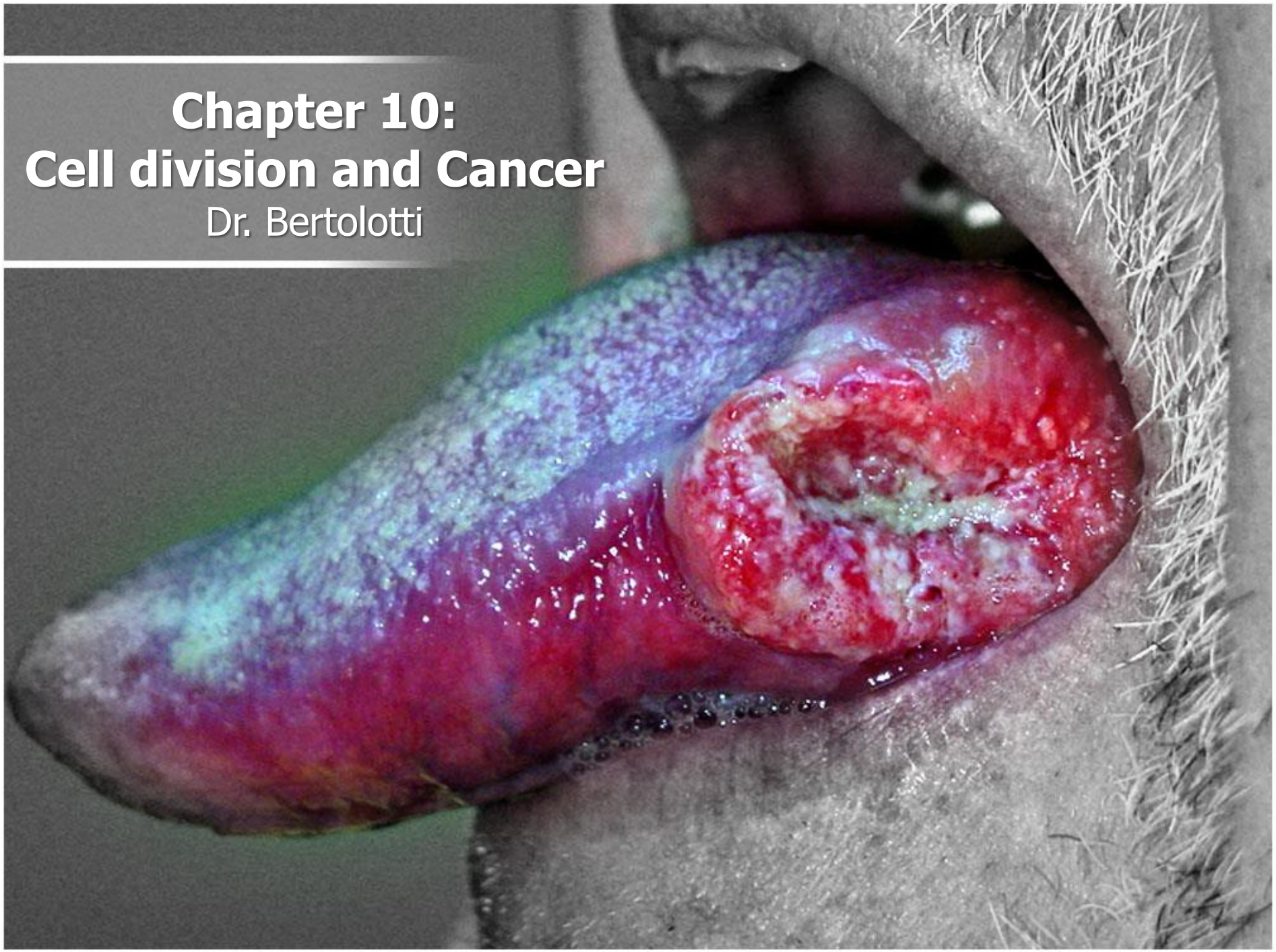
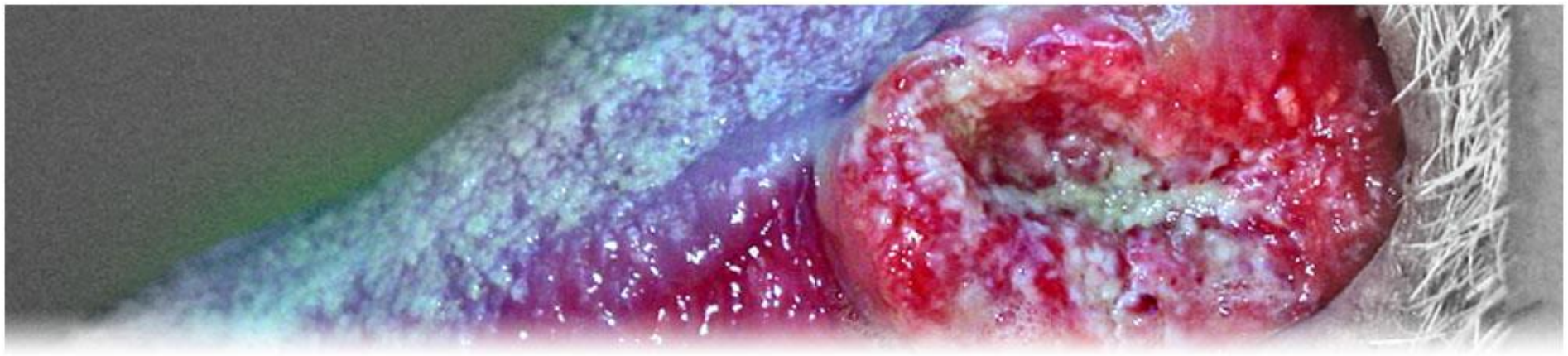
Chapter 10:
Cell division and Cancer

