Bio 1140 Laboratory Exam Review

Introduction to Cell Biology (University of Ottawa)

BIO 1140 Laboratory Exam Review

Lab #1(LabManual and Biolabo)

- Introduction to microscopy and observation of prokaryotic and eukaryotic cells

Oculars	Screen
• Greater solution • Wider field of view	• Can share your observation with others • More comfortable for users • Take pictures while observing

The compound microscope-

- The microscope consists of a system of lenses, a light source, and a geared mechanism for adjusting the distance between the lens system and the object being observed
- **REVOLVING NOSEPIECE:** Supports the various objectives - You will only use the 4x, 10x and 40x objectives in the BIO1140 labs (not the 100x).
- **STAGE:** Supports the specimen being observed. A system of knobs on the side of the stage allows you to move the specimen under the objective on the X and Y axes. Try and move the stage.
- **COARSE FOCUS KNOB:** Permits rapid change in distance between the specimen and the objective thereby allowing for rough focussing – Do not use when focusing with the 40x objective.
- **FINE FOCUS KNOB:** Permits small changes in distance between the specimen and the objective and thereby allows for final focussing of the image. It should be used with the 40x objective.
- **OCULAR OR EYEPIECE:** A magnifying element in the microscope, usually 10x. It is through the ocular, or eyepiece, that one looks at the specimen. All our microscopes are parfocal, so that when an object is in focus with one objective, the focus will not be completely lost when changing to the next objective.
- **OBJECTIVES:** The magnifying element which is closest to the specimen. See figure 1 to find out about the engravings on the side of each objective.
- **CONDENSER:** System of lenses that concentrates the light furnished by the illuminator. It does not magnify the object.
- **CONDENSER HEIGHT ADJUSTMENT KNOB:** Allows one to focus the concentrated light onto the specimen.
- **APERTURE IRIS DIAPHRAGM:** Used to reduce glare from unwanted light by adjusting the angle of the cone of light that comes from the condenser.

- Start at 4X
- As working distance decreases, the magnification increases.

- **Depth of field** (depth of focus)- Lenses have a depth of field, it is the number of planes in which an object appears to be in focus. With a microscope or any other object, when it is focussed on one surface, the surfaces located above and below will be out of focus. A high number of surfaces in focus mean you have a great depth of field (also referred to as deep focus). The depth f field varies with several factors.

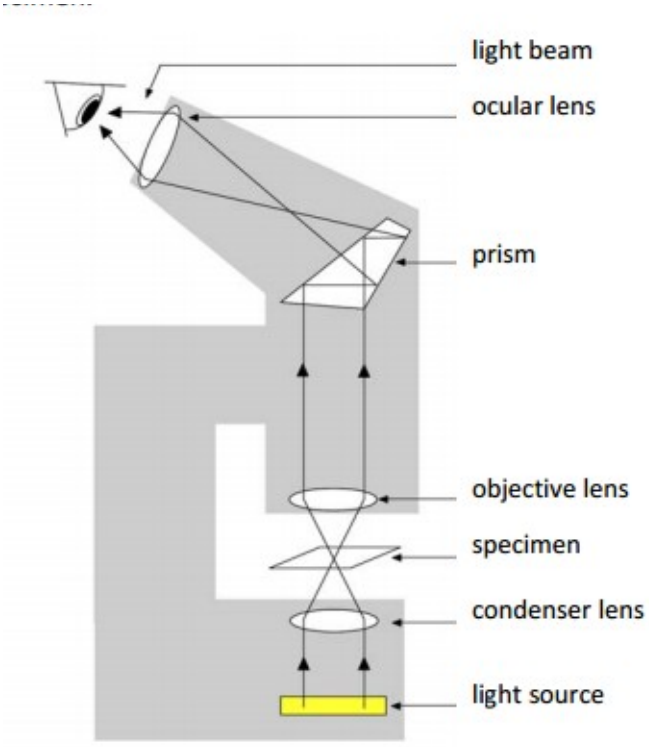


Figure 2: Image production in a compound microscope.

- **Magnification-** the magnification given by objectives and oculars is engraved on the. The total magnification for any combination of objective and ocular is the product for any combination of objective and ocular is the product of the magnification of each lens

Magnification factor= measured size of object / actual size of object=(260X)

- The general principle is fairly simple: 2 objects have the same relative size (expressed as a ratio) in the real world and under the microscope.
- Measuring the object, using the field of view (FOV)

Measuring an object using the field of view (FOV):

There are many methods to determine the size of an on-screen object. The simplest one is to use the known size of the whole field of view (FOV, the whole picture from left to right):

1 - On the computer screen (using a ruler and without writing anything on the screen), measure the object of which you want to determine the size (=A_2)

2 - Then, measure the width of the whole picture on the screen (=B_2).

3 - Refer to table 2 on page 20 to know the actual size of the field of view for the objective you're using (=B_1)

4- Use the following formula:

$$\text{actual size of the object } (A_1) = \frac{\text{actual size of the FOV } (B_1)}{\text{on-screen size of the FOV } (B_2)} \times \text{on-screen size of the object } (A_2)$$

The stereoscopic microscope –

- Used to view objects that are too large or too thick to view under the compound microscope
- Can be used with **reflected** or **transmitted** light.
- *Reflected light* is directed unto to opaque specimens from above and is reflected to the viewer.
- *Transmitted light* is directed unto to the translucent specimens and passes through the specimen beneath the stage.

Prokaryotic and Eukaryotic cells

- Prokaryotes- Archaea and Eubacteria
- Smaller than E
- Most abundant organism on the planet
- Do not have a nucleus, mitochondria or chloroplasts.
- Genetic material is composed of one circular chromosome plus other extra chromosomal elements called plastids
- Eukaryotes- much larger than P
- Membrane bound nucleus, organelles more complex and numerous, genome is larger than P.
- Organisms can be uni or multicellular

What important biological process takes place in the chloroplasts?

- Photosynthesis

What pigment is responsible for their green colouration?

- Chlorophyll

Chloroplasts are either a round oval or disk shape

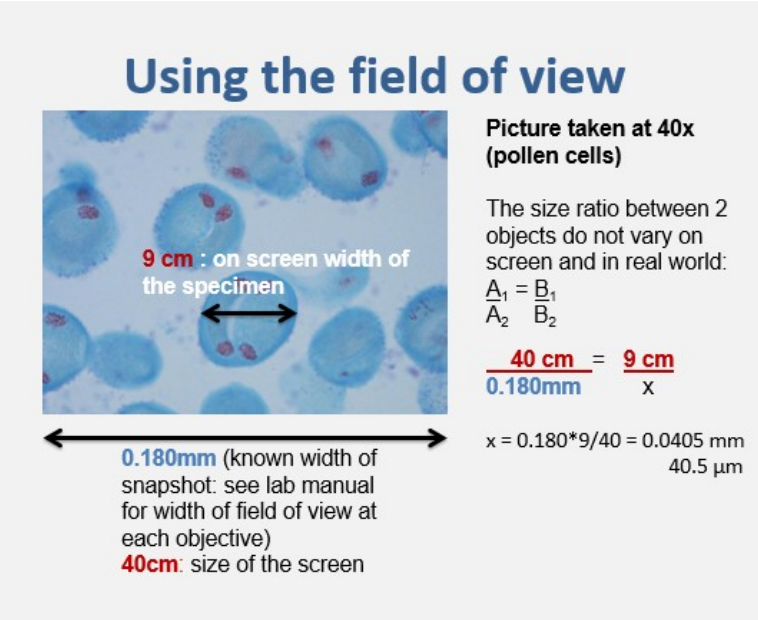
What movement do chloroplasts have?

