECTRON ACCEPTOR lactate
11. Two other pathways allow the recycling of reduced NAD formed during glycolysis:

Ethanol pathway, e.g. by yeast Anaerobic fermentation in yeast- final products are ethanol and CO_2

EXAM2014

a.

b. Lactate pathway: e.g. by mammalian muscle.

LINKED REACTION

1. If oxygen is available, each pyruvate now moves into a mitochondrion,
2. where the link reaction and the Krebs cycle take place.
3. During these processes, the glucose is completely oxidised.
4. The Krebs cycle occurs in the matrix of the mitochondrion and is the aerobic phase and requires oxygen.
   This is also known as the citric acid cycle or the tricarboxylic acid cycle.
5. The Krebs cycle is a series of steps catalysed by enzymes in
6. A 2-carbon atoms Acetyl CoA enters the cycle and combines with a 4-carbon compound (oxaloacetate) to give a 6-carbon compound (citrate/citric acid).
7. Coenzyme A is reformed.
8. Cycle turns twice for each original glucose molecule.
   The citrate is then gradually converted back to the 4-carbon oxaloacetate again in a series of small enzyme-controlled steps involving decarboxylation and dehydrogenation.
9. 2 C atoms are released in 2 CO_2 molecules and 4 pairs of H atoms are removed.
   The CO_2 removed is given off as a waste product. It diffuses rut of the mitochondrion and out of the cell.
   The hydrogens removed are picked up by NAD and another coenzyme called FAD (flavin adenine dinucleotide).
10. 1 FAD and 3 NAD molecules are reduced during each turn of the cycle. H in reduced NAD/FAD will be released in oxidative phosphorylation.
11. The main role of the Krebs cycle in respiration is to generate a pool of reduced hydrogen carriers to pass on to the next stage.
    The regenerated oxaloacetate can combine with another ACoA.
    1 ATP is produced directly by substrate-level phosphorylation for each ACoA entering the cycle.
12. Amino acids and fatty acids can be broken down and fed into cycle.

See C02 production – 2010 EXAM QUESTION
NO need to remember the intermediates
2 ATP form EXAM2012

ICPT

ELECRON TRANSPORT CHAIN

1. The **final stage** of aerobic respiration is termed as **oxidative phosphorylation** or electron transport chain (ETC).
2. This takes place in the **inner mitochondrial membrane**
3. Reduced **FAD** and reduced **NAD** split into protons (H^+) and electrons (e^-).
4. Electrons (e^-). from reduced FAD and reduced NAD first pass to **hydrogen carriers** in the inner membrane
5. As the electrons move along the chain, they **lose energy**.
6. This energy is used to actively transport **H^+** from the matrix of the mitochondrion, across the inner membrane and **into the space** between the inner and outer membranes.
7. This builds up a **high concentration of H^+** in this space.
8. The H^+ are allowed to **diffuse back** into the matrix through special channel proteins that work as ATPases.
9. The movement of the H^+ through the **ATP synthase** provides enough energy to cause ADP and inorganic phosphate to combine to make **ATP**.
10. They combine with **oxygen** to produce water.
11. END PRODUCTS: **H_2O, ATP, NAD^+, FAD^+** (**EXAM2016**)

Respiratory quotient

1. **Respiratory quotient** is the **ratio of the volume of carbon dioxide produced to the volume of oxygen** consumed in respiration over a period of time.
2. Its value can be **one, zero, more than 1** or less than one.
3. **RQ = Volume of C02 evolved/Volume of 0_2**
4. Respiratory quotient is equal to unity if carbohydrates are the respiratory substrate and the respiration is aerobic.

$C_6H_{12}0_6 + 60_2 \rightarrow 6C0_2 + 6H_20$

RQ = $6C0_2/60_2 = 1$

Glycolysis

4 made - 2 used= 2 ATP substrate level
2 NADH x 2= 4 ATP (enters at complex II)

Pyruvate Decarboxylation
1 NADH x two pyruvate= 2 NADH x 3= 6 ATP

Krebs Cycle
3 **NADH** x two pyruvate= 6 x **3**= 18 ATP
1 GTP x two pyruvate= 2 GTP= 2 ATP substrate level
1 **FADH2** x two pyruvate= 2 FADH2 x **2**= 4 ATP

Total: 2+4+6+18+2+4= 36 ATP

substrate level total 4 (4/36 x 100 = 11%)
oxidative phosphorylation ETC 34 (32/36 x 100 + = 89%)
EXAM2013