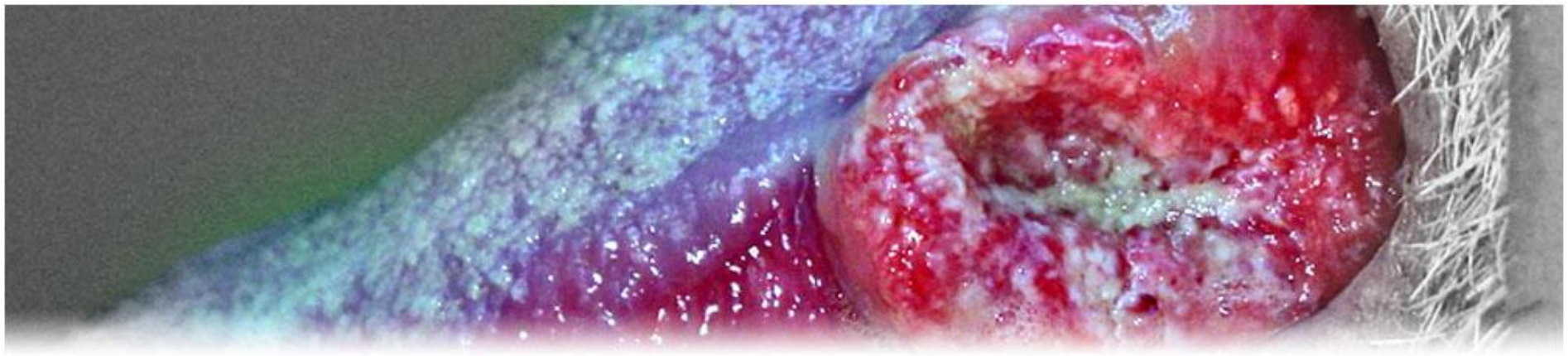
Dr. Bertolotti



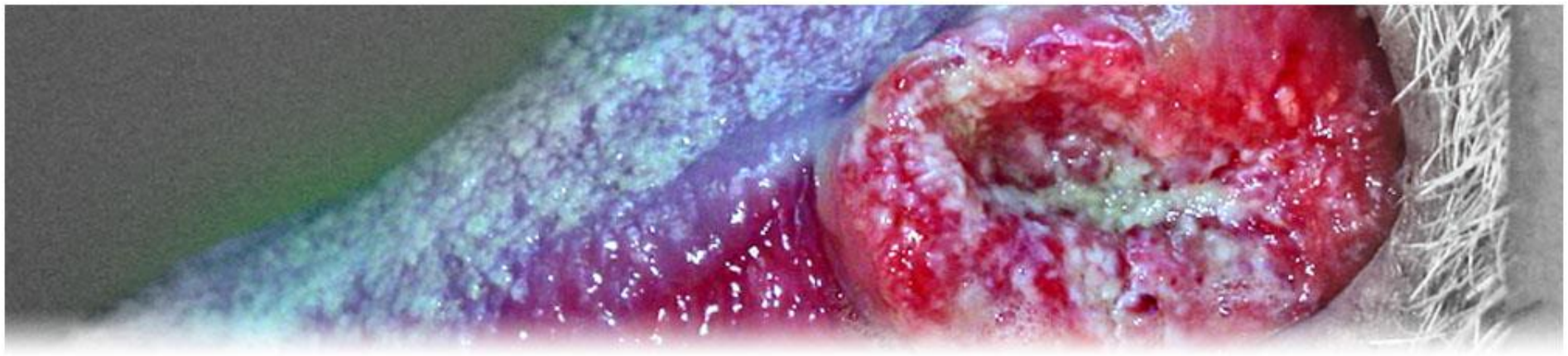


Essential Question

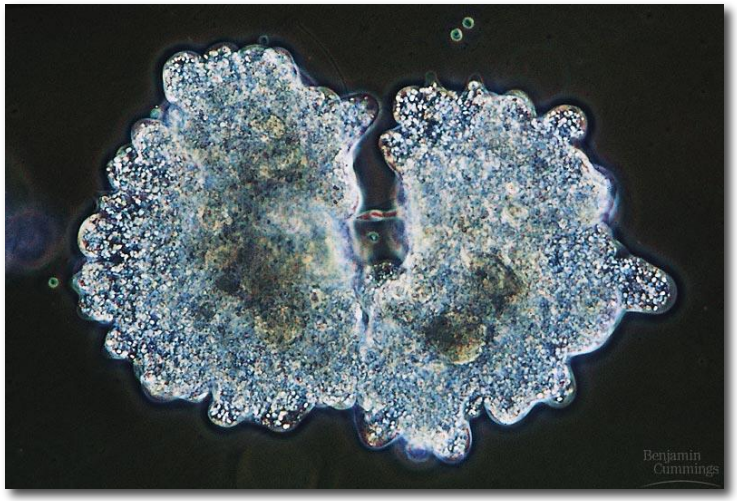
- How does a cell produce a new cell?

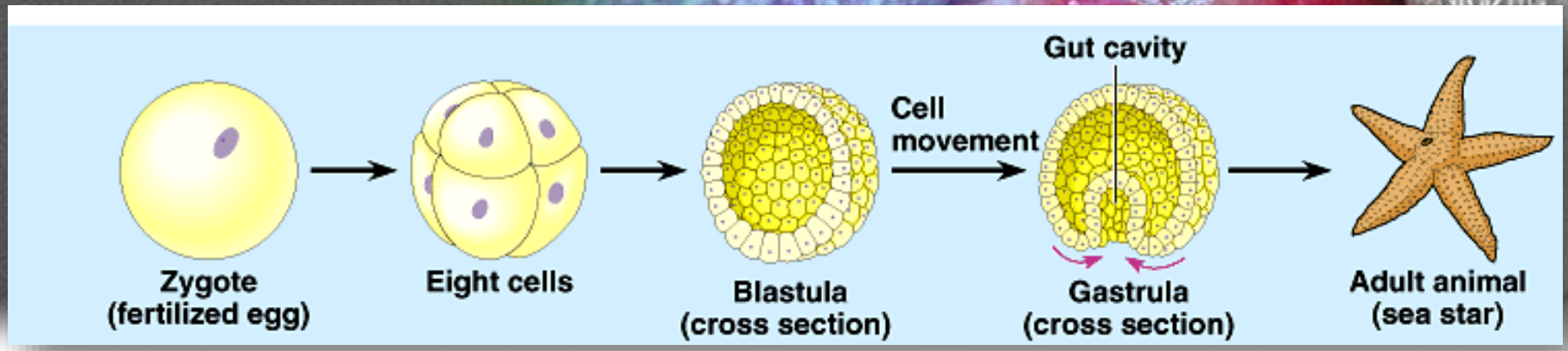


How do asexual and sexual reproduction compare?