- Cyclosis or Cytoplasmic streaming
- Functional for the transportation of material within the chloroplasts

If a plant cell is placed in a salt solution, water will diffuse out of the cell by osmosis, thereby decreasing the cell volume. What can then be seen is a space between the cell and the limiting boundary of the **protoplast** (the cell minus the cell wall) which thereby becomes visible.

- The large central vacuole becomes rigid during plasmolysis.

You can see various moving green filaments on a plant cell wet mount slide.



3 - Metric system units (see also appendix II at the end of lab manual):

1 centimetre cm = 10^{-2} metres (m)

1 millimetre mm = 10^{-3} metres

1 micrometre µm = 10^{-6} metres

1 nanometre nm = 10^{-9} metres

Lab # 2- Permeability of the Red Blood Cell

- Studying the spontaneous movement of molecules (water and solutes) through the membrane of animal cells.
- Erthrocytes (RBC's) contain large quantities of the pigment hemoglobin. When the volume of a cell exceeds a critical volume, the cell ruptures and pigment is released to the external environment. This is called **Hemolysis**
- **Osmosis-** spontaneous movement of water molecules across a semi permeable membrane. Water can freely cross the plasma membrane, mostly thanks to specialized proteins called **aquaporins** that form canals through the membrane. Water will move from the compartment with a lower solute concentration to the compartment with a higher solute concentration.
- **Tonicity-** the ability of a solution to create movement of water. Therefore, the volume of a cell placed in a **hypotonic solution** will increase due to massive entry of water inside the cell, in order to decrease the concentration of solute in the intracellular environment. **Hypertonic solution-** will cause water to flow from the inside of the cell to the outside. The volume of the cell will decrease and the plasma membrane will start folding (like a deflated balloon).
- **Diffusion-** molecules in a solution can also spontaneously cross he membrane following their own concentration gradient.
- When Erythrocytes are placed in a hypotonic environment, water enters the cells and their volume increases, cells eventually reach a critical volume and undergo hemolysis. Hemolysis can be reached by placing the cells into an isosmotic solution of a penetrating substance. A solution may be called isosmotic if it has the same concentration of solutes (penetrating and non penetrating) as the cellular fluid. As the penetrating substance enters the red blood cells, the tonicity and the osmotic pressure change. Osmotic pressure inside cell increases, while the external environment becomes hypotonic. Water enters cell through osmosis to try to maintain equilibrium. As water enters, cell swells and undergoes hemolysis.

Calculation of mean and standard error of the mean

Y= measurement; n=sample size

Arithmetic Mean : $\overline{Y} = \frac{\sum Y}{n}$ Standard deviation: $s = \sqrt{\frac{\sum Y^2 - \frac{(\sum Y)^2}{n}}{n-1}}$

Standard Error : $SE = \frac{s}{\sqrt{n}}$

Part II: procedure

- Adjust focus, condenser, light intensity and set the colour balance (see guide Biolabo).
- Observe the **shape** and measure diameter of RBC in **micrometers (µm) at 40x**
- Clean up lenses if needed (ask your TA how to)
  - **TIP:** To clearly see shape of RBCs, adjust the **aperture iris diaphragm** on the microscope**:**
    - closed → more contrast, less light
    - open → less contrast more light and colors.
  - Try different apertures.

Lab 2 Report questions

Interpretation:

1. **What are the factors that affect the diffusion of the solutes tested in the permeability experiment?**

   The factors that affect the diffusion of solutes tested in the permeability experiment were the solutes in the solutions, and as a result, whether those solutions were isosmotic and hypertonic.

2. **How do these factors affect the diffusion of solutes?**

   Water and Triton X were both very hypertonic – when the concentration of solutes outside the cell (in the solution) is less than the concentration of solutes inside the cell. Because of this, the solutions flowed through the membrane to decrease the concentration of solutes inside the cell in attempt to balance the concentration on either side of the membrane. Too much water enters the cell and eventually it bursts, which is hemolysis. Ethanol, as well as dextrose and thiourea, are isosmotic solutions, meaning that there are the same number of dissolved solutes in the solution as there are solutes inside the cell. When the membrane penetrating solutes are moving across the membrane from the solution to the inside of the cell, the osmotic pressure changes within the cell while the outside of the cell remains at the same pressure. The solution surrounding the cell becomes hypotonic. After a given period of time, the cell will swell and burst.

LAB #3- Cellular processes in *Amoeba proteus*

- *Amoeba proteus* – **a single celled eukaryote organism.** It extends its pseudopodia to move and to catch food (including preys) that will then be digested in food vacuoles.
- Amoebas are very sensitive to light of short wavelengths and to heat. So turn off the light of the microscope between observations and use relatively low light intensity when observing.
- After one or several pseudopodia form the rest of the cell seems to crawl in that direction.
- The formation of pseudopodia is relatively well described and relies on the process shared by all moving cells: extension of long polymers of **actin**.
- During the formation of pseudopodium, molecules of free actin (G-actin) bound to each other create a series of long polymer fibers (F- actin in this form) .
- As these fibers grow they push the plasma membrane in the direction of the extending pseudopodium. Adhesive molecules will attach the newly formed pseupodium to the substratum, whereas the same adhesive molecules will detach at the “back” of the cell (called the uroid). Then a series of contractions occur at the uroid (one can see the

membrane folds in the uroid region where these contractions occur) helping the cell content to be pushed toward the “front” of the cell.

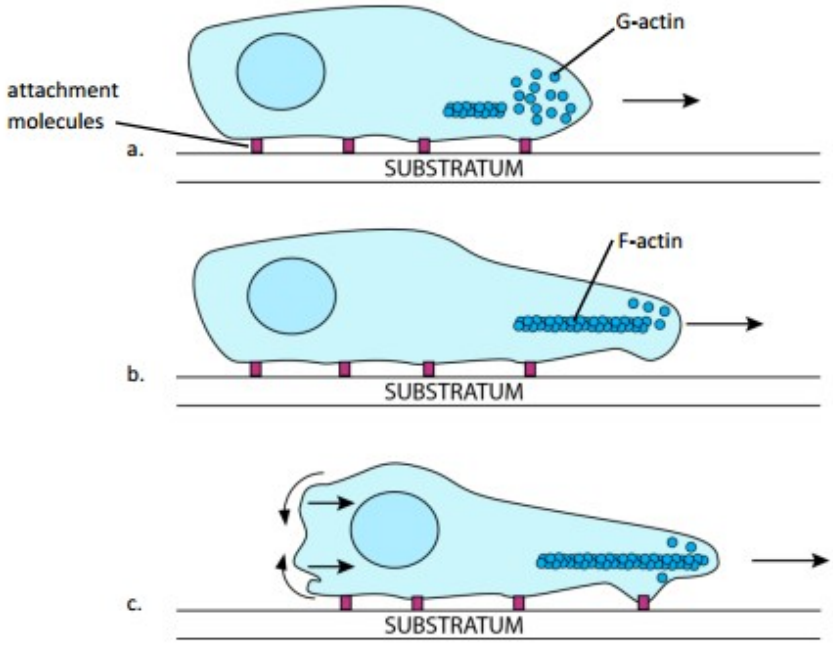


Fig. 1: Schematic representation of amoeboid movement (Modified form ref.1).

