BIO 101

BASIC PRINCIPLES OF REPRODUCTION AND GROWTH

COURSE OUTLINE

1. Introduction to Basic principles of reproduction
2. Types of reproduction
    i. Sexual reproduction
    ii. Asexual reproduction
    iii. vegetative
3. Growth definition
4. Growth phases
5. Growth rates
6. Planes of cell division
7. Interphase + Mitosis + Cytokinesis (The cell cycle)

INTRODUTION TO BASIC PRINCIPLES OF GROWTH

Reproduction (or procreation) is the biological process by which new individual organism exists as the result of reproduction. There are two forms of reproduction: asexual and sexual.

In asexual reproduction, an organism can reproduce without the involvement of another organism. Asexual reproduction is not limited to single-celled organisms. The cloning of an multi-celled organism is a form of asexual reproduction. By asexual reproduction, an organism creates a genetically similar or identical copy

of itself. The cell is able to do so by dividing by mitosis. On the other hand there is sexual reproduction.

Sexual reproduction typically requires the sexual interaction of two specialized cells of organisms, called gametes, which contain half the number of chromosomes of normal cells and are created by meiosis, with typically a male fertilizing a female of the same species to create a fertilized zygote. This produces offspring organisms whose genetic characteristics are derived from those of the two parental organisms.

ASEXUAL REPRODUCTION

Asexual reproduction is a process by which organisms create genetically similar or identical copies of themselves without the contribution of genetic material from another organism. Bacteria, Amoeba divide asexually via binary fission; viruses take control of host cells to produce more viruses; Hydras (invertebrates of the order Hydroidea) and yeasts*(Saccaromyces cereviseae*) are able to reproduce by budding. These organisms often do not possess different sexes, and they are capable of "splitting" themselves into two or more copies of themselves. Most plants have the ability to reproduce asexually and the ant species *Mycocepurus smithii* is thought to reproduce entirely by asexual means.

Some species that are capable of reproducing asexually, like hydra, yeast and jellyfish, may also reproduce sexually. For instance, most plants are capable of vegetative reproduction—reproduction without seeds or spores—but can also reproduce sexually. Likewise, bacteria may exchange genetic information by conjugation.

Other ways of asexual reproduction include parthenogenesis, fragmentation and spore formation that involves only mitosis. Parthenogenesis is the growth and development of female (ovule) into young embryo without fertilization by a male. Parthenogenesis occurs naturally in some species, including plants (where it is called apomixis), invertebrates (e.g. water fleas, aphids, parasitic wasps), and vertebrates (e.g. some reptiles, fish, and, very rarely birds and sharks). It is sometimes also used to describe reproduction modes in hermaphroditic species which can self-fertilize themselves

SEXUAL REPRODUCTION

Sexual reproduction is a biological process that creates a new organism by combining the genetic material of two organisms in a process that starts with meiosis, a specialized type of cell division. Each of two parent organisms contributes half of the offspring's genetic makeup by creating haploid gametes. Most organisms form two different types of gametes. In these anisogamous species, the two sexes are referred to as male (producing sperm or microspores) and female (producing ova or megaspores. In isogamous species, the gametes are similar or identical in form (isogametes), but may have separable properties and then may be given other different names. For example. in the green algae eg *Chlamydomonas reinhardtii*, there are so- called "plus" and "minus" gametes (gram positive and gram negative strains). A few organisms. such as ciliates, *Paramecium aurelia* have more than two types of sex called syngens. Some other type, the Oogamous species have non–motile bigger ova or egg (female gamete) and motile small sperm (male gamete) a good example is human being.

Most animals (including humans) and plants reproduce sexually. Sexual reproducing organisms have different sets of genes for every trait (called alleles). Offspring inherit one allele for each trait from each parent. Thereby ensuring that offspring have a combination of the parents' genes. Diploid having two copies of every gene within an organism, it is believed that "the masking of deleterious alleles favors the evolution of a dominant diploid phase in organisms that alternate between haploid and diploid phase "here recombination occurs freely.