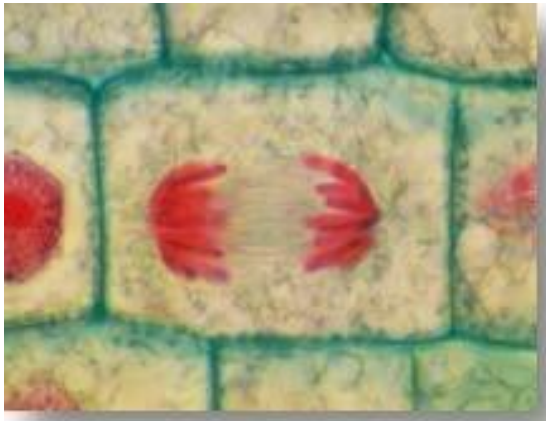


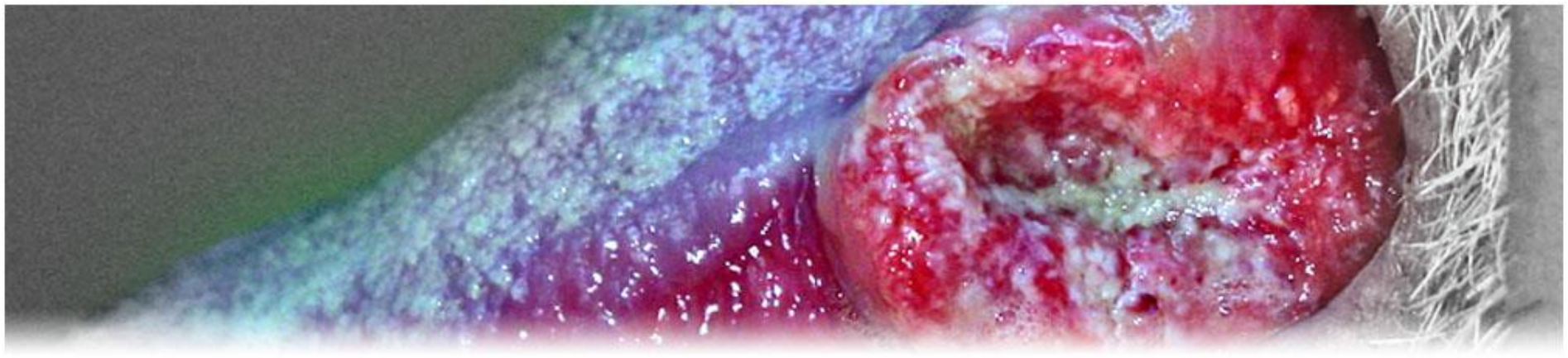
Biology is the only subject in which **multiplication** is the same thing as **division**…





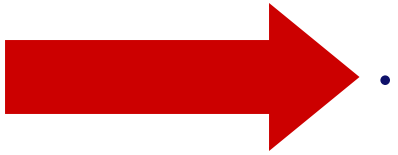
MITOSIS:
Making New Cells
Making New DNA





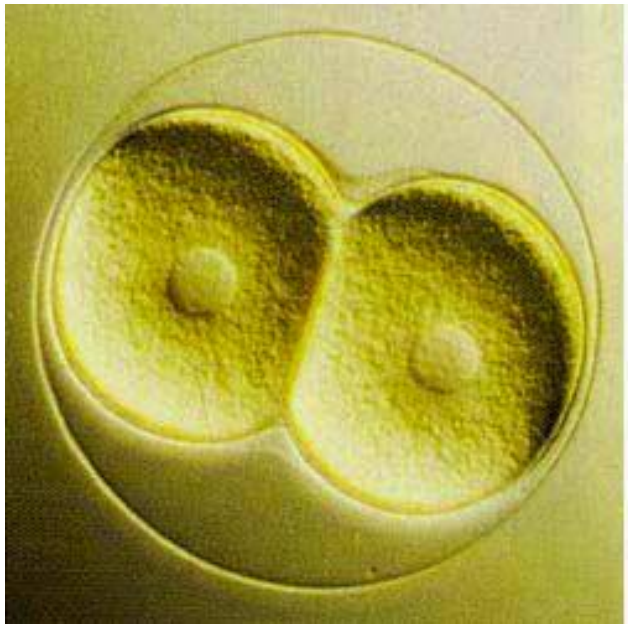
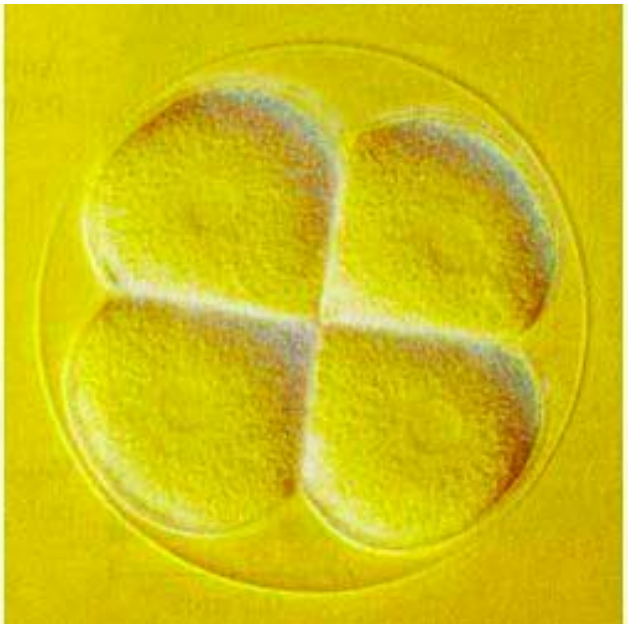
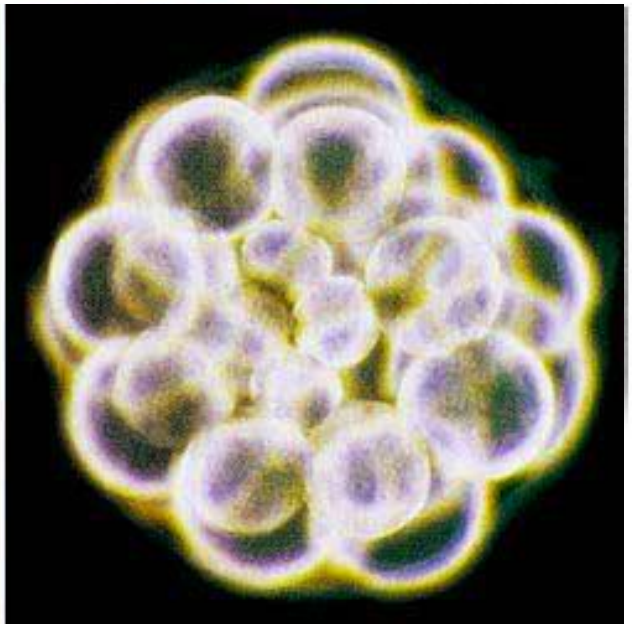
Where it all began…

You started as a cell smaller than a period at the end of a sentence…



And now look at you...

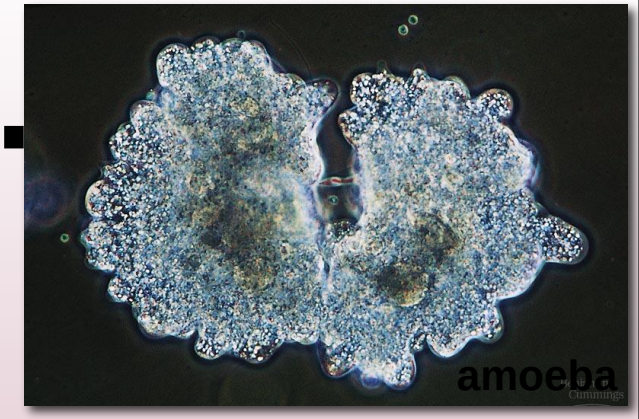
How did you get from there to here?