Contractile vacuole-

- Like all organisms that live in water, especially single celled ones, amoeba must constantly fight excess water entry by osmosis (the extracellular environment is hypoosmotic compared to amoeba’s cytosol).
- Amoebas, as well as many other protists, release the excess water thanks to a **contractile vacuole.**
- This organelle goes through a cycle during which it fills up by taking in water in the cytosol, and then releases this water into the extracellular environment. The size and number of contractile vacuole (s) varies depending on species. *Amoeba proteus,* only has one contractile vacuole.
- Time zero- corresponds to the time when the amoeba empties the content of its contractile vacuole to the outside (=**systole**)
- A typical contractile vacuole cycle lasts for 4-6 minutes but it sometimes takes more time.

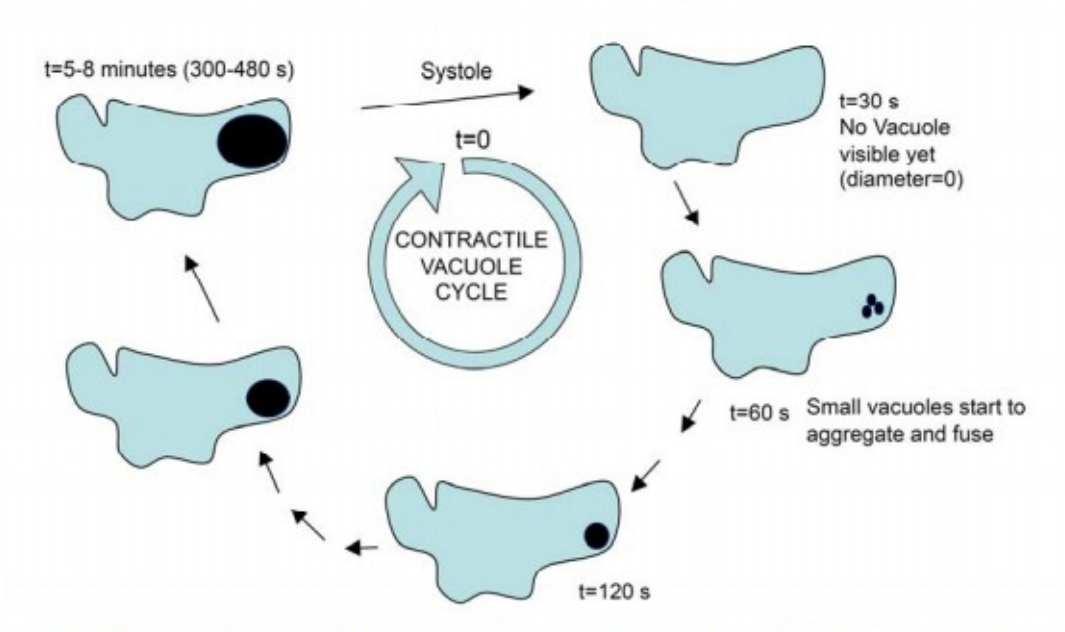
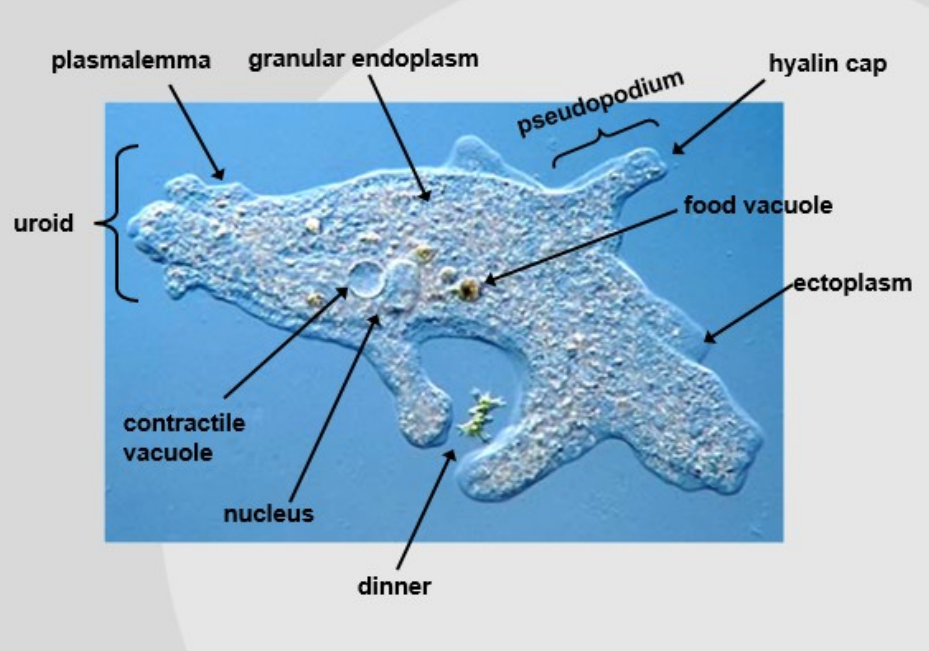
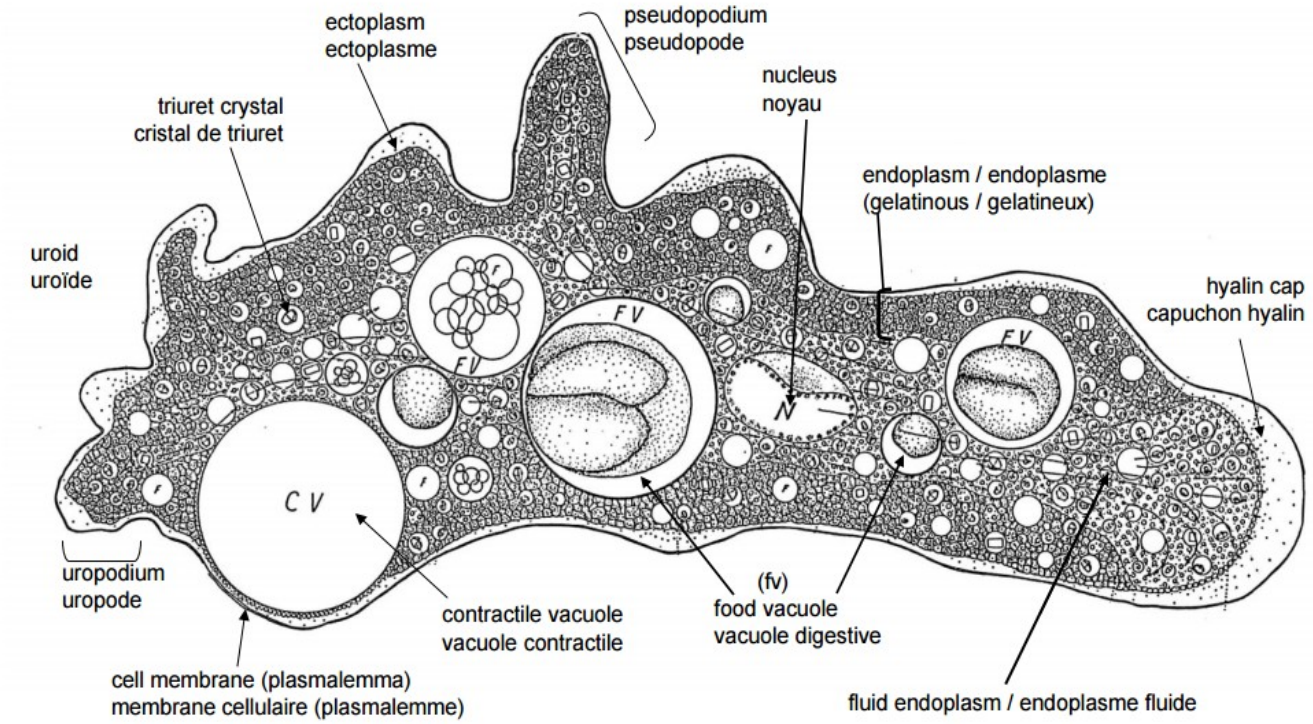


Figure 2: Schematic representation of the contractile vacuole (CV) cycle. Durations are approximate.