Bryophyte reproduces sexually but its commonly seen/ dominant life forms are all haploid, which produce gametes. The zygotes of the gametes develop into sporangium. which produces haploid spores. The diploid stage is relatively short compared with that of haploid stage. i.e. *haploid dominance*. The advantage of diploid, e.g. heterosis, only takes place in diploid life stage. Bryophyte still maintains the sexual reproduction during its evolution despite the fact that the haploid stage does not benefit from heterosis at all. This may be an example that the sexual reproduction has a bigger advantage by itself, since it allows gene shuffling (hybrid or recombination between multiple loci) among different members of the species, that permits natural selection of the fit over these new hybrids or recombinants that are haploid forms.

Allogamy: Cross fertilization between individuals of a species. Also used for cross pollination. Allogamy is the fertilization of an ovum from one individual with the spermatozoa of another.

Autogamy "Geitogamy": Self-fertilization, also known as autogamy, occurs in hermaphroditic organisms where the two gametes fused in fertilization come

from the same individual, e.g., some foraminiferans, some ciliates. The term “autogamy” is also used for pollination (not necessarily leading to successful fertilization) and describes self-pollination within the same flower, distinguished from geitogamy, transfer of pollen to a different flower on the same flowering plant, or within a single monoecious Gymnosperm plant. For example, species *Helonias bullata* suffer for low self-fertilization.

Some flowering plants are cleistogamous or chasmogamous a type of self fertilization in which the flowers do not open to allow pollen from another pollinate the flower of the plant e.g. *Viola pubescens.*

Assignment : Give brief notes on gametogenesis and sporogenesis

GROWTH

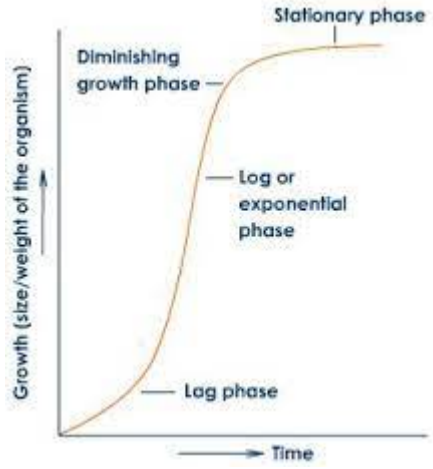
This is the process of irreversible increase in size (height, girth, volume, weight) of an organism or plant biomass in a particular community. This occurs as a result of increase in cell size and number in the body of the individual organism. Growth is measured as a unit of size per time. It occurs throughout the lifespan of plants

In other for any living organism to live and continue life, its cell(s) must grow and multiply. Unicellular organism have to multiply their cell in the different asexual type of reproduction just like multicellular organisms uses it to grow their own body. The type of cell involved is known to be somatic. Somatic cells unlike Gametic cells (used in sexual reproduction divide through mitosis the equation division and not by meiosis the reduction or halving division

Growth phases

There different phases of growth are the formative (lag); accelerating growth (exponential/ log); Maturity/ developmental (stationary) (which is expressed in flowering plants with anthesis of flowers); and the decelerating/aging (called senescence in plants) phases. The phase are expressed in an S shaped curve known as the sigmoid growth curve

Each organism has its own period of time in which these phases occur, just like it takes different cells to complete their cycle



The sigmoid growth curve

Growth rates

Organisms body and species population progress in two distinct rates, arithmetic and geometric progression. Arithmetic progression occurs usually at the formative and stationary phases, while geometric growth is observed during the exponential or log phase.

Arithmetic Growth:

It is a type of growth in which the rate of growth is constant and increase in growth occurs in arithmetic progression- 2, 4, 6, 8, 10, 12. Some parts of organism body do grow in arithmetic pattern e.g. nails , tooth.

In plants, arithmetic growth occurs in root and shoots elongating at a constant rate.