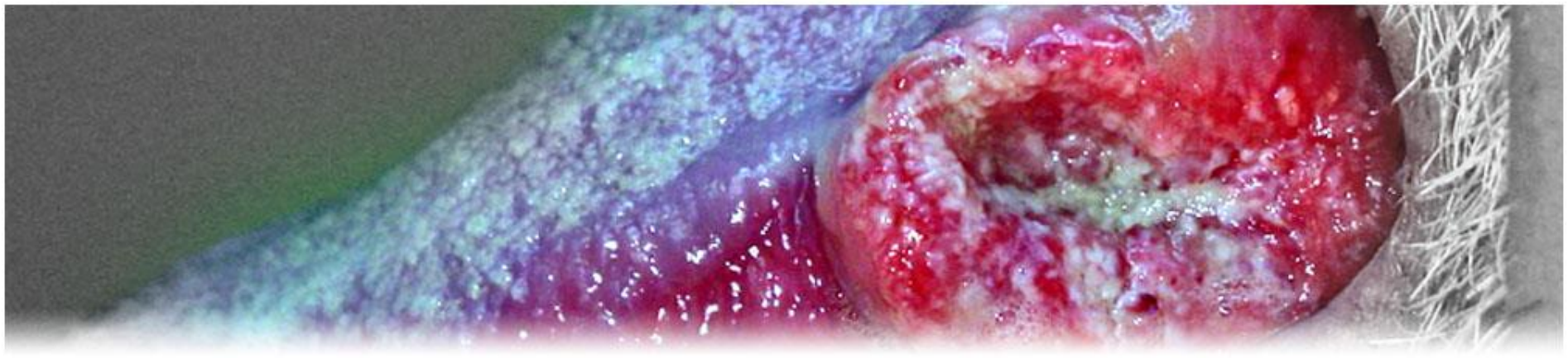
Getting from there to here…

- Going from egg to baby….
  - the original fertilized egg has to divide…
    - and divide…
      - and divide…
        - and divide…

Why do cells divide…

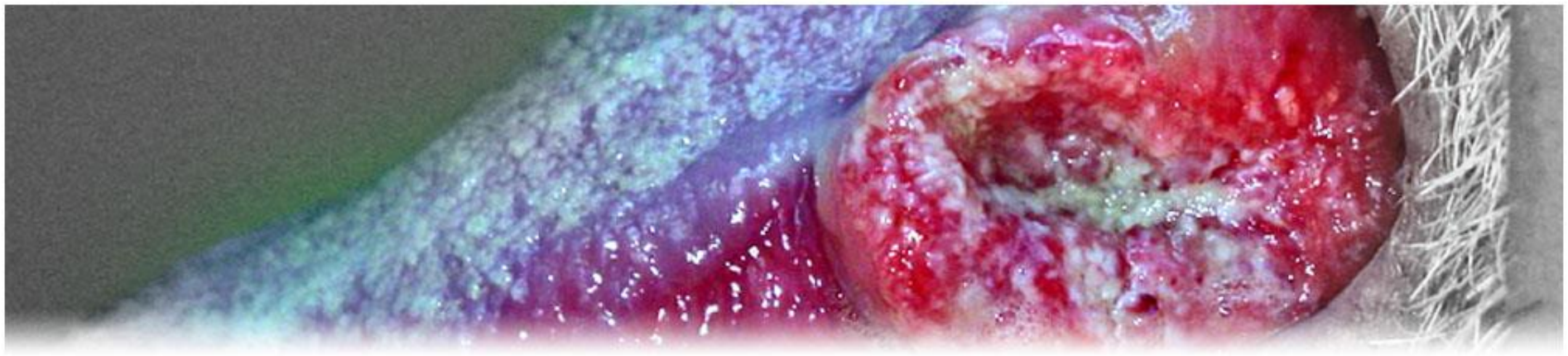


- One-celled organisms
  - for reproduction
  - asexual reproduction (clones)
- Multi-celled organisms
  - for growth & development
    - from fertilized egg to adult
  - for repair & replacement
    - replace cells that die from normal wear & tear or from injury



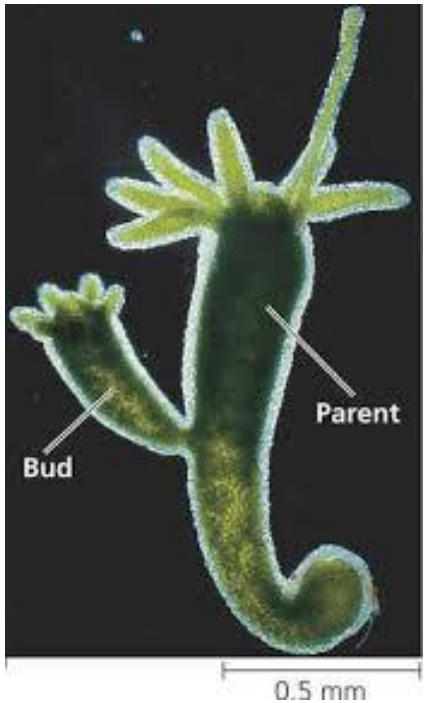
Asexual v. Sexual Reproduction

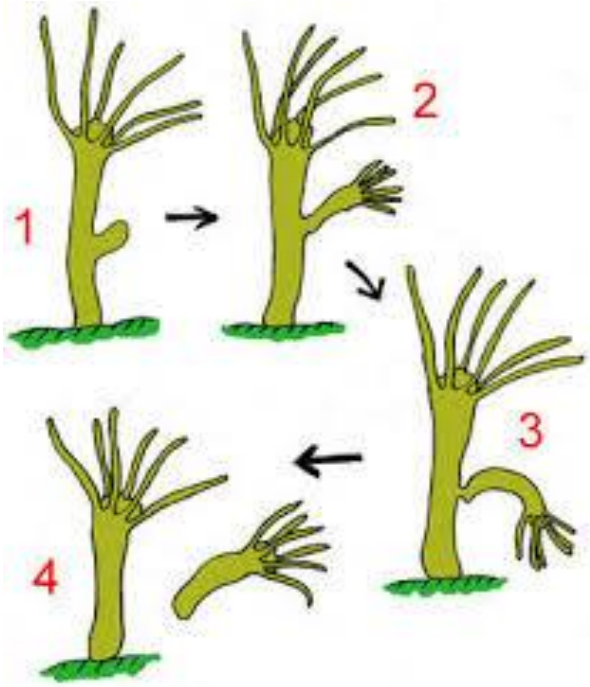
Asexual Reproduction	Sexual Reproduction
Only 1 parent required	Two parents are required
Offspring are genetically identical and ensure the survival of the population when the environment is stable	Offspring are genetically diverse and helps ensure that the population survives when the environment changes
Common among single-celled organisms and some multi-cellular organisms	Common among multi-cellular organisms such as plants and animals
Process is simple, efficient, and effective to produce a large population	Process is complex, energy-consuming, and effective
Examples of organisms that rely on this process include: bacteria, hydra	Examples of organisms that rely on this process include: humans, flowering plants