Endocytosis

- (Bulk-phase endocytosis or pinocytosis)
- Bulk- phase (or non specific) endocytosis may be induced by a large variety of substances: proteins, amino acids, salts (cations), basic stains, etc. We will use a solution containing **1 % bovine plasma albumin** to induce pinocytosis.
- Once the amoeba is in contact with the inducing agent, the cell will stop moving and its shape will become “rounder”.
- The endoplasm flow will also stop and endoplasm will become restricted to the central region of the cell.
- Small protrusions (like mini pseudopodia) will appear.
- Endocytosis canals can be observed more easily in these structures.





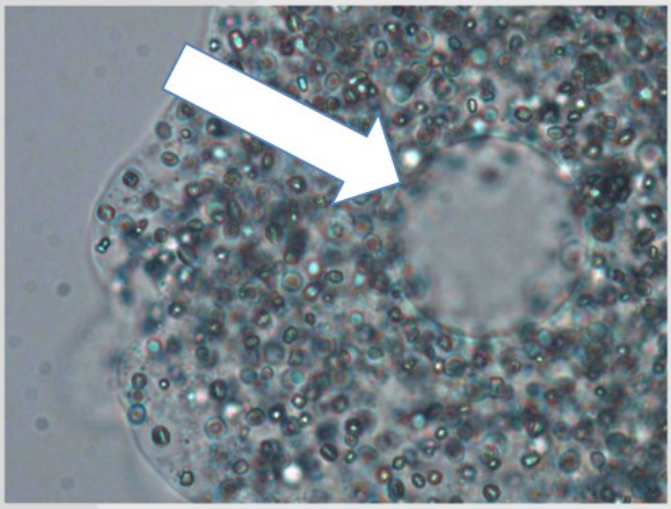
Part III: Contractile vacuole cycle

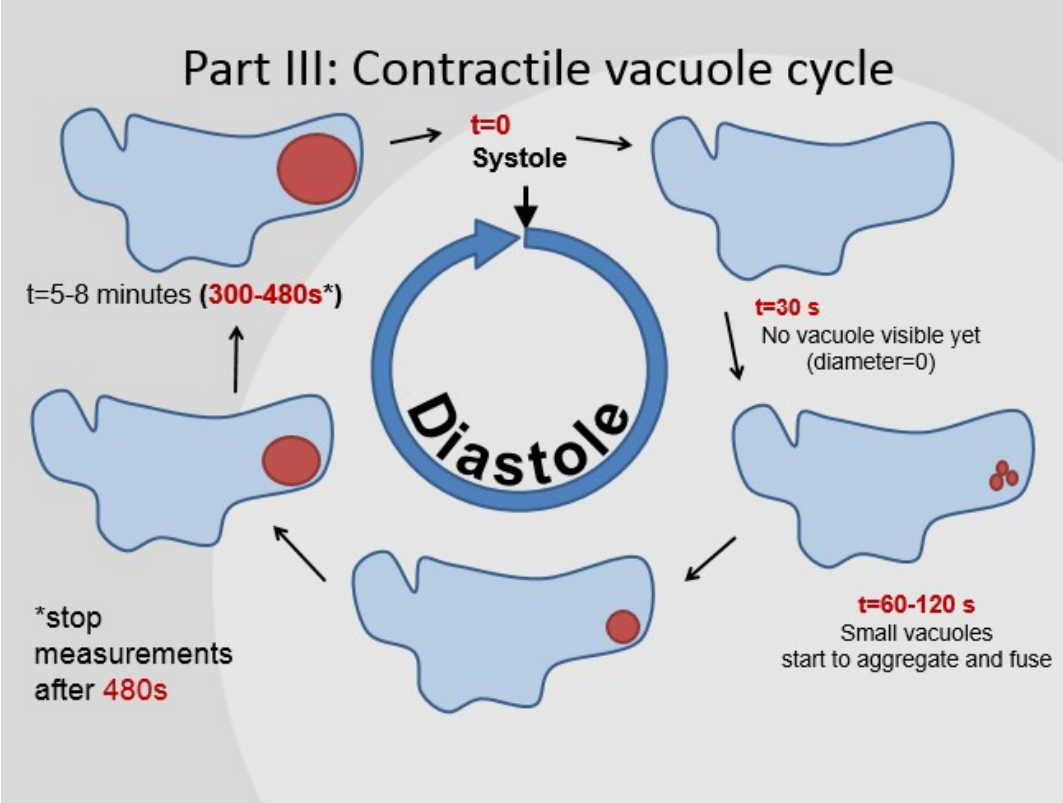
Your task: measure the contractile vacuole (CV) diameter throughout its cycle.

Contractile vacuole:

- Function: osmoregulation and waste removal
- Location in the cell: variable
- Duration: **about 5 minutes at 20°C** (cycle duration increases with temperature).
- Cycle components:
  - Diastole (coalescence and continual growth)
  - Systole (release of CV contents to exterior).

Part III: Contractile vacuole cycle





Lab # 4 – Mitosis

- All cells have in common the fact that they all have to reproduce.
- This process is called cellular division
- Prokaryotes and unicellular eukaryotes rely on cell division to produce new individuals
- In multicellular organisms' cell division allows the development of an embryo (from one cell to a complete organism), the growth of structures and replacement of cells due to ageing or damage.

In eukaryotes there are two types of cell division:

1. Cell division that will give rise to two daughter cells identical to the original mother cell. **Mitosis** belongs to this type of division and it designates the process where genetic material is evenly separate in two.

2. Cell division that will produce gametes (meiosis). Cells produced by meiosis are different from the original cell and contain a different genetic content. These cells will be used for sexual reproduction.

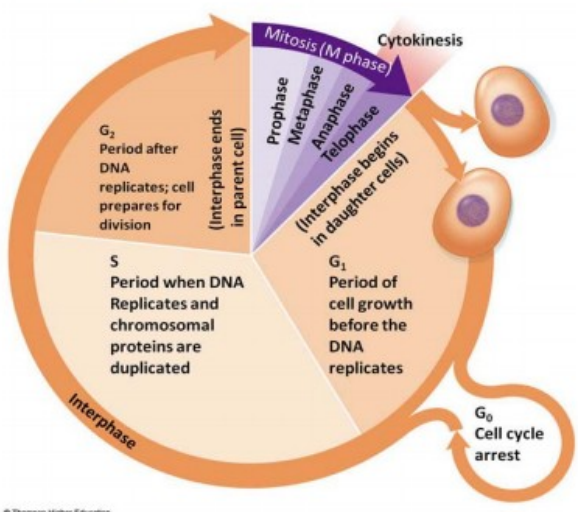
The cell cycle –

Cell cycle: M Phase + Interphase

Mitosis + cytokinesis $G_1 (+- G_0) + S + G_2$

- **Cell division (**or **M Phase)** as seen in this equation is composed of both nuclear (mitosis) and cytoplasmic (cytokinesis).
- **Interphase-** is the phase separating two cell divisions, in which cells enter a period of growth and potentially preparation to the next M phase.
- Cells spend most their time in interphase and it is during this time that most cellular processes are carried out. Interphase may be further divided into sub stages: the G_1 (first gap) stage is a period of growth ad active synthesis of all groups of macromolecules.
- It is also during G1 that cytoplasmic organelles (like mitochondria , ribosomes, etc…) are duplicated.
- **The S phase (synthesis phase) -** follows with precise replication of all DNa and sunthesis of DNA associated proteins (histones) , or microtubule-associated proteins (centrioles). At the end of the S phase each chromosome consists of two chromatids joined together by protein complexes called cohesins.
- **The G2 stage-** involves protein synthesis and production f structures needed for mitosis, like spindle fibers.
- Among the cells that stop their cycle during interphase, most of higher plants and animals arrest in G1. Other leaves the cell cycle entirely and enter stage known as **G0**

- This may be permanent withdrawal from the cycle or only a temporary stay before returning to the G1 stage.