Geometric Growth: Growth progresses rapidly as the mitotic daughter cells retain ability to divide and continue to divide. Plants meristematic cells at the growing point (usually tips of roots and shoots) divide in such a manner that one daughter cell remains meristematic while the others grow and differentiate. it increases rapidly at an exponential rate (this occurs during the log or exponential stageof developmental phase)**.**

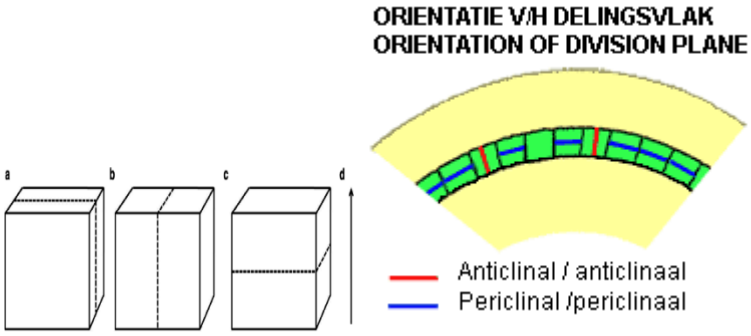
Planes of cell division

Meristematic cells divide in different fashions toform tissues of organs in organisms. The plane of cell division when at a perpendicular(right angles) to outer surface of plant part is known as anticlinal division. On the other hand, the plane of division of cells, running parallel to the surface of plant part is known as periclinal division. Plane of division could also be in an unorganized way,

Different tissues are formed due to these different patterns of meristematic cells division

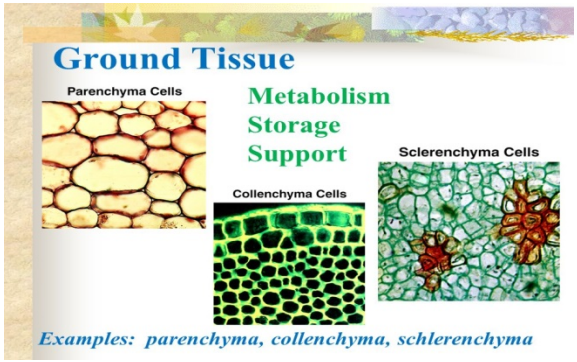
i. Rib/ file tissues formed by a periclinal or anticlinal cell division only respectively

ii. Plate tissues formed by both anticlinal and periclina cell division



a and b Anticlinal division; c periclinal division; d anticlinal and periclinal division in an epidermal tissue of a plant

iii. Mass tissues formed by different types of planes of division in no particular fashion



The cell cycle

There are two phases of cell cycle, the Growth and Division phases. Each organism/species differs in time of completion of a cell cycle time frame of each phase within the cell cycle. Even within an organism cell cycle duration may differ in different parts or organs of the species. For example, the root tip of *Daucus carota* (carrot) cell cycle lasts 7.5 hours whereas that of *Zea mays* (corn) will last about 10hours

The growth phase of the cell cycle

The growth phase is also known as the resting phase or interphase. The cell is actually most active during the interphase and there are three distinct phases detected within interphase, the G_1, S and G_2

G_1 (GAP1) phase: This is the first stage after division when new daughter cells have been made. The cell is just recovering from division and conducting most of its normal metabolism. One important process is the synthesis of nucleotides that are used for DNA replication. It is the longest period in the cycle of any organism.

S (synthesis) phase: During the S or synthesis phase the genes in the nucleus are replicated.

Gene "Polymer of nucleotides" and each gene has a unique sequence of nucleotide. Many higher plants and animals need about 100,000 types of genes to store all the information required to make proper enzyme, structural proteins and hormones needed for the organism life. The whole complex of genes for an organism is its genome