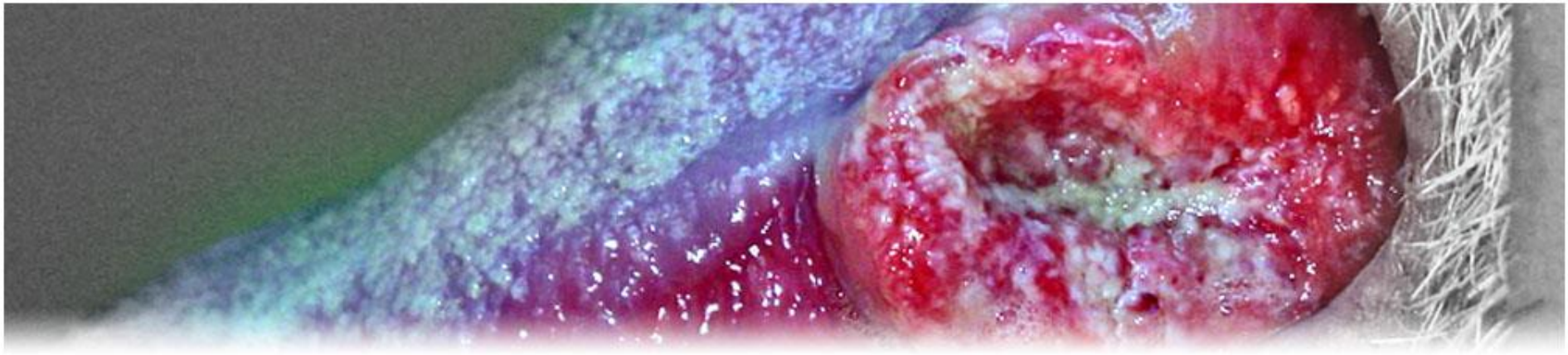
Budding

- Ex. Hydra (below) and yeast (on the bottom right)



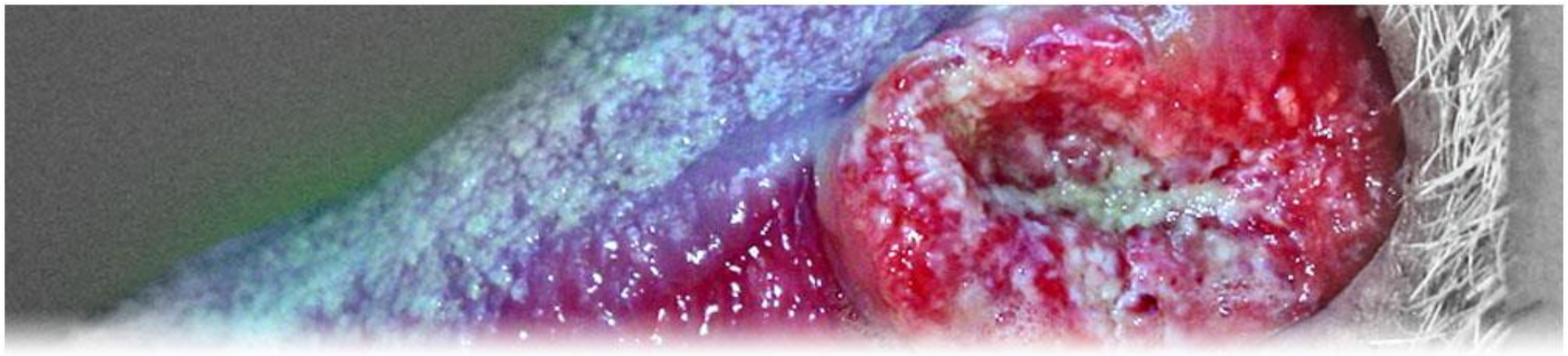


Budding Yeast (*S. cerevisiae*)