Mitosis-

- Mitosis is the part of cell division which refers specially to the process of nuclear division where the chromosomes are equally distributed between two daughter nuclei. After mitosis and cytokinesis, both daughter cells are identical to each other and to the parental cell. +
- After these two processes, three different cell types may be found
    - i) Cells that divide continually
    - ii) Cells that leave the cell cycle and do not divide during the life of the organism.
    - iii) Cells that enter a resting state (G,0,1,2) but are some stimulus return to the cell cycle and divide.

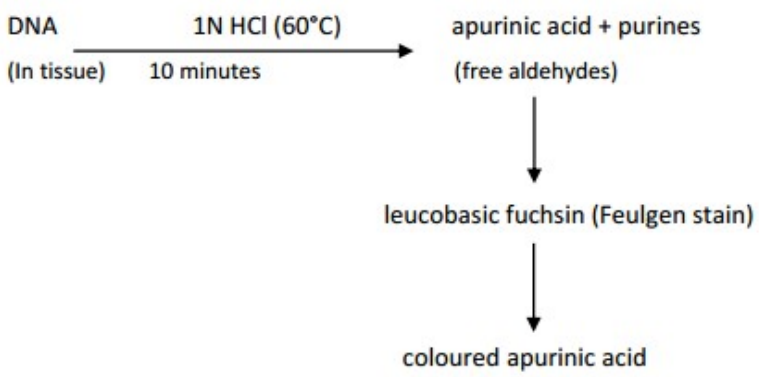
- **Mitosis is divide into 5 phases – (prophase, prometaphase, metaphase, anaphase, telophase)**
- It is a sharp series of changes with no sharp breaks in between.
- Closely associated with (but not always), with nuclear division is the division of the cytoplasm known as **cytokinesis.** Begins in late anaphase and continues through telophase. It is seen as a **cleavage furrow** which forms in the middle of animal cells or **cell plate,** which is laid down at the equator of plant cells.

Summary of cell cycle phases in plants

- **Interphase:** this is the stage that cell is in between mitotic divisions. Growth, synthesis of macromolecules and assembly of organelles, as well as DNA replication occur during this phase.
- **Prophase: Chromosomes** shorten and thicken and each one can now be seen to consist of two chromatids attached at the centromere region. Each chromatid of a chromosome contains identical information and comprises the DNA duplicated during interphase (S phase. During prophase in animal cells, the two centrosomes separate and migrate towards the opposite poles of the cell. Centrosomes are also the site where microtubules of the mitotic spindle are produced.
- **Prometaphase:** breakdown of nuclear membrane marks the initiation of prometaphase. Centrosomes will be found at opposite poles of the cell (spindle poles. The kinetochore of one sister chromatid attaches to microtubules from one pole while the kinetochores of the other sister chromatid attaches to polar microtubules from the opposite pole. As chromosomes are being pulled toward opposite poles simultaneously, they slowly migrate toward the metaphase (equatorial plate).
- **Metaphase:** Mitotic spindle microtubules are fully formed between the poles. Cohesion complexes are cleaved by an enzyme called seperase , which releases the junctions between sister chromatid. Then centromeres start to separate.
- **Anaphase:** Each chromatid (now called a daughter chromosome) moves to opposite poles of the cell.
- **Telophase :** chromosomes are now located at the poles decondense and become longer and thinner. Nuclear membrane reappears and the nucleolus reforms. Spindle disappears. Cytokinesis usually occurs during this phase .

Feulgen Stain-

- Specifically colours the DNA in magenta red.
- Will react with aldehyde groups to form a colour reaction product.
- Intact DNA doesn't contain free aldehyde and wont react with Feulgen directly.
- Although, the DNA contains deoxyribose sugar molecules chemically linked through aldehyde groups to purine and pyrimidine bases.
- To form free aldehyde in DNA to react with Feulgen, DNA is first hydrolysed with hot (60*) 1N HCL which removes purine bases and frees aldehyde from deoxyribose.
- Results in **apurinic acid** .
- Time of acid hydrolysis is very important (**10 min**)
- Reaction of a shorter time will not free all aldehyde groups
- And if kept in too long the apurinic acid will destruct.
- BOTH LEAD TO REDUCED STAINING



CAUTION: Feulgen stain looks like an inoffensive chemical but it can stain clothes and skin in a vivid magenta colour. Wear old clothes or a lab coat.

How is root growth accomplished?

- Growth can be accomplished by increasing the number of cells by cell division or by increasing the size of individual cells.
- What's happening? Many cells in the root tip are undergoing mitosis.

Animal mitosis-

- Mostly same as plants, but because there is no cell around the cell membrane , and no cell plate is formed at telophase.
- At the end of the nuclear division the membrane simply pinches together in the middle dividing the two new cells. In animal cells there is an **aster,** a semicircle of fibrils around each end of the spindle.

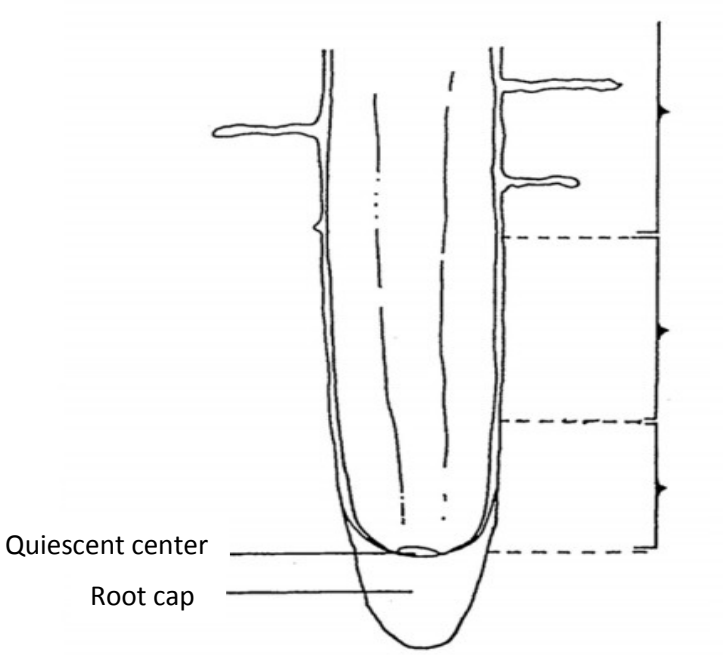


Figure 2: Longitudinal section of an onion (*Allium cepa*) root tip (add labels to drawing)

Lab 5 Meiosis-

- Is the process of a nuclear reduction division.
- There is also DNA duplication like mitosis, but it is followed by two divisions.
- Net result of meiosis is 4 cells , because of evens that occur during meiosis the 4 daughter cells are not identical to the each other or the parent cells.
- Each daughter cell only contains n chromosomes, hald the number in the mother cell.
- Upon fertilization the 2n number of chromosomes is restored.
- Meiosis assures 3 things
  1) That the chromosome number will be stable from generation to generation
  2) That each offspring resulting from sexual reproduction will receive two entire sets of genetic instructions
  3) That genetic diversity is promoted among the product.
- Only occurs in sexually reproducing organisms.