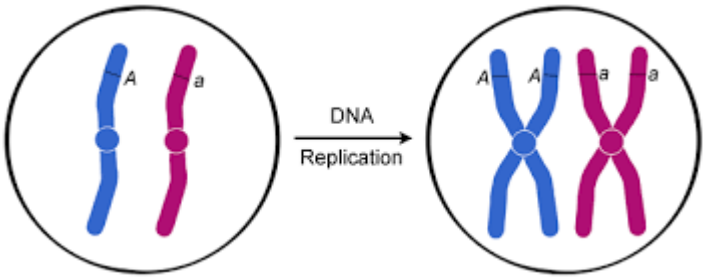
Several, up to thousands of genes attached together in a linear sequence in a structure called chromosomes. Although it might be reasonable for all these several genes to link together in a single chromosome but such a long chromosome would become extremely tangled, therefore the genes are lined on more than one chromosome. Only a few plants have as few as two chromosomes for their genome. Most have between 5 to 30 chromosomes.

Number of chromosomes in a diploid set in some common plants

	Species	Common name	Number of chromosome

			(2n)
1.	*Vicia faba*	Bean	12
2.	*Pisum sativum*	Pea	14
3.	*Beta vulgaris*	Beet	16
4.	*Allium cepa*	Onion	16
5.	*Oryza sativa*	Rice	24
6. 7.	*Solanum tuberosum* Homo sapiens	Potato Human being	48 46

DNA pieces are linked by Centromere forming chromatid. Before the S phase each chromosome has one chromatid and a copy of each gene, after S phase each chromosome has two chromatids and two copies of each gene

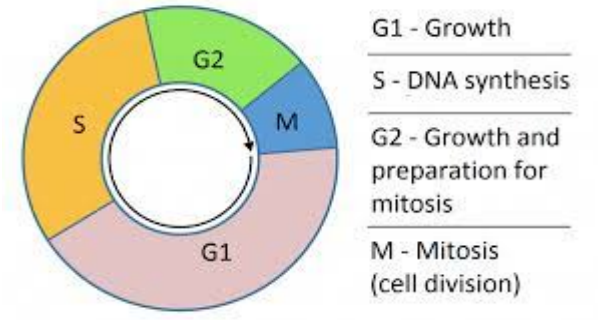


Note: many cells stop at G_1 and do not proceed to the S phase when they cease dividing i.e. the **G_0 phase.**

Not all cells are continually replicated. Non-replicating cells are found in a stage of the cell cycle called G_0. These cells may be quiescent (dormant) or senescent (aging or deteriorating). Such cells generally enter the G_0 phase from G_1. Cells may remain quiescent in G_0 for an indeterminate period of time (when no more new cells are needed), only to re-enter G_1 phase and begin dividing again under specific conditions. While quiescent cells may re-enter the cell cycle, senescent cells do not. One reason that cells trigger senescence is to ensure that damaged or defective DNA sequences is not passed on to daughter cells.

G_2 (GAP 2) phase: Following the S phase the cell progresses into G_2 phase during which cell prepare for division. This phase usually last only about 3 to 5 hours. There is formation of alpha and beta tubulin necessary for the spindle microtubules, proteins necessary for processing chromosome and break down(enzymes) of the nuclear envelope.

After the G_2 phase, the division of a cell can occur



Division phase of the cell cycle

The actual division involves two processes

1. Division of the Nucleus called **Karyokinesis** and 2. Division of the protoplasm called **cytokinesis**

Karyokinesis: There are two types of karyokinesis, mitosis (occurs somatic cells) and meiosis (occurs in gameticcells)

Mitosis

Mitosis is a duplication division, It is the more common type of karyokinesis. It is the method that any multicellular organism uses as its body is growing. It is also used by eukaryotic unicellular organisms, when they are not undergoing sexual reproduction.