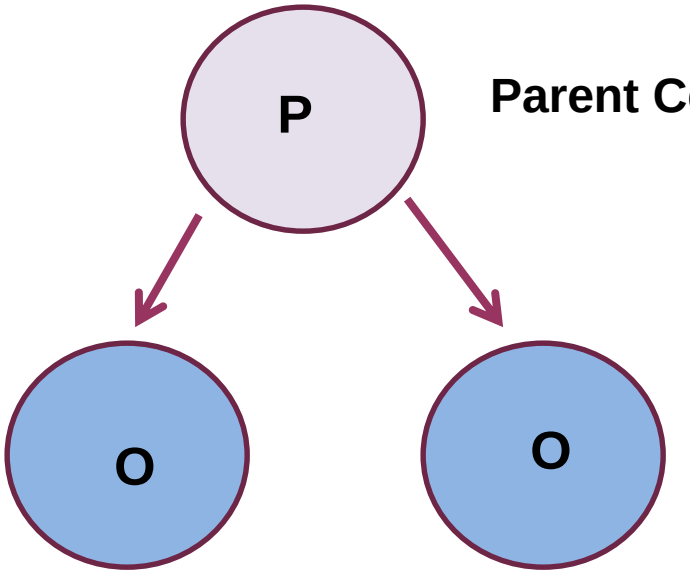
Vegetative propagation

- Ex. Strawberry and mint

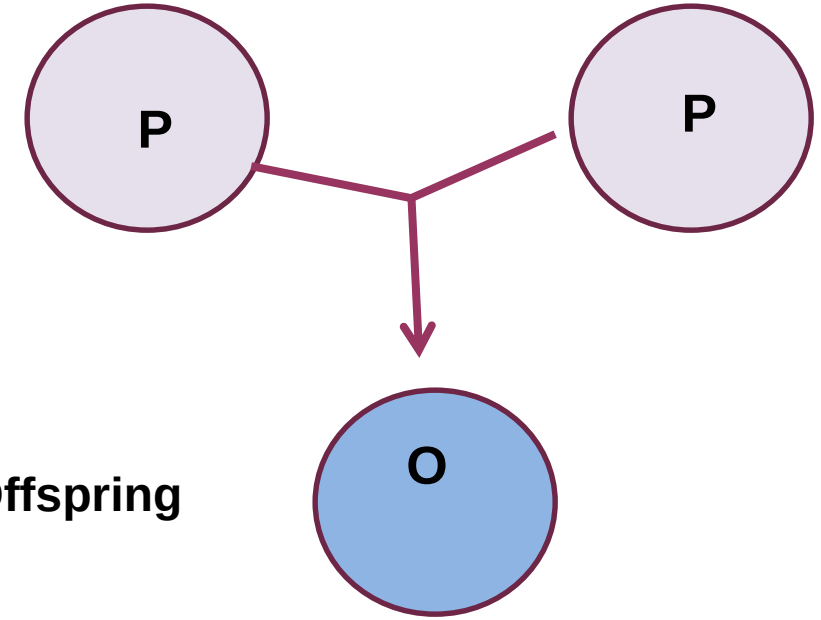


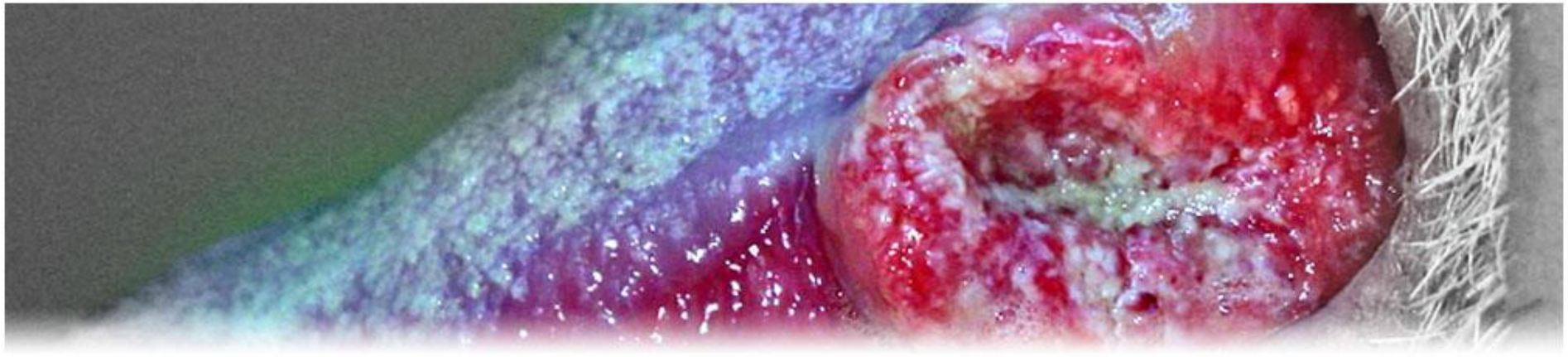
Asexual v. Sexual Reproduction

Asexual Reproduction



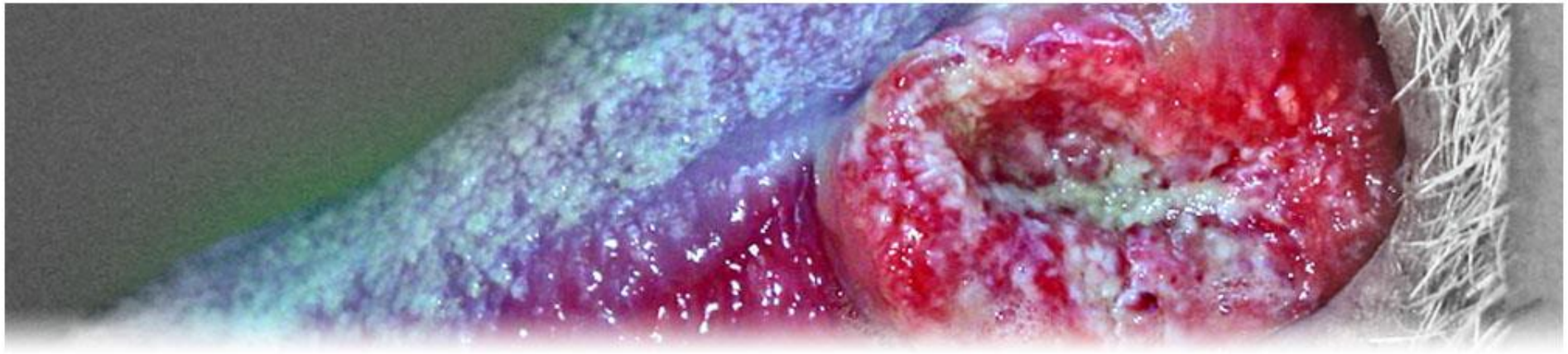
Sexual Reproduction



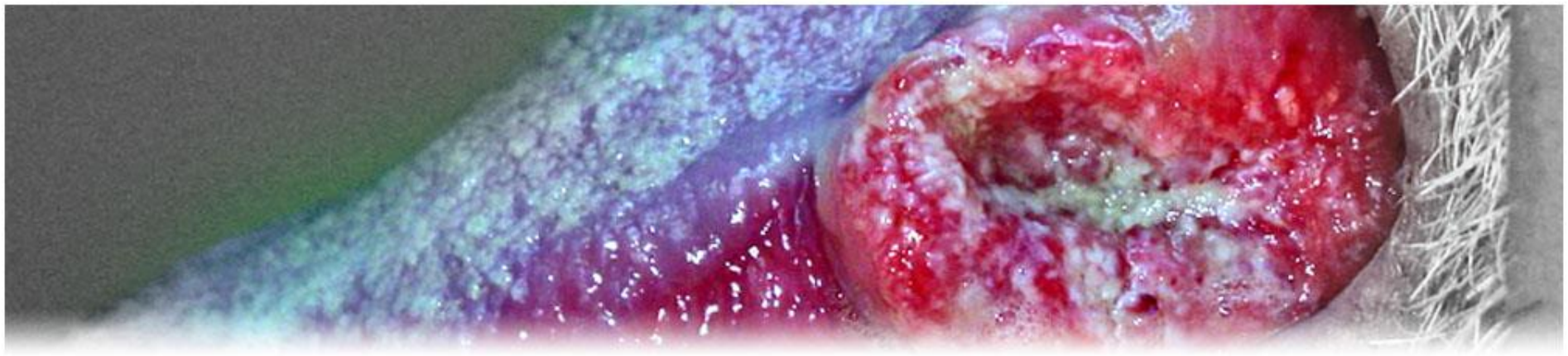


QUESTION AND ANSWER

How do asexual and sexual reproduction compare?