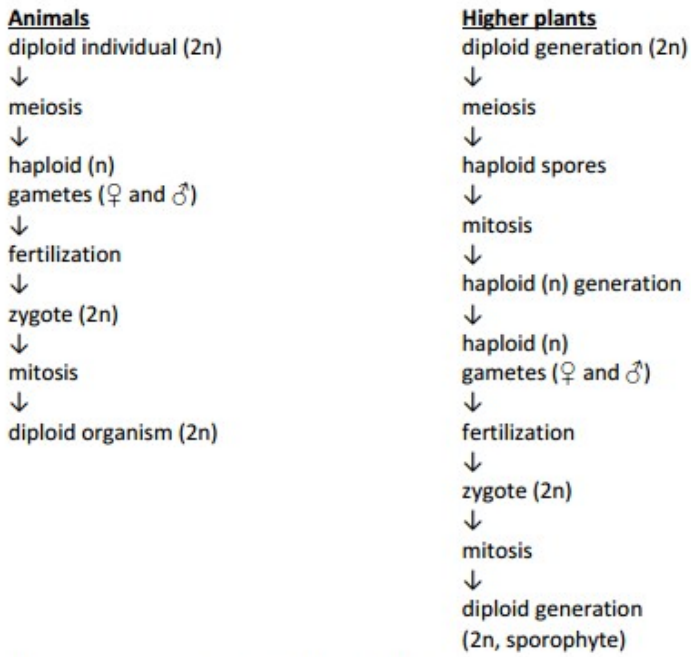


Fig 5.1: Comparison between meiosis in animals and plants

In most animals, an alternation of **ploidy level** also occurs. The diploid individual produces haploid gametes by meiosis (**gametogenesis**). Male and female gametes fuse to form a

- **Meiosis I**

- **Premeiotic interphase :** composed of sub stages similar to the mitosis stages. Although S phase in meiosis is a lot longer than mitosis S phase. Chromosome replication (DNA and proteins) occurs during this stage. Results in two identical sister chromatids attached at the centromere.
- **Prophase I:** homologous chromosomes pair, recombination occurs and large amounts of RNA are synthesized. This is one of the longest stages in meiosis ranging from wees to years. 5 substages.
- **Anaphase I:** The centromeres of the doubled chromosomes do not split, but the complete homologues are pulled away from each other toward opposite poles.
- **Telophase I :** Chromosomes decondense, spindle breaks down and nuclear membrane reforms. Cytokinesis continues, resulting in two daughter cells, each with half the number of chromosomes, but with each containing two chromatids.
- **Interkinesis:** stage between part I and II , no DNA replication occurs. Centrioles don't duplicate.

Stages of Meiosis II

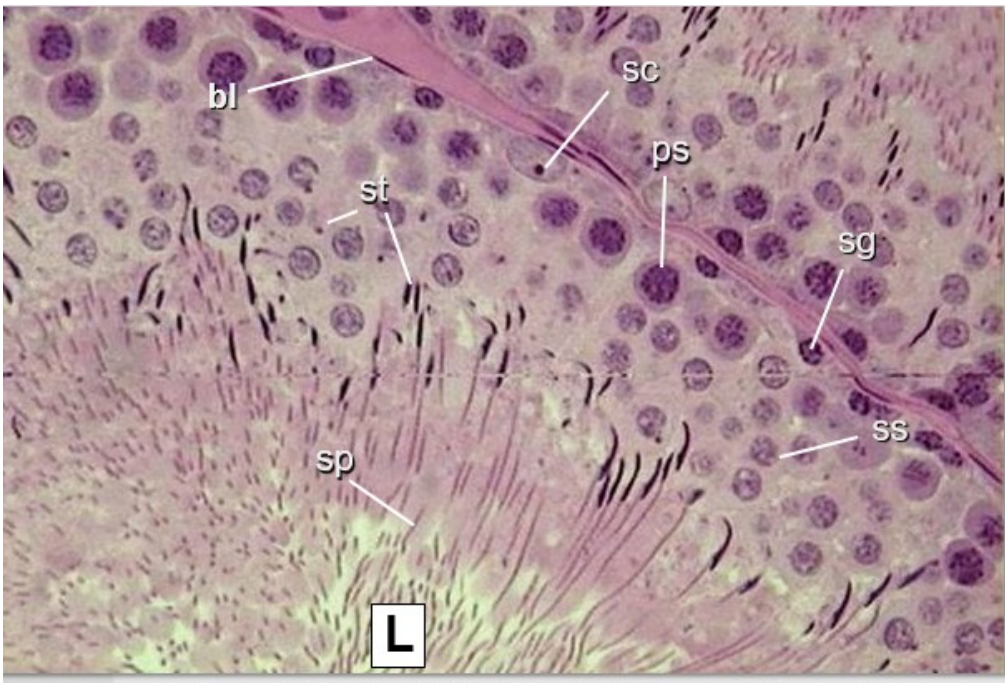
- **Prophase II:** The nuclear envelope breaks down and chromosomes recondense. Spindle forms with kinetochores attached to spindle microtubules. Chromosomes begin to move to equator.
- **Metaphase II:** the chromosomes, line up at the metaphase plate.
- **Anaphase II:** Sister chromatids separate and move to opposite spindle poles. Cytokinesis is delayed in this stage.
- **Telophase II:** Chromosomes decondense, nuclear membranes form around each product, nucleoli reform and cytokinesis finishes. After cytokinesis , 4 haploid cells are present.

Meiosis in Animals:

- In formation of the male gametes(**spermatogenesis**) four viable sperm are produced from each pair of meiotic divisions.
- In the female (**oogenesis**) , whole cytoplasm and stored food must be retained in the egg for use of the developing embryo.