Mitosis is called duplication division because the nuclear genes are first copied and one set of genes is separated from the other, and one daughter nucleus is basically a duplicate of the mother nucleus and a twin of one another, except for occasional errors and cases known as polyploidy. Its can also referred to as the equation division. Mitosis consist of the following 4 phases: Prophase , metaphase, anaphase, and Telophase

Prophase

- Chromosomes condense i.e. become shorter and thicker by coiling repeatedly to about 2 to 5vμm until visible.
- The chromosome now moves easily within the cell
- Nucleolus (organelles within the nucleus where RNA is synthesized and assembled) is less distinct or disappears

- Nuclear envelope/membrane is broken down by action of enzymes
- Sister chromatids migrate to opposite poles of the cell
- Spindle (long set of microtubules) from opposite poles are formed and attached to the centromere

Metaphase

- Once spindles are formed chromosomes are pulled together to the centre and aligned at the centre
- Centromere between chromatids are duplicated
- The two chromatids of each chromosome are freed of one another
- Number of chromosomes is doubled but the size is halved

Anaphase

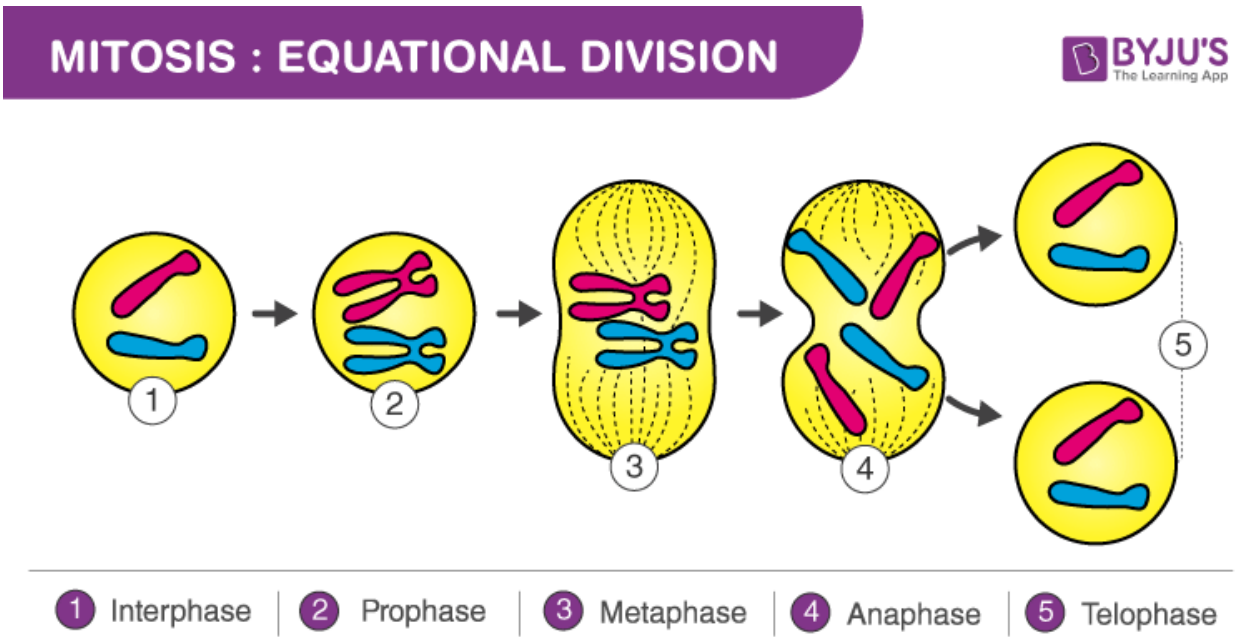
- Spindles are shortened
- Each daughter chromosome is pulled away from its twin to opposite ends of the cell
- Chromosomes at each end of the cell are pulled together into compact space

Telophase

- Nuclear envelope appears around the two sets of chromosomes at each side of the cell.
- Chromosome starts to become less distinct as they starts to uncoil.
- New nucleoli appear as ribosomal genes become active and produce ribosome.
- Spindles depolymerise completely and disappear.

- Two new nuclei are formed.