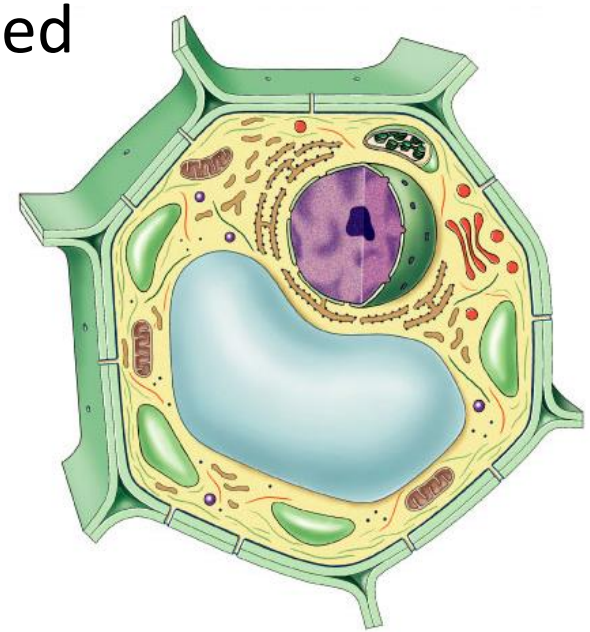


What events occur during each phase of the cell cycle?

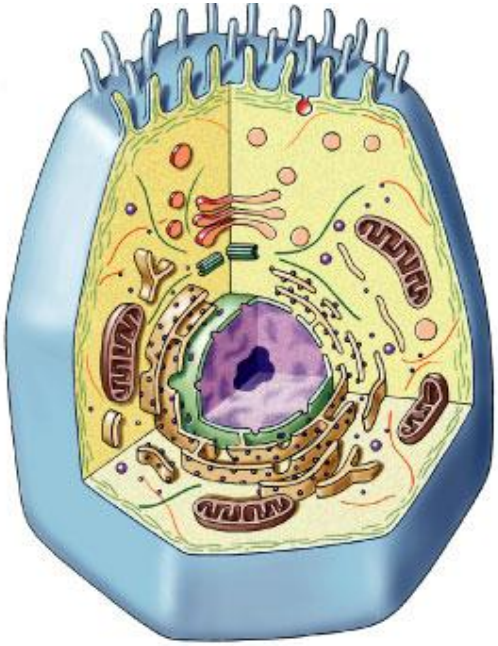


Dividing cells…

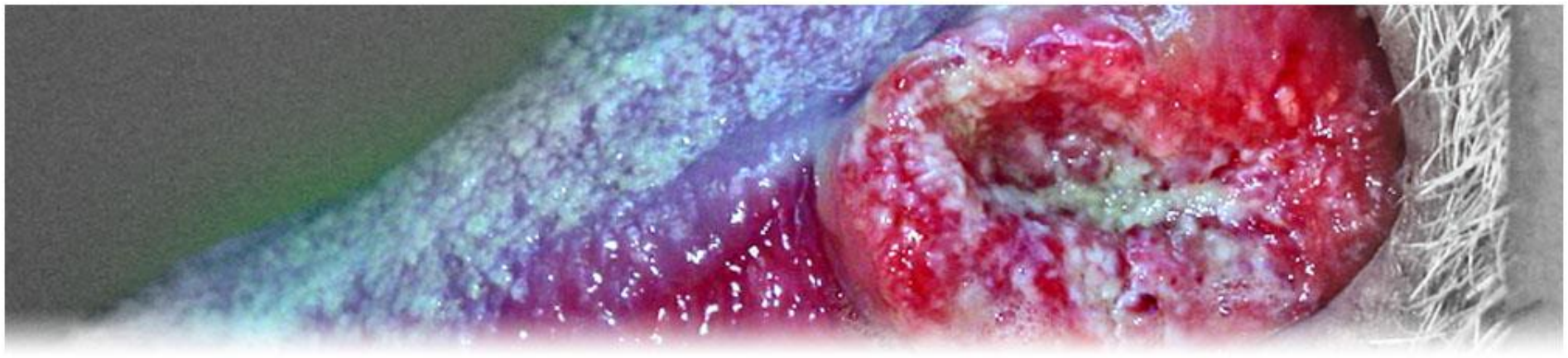
- What has to be copied
  - DNA
  - organelles
  - cell membrane
  - lots of other molecules
    - enzymes