Gametogenesis in mammals:

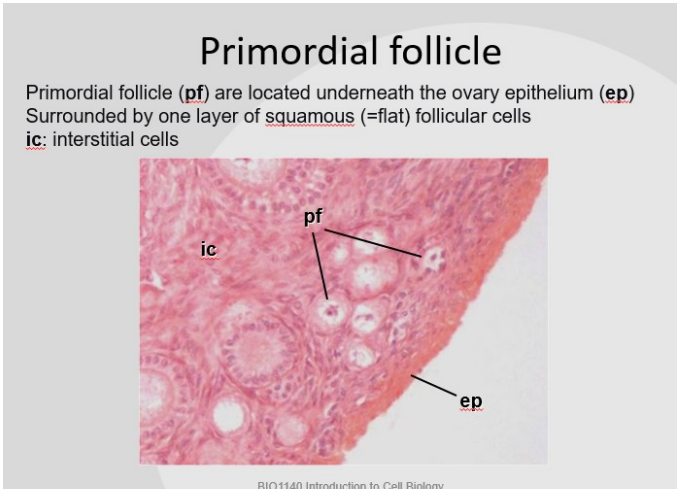
- **Spermatogenesis:** can be observed within the cross section of one tubule.
  1. **Spermatogonia (2n)-** large darkly stained outer cells with well defined nuclei. Divide by mitosis to produce more spermatogonia.
  2. **Primary Spermatocytes(2n)-** Located just below the spermatogonia and not as darkly stained, they are larger undergoing first meiotic division.
  3. **Secondary spermatocytes (2n)-** Smaller than primary and closer to lumen. Product of first meiotic division. Harder to observe bc they rapidly go into meiosis II to produce spermatids.
  4. **Spermatids(n)-** small circular cells differentiate into functional spermatozoa.
  5. **Spermatozoa (n)-** upon maturity these are easily recognizable by their very long thing flagellum bordering the lumen.



bl: basal lamina, L: lumen of the tubule, sc: sertoli cell nucleus, sg: spermatogonia, ps: primary spermatocyte, ss: secondary spermatocyte, sp: sperm cells (cross section), st: spermatids

Oogenesis:

- Female already contain all **oogonia** shell ever need during her reproductive years.
- **Primary follicles:** are numerous small round structures at the periphery of the ovary. Contains one oogonium (2n) filling most of the space within one layer of follicular cells.
- **Growing follicles:** larger follicles with a few layers of follicular cells. Each growing follicle contains primary oocyte or secondary oocyte in its small fluid filled cavity.



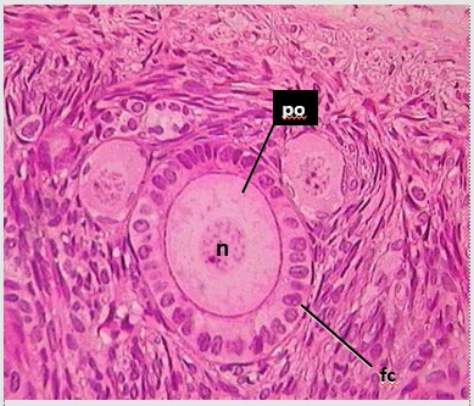
Primary unilaminar follicle

Located deeper in the ovary

Surrounded by one layer of cuboidal follicular cells (**fc**)

Contains a primary oocyte (**po**)

n: oocyte pronucleus



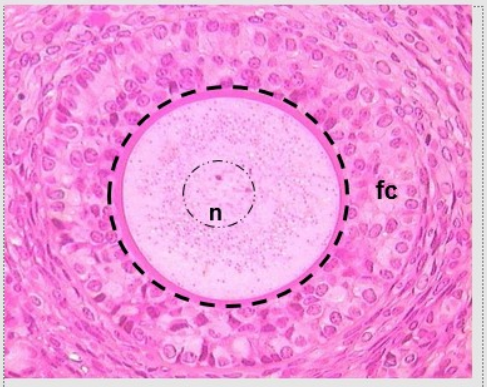
Growing follicle (primary multilaminar):

Slightly deeper in the ovary

Surrounded by several layers of follicular cells (**fc**)

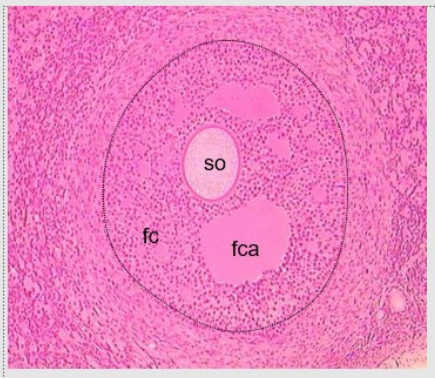
Contain primary oocyte (dash lines).

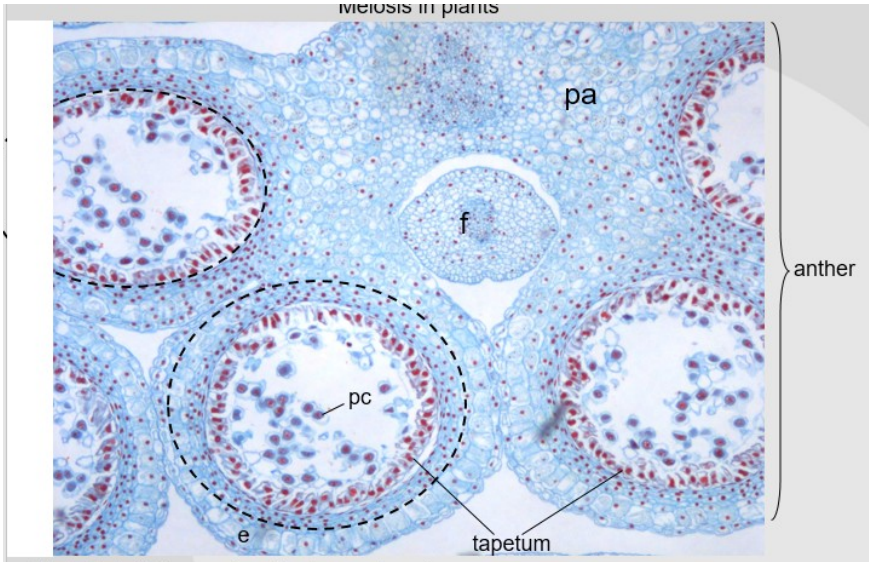
n: oocyte pronucleus



Mature or Graafian Follicle

- Largest follicle
- Many layers of follicular cells (**fc**)
- One big or several fluid-filled cavities (**fca**)
- Contains secondary oocyte (**so**) stopped in metaphase II = mature oocyte
- Comes near to ovarian epithelium prior to ovulation





Meiosis in *Lillium* anther (early prophase):
e: epidermis; f: filament; pa: parenchyme; pc: pollen cell precursor (prophase)
( ) pollen sacs (microsporangia)