Note: Actions in telophase are mostly opposite of those in the prophase



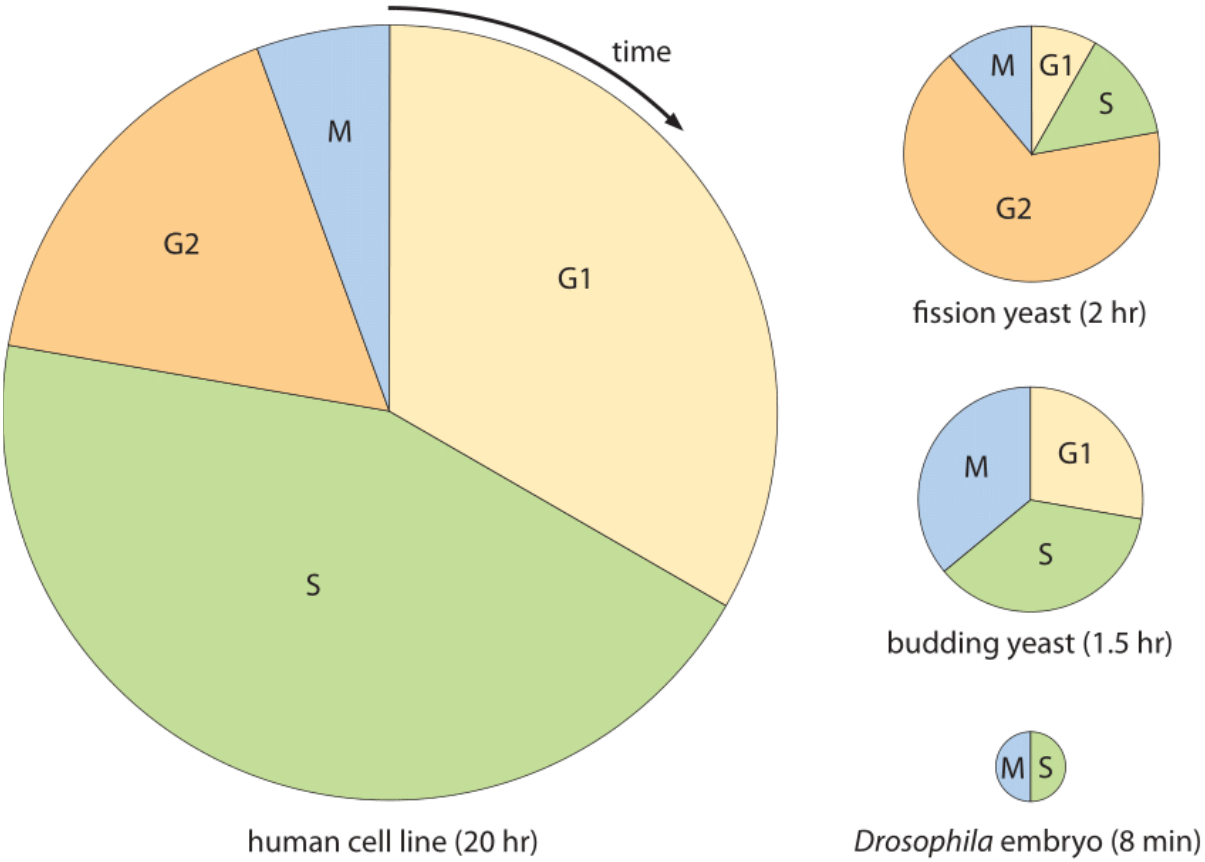
Assignment - On a table give the differences between mitosis and meiosis, and between both types of divisions in plants and animals

Cytokinesis

The division of protoplasm is much simpler than the division of the nucleus. There is a random distribution of mother organelles, each daughter cell is made sure to contain some mitochondria, endoplasmic reticulum, vacuoles, plastids etc.

In plants, the process involves formation of a phragmoplast (set of short microtubules orientated parallel to the spindle microtubules) catching dictyosomes and taking them towards original cell wall. A cell plate then is formed. The dictyosomes grows outward making new wall along the edge. The

new walls meet and fuse with the old/mother cell wall completing the division of the mother cell into two daughter cells.



DURATION OF SOME CELL CYCLE PHASES IN DIFERRENT ORGANISMS

EXERSCISE – Read up the differences in cell cycle duration of organisms and in different parts/ tissues of their body