plant cell

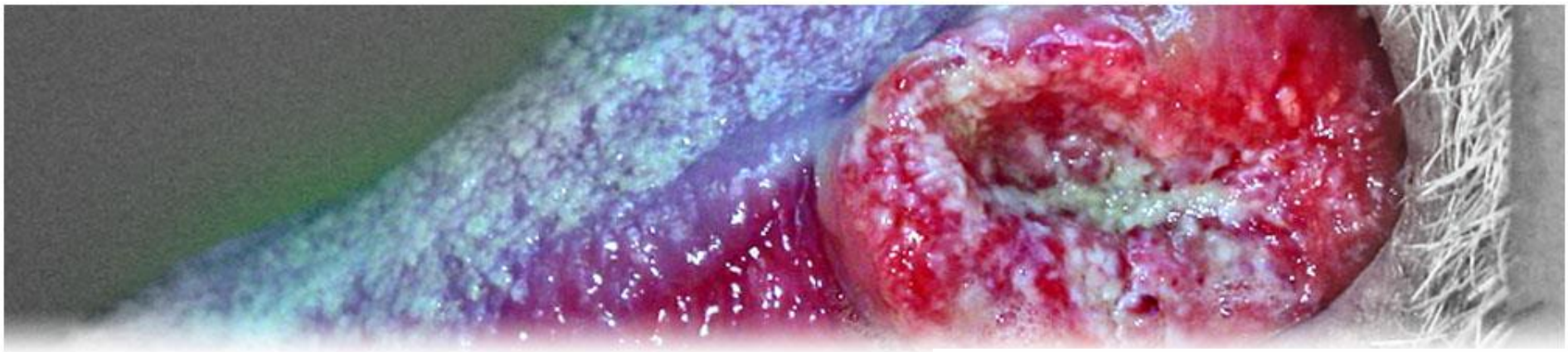


animal cell



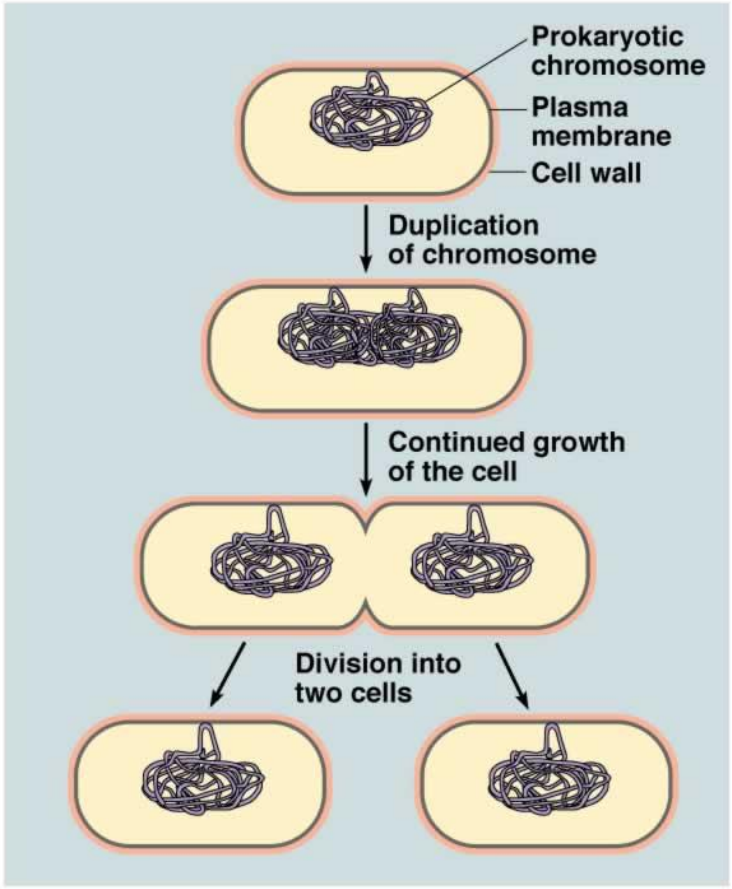
3 Types of Cell Division

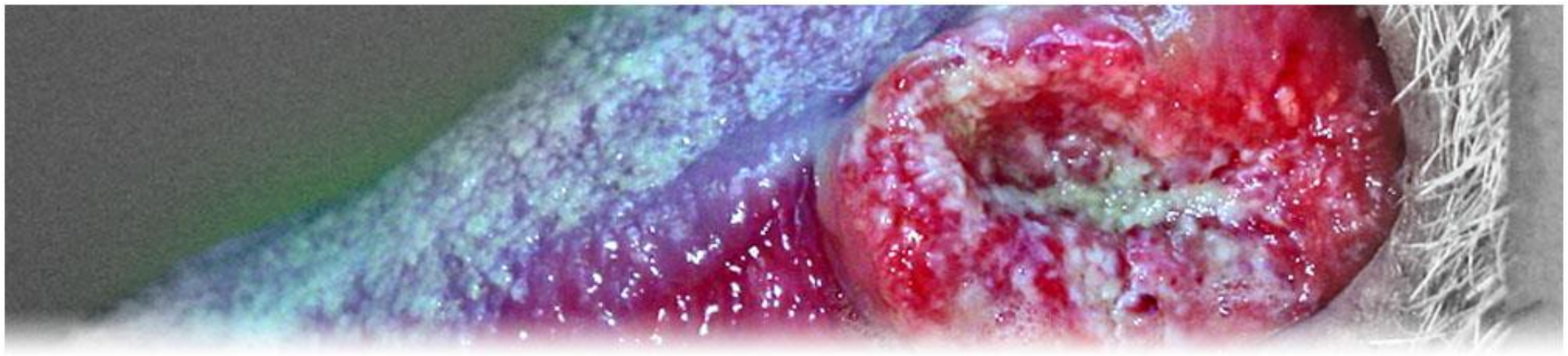
- Cell division is the process by which a cell divides into **2** new daughter cells. Before this process occurs, the cell replicates or copies its DNA.
- **1. Binary fission**
  - cell division in prokaryotes which produces clones
- **2. The cell cycle (mitosis)**
  - cell division in eukaryotes which produces clones
- **3. Meiosis**
  - cell division to form sex cells (egg and sperm)



Binary Fission

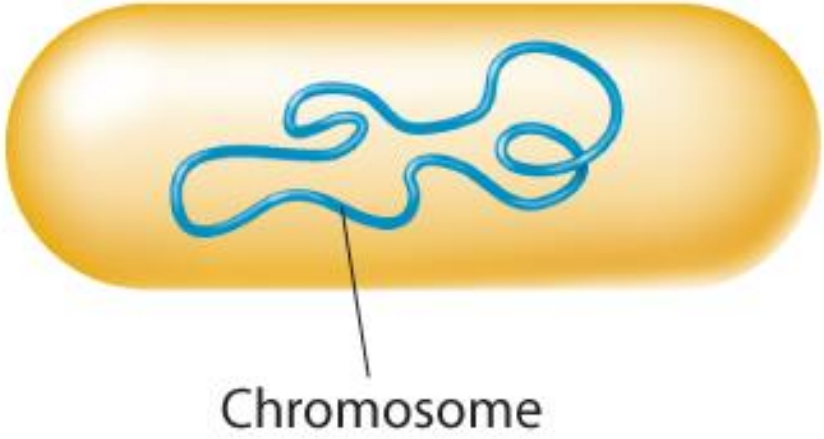
- Used by prokaryotes using circular DNA
- Results in two cells genetically the same (clones)
- Reproduction by binary fission is considered **asexual** as the products of binary fission are genetically identical to the parent cell

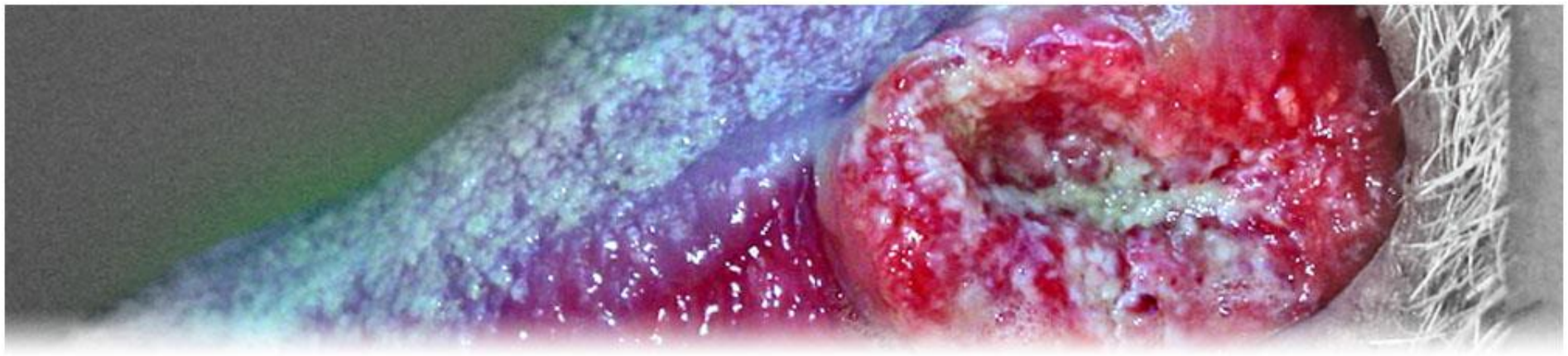




Prokaryotic Chromosomes