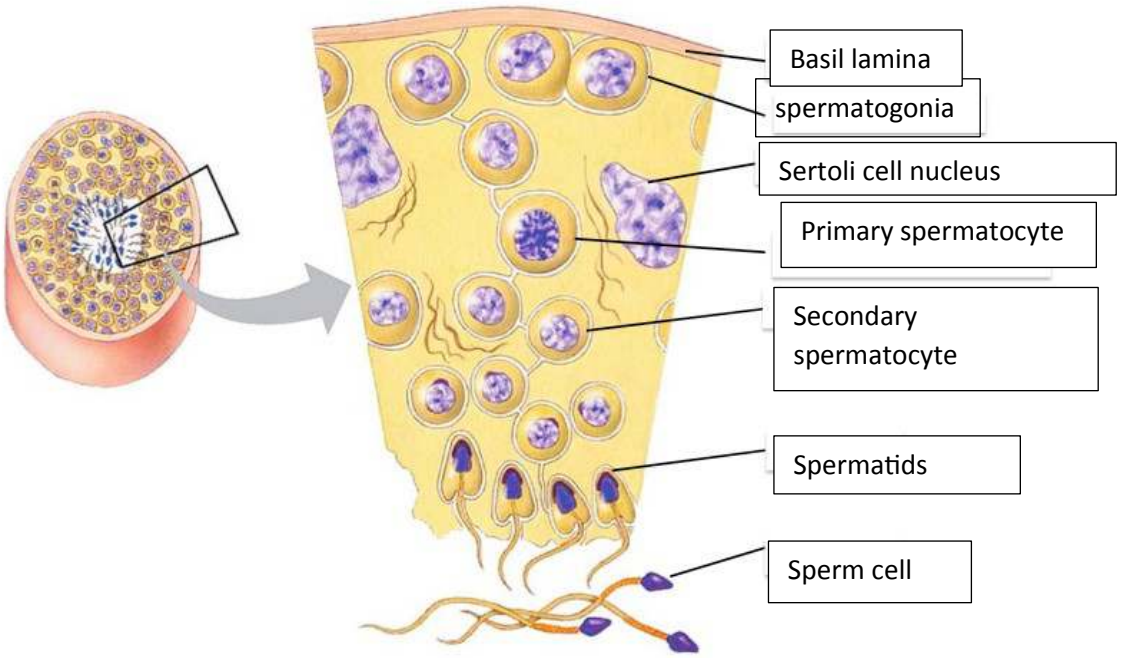


Table 1: Characteristics of Mitosis versus Meiosis

Mitosis	Meiosis
(1) Sister chromatids separate at anaphase.	(1) The first stage is a reductive division which separates homologous chromosomes at first anaphase; sister chromatids separate in an equational division during the second anaphase.
(2) One division per cycle	(2) Two divisions per cycle
(3) Chromosomes fail to synapse; no chiasma forms; genetic exchange between homologous chromosomes does not occur	(3) Chromosomes synapse; chiasma forms; Genetic exchange occurs between homologues
(4) Two products (daughter cells) produced per cycle	(4) Four cellular products (gametes or spores) produced per cycle.
(5) Genetic content of mitotic products is identical	(5) Genetic content of products is different; chromosomes may be replicas of either maternal or paternal chromosomes or various combinations of both.
(6) Chromosome number of daughter cells is the same as that of the mother cell.	(6) Chromosome number of meiotic products is half that of the mother cell
(7) Mitotic products are usually capable of undergoing additional mitotic divisions	(7) Meiotic products cannot undergo another meiotic division although they may undergo a mitotic division
(8) Normally occurs in most somatic cells.	(8) Occurs only in specialized cells of the germ line

Instructions for the lab report can be found on the lab website

Lab exam covers all specimens observed in lab5 (as well as those observed in the other labs).

APPENDIX-

1. Quantitative variables are placed along one axis only, in the __**yaxis**_____ axis for vertical bar graphs.
2. _____**Histograms**_____ have quantitative scales along both axes.
3. _**Straight line graphs**_____ graphs are used when many data points (n>30) are available at constant intervals, in order to see trends or changes in a variable through time.
4. ____**Scatterplots**_____ are used to investigate the relationship between two different sets of data.
5. While the graph takes up 2/3 of the page, the bottom 1/3 should be used for the _____**Caption**_____.
6. Only _____**labelled?**_____ tick marks can be placed per quantitative axis, but there is no limit in the qualitative axis.
7. If means are plotted, _____**error bars**_____ bars must be indicated and be slightly less prominent than the data points.
8. For more than 2 symbols used, a _____**key**_____ should be created. Less than 2 symbols can be described in the caption.
9. When underlying the genus and species, each must be underlined ___**when hand written.**_____.
10. The caption is located _____**below**_____(above/below?) the table body.
11. No _____**vertical**_____ lines should be used when creating a table.
12. ___**IV/Footnotes**_____ may be used to explain an abbreviation, symbol or term in the caption, heading or body of the table.
13. The biological drawing should be located either in the center or slightly to the _____**left**_____ of the page, and should take up about _____**half**_____ the page.
14. Should a frame be present around your drawing? __**no**_____
15. Should there be shading, stippling and cross-hatching? _____**no**_____
16. All labels should be located _**on the drawing**_____, not off to the side. If needed, a ___**Pointer**_____ can be used, which is a straight line.

17. No unlabeled structures should be shown, and a _____**a scale bar**_____ bar should be presented in the bottom right corner of the diagram.
18. The caption should be located immediately ____**below**_____ the drawing and begin with a figure number.
19. Abbreviations used on the drawing must be listed at the _____**end**_____ of the caption alphabetically.

Non-SI units sometimes used:

litre (L or l) as a special name for dm^3, used to measure volume.
Angstrom (Å) as special name for 10^{-10}m (100pm) (should not be used).
Minute (min), hour (h), day (d) for the quantity of time.
Degree Celsius (°C) for thermodynamic temperature: temperature (°C) = temperature (K)-273.15

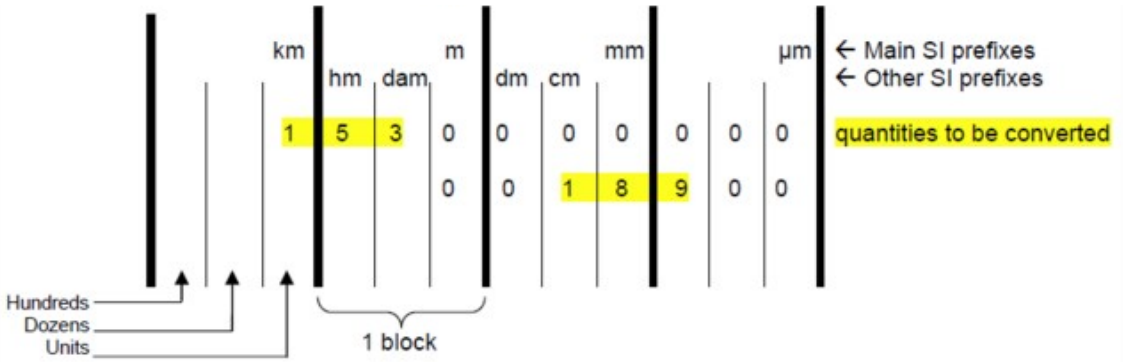
SI prefixes:

SI prefix	SI symbol	Decimal value	10^x (scientific) value
pico-	p	0.000000000001	10^{-12}
nano-	n	0.000000001	10^{-9}
micro-	μ	0.000001	10^{-6}
milli-	m	0.001	10^{-3}
centi-	c	0.01	10^{-2}
deci-	d	0.1	10^{-1}
(no prefix)		1	10^{0}
deca-	da	10	10^{1}
hecto-	h	100	10^{2}
kilo-	k	1,000	10^{3}
mega-	M	1,000,000	10^{6}
giga-	G	1,000,000,000	10^{9}
tera-	T	1,000,000,000,000	10^{12}

Adapted from Let's get ready for biology – Pearson Benjamin Cummings ©2005-2007

External references:

Prefixes: http://www.bipm.org/en/si/si_brochure/chapter3/prefixes.html
Base units: http://www.bipm.org/en/si/base_units/



How to Use the Table

This table consists of repeated **blocks**, each containing 3 columns (the left and right borders of each block are thicker to make it easier to read).
Each column represents one prefix of a given SI unit (in the example above, prefixes of the metre).

In the right column of each block (*units* column), write down the main SI prefixes (i.e. kilo-, base, milli-, micro-, nano- etc....) of the unit you're working with.

Optional: enter secondary prefixes (hecto-: h-, deka-: da-, deci-: d- and centi-: c-) in the appropriate columns if needed. Read the SI Units appendix if needed.

In order to convert a quantity, write down its value in the appropriate column (see example below). You may then add as many zeros on the left and right sides as you need.

Example:
Measured quantity: 1.53 km.
1. First, enter the quantity in the table: put 1 in the km column, then 5 then 3 in the columns immediately at the right. You don't have to write the dot separating the decimals. You're done!
2. You're done! You now can easily read directly in the table that 1.53 km = 153 dam, 1530 m, 153000 cm and 1530000000 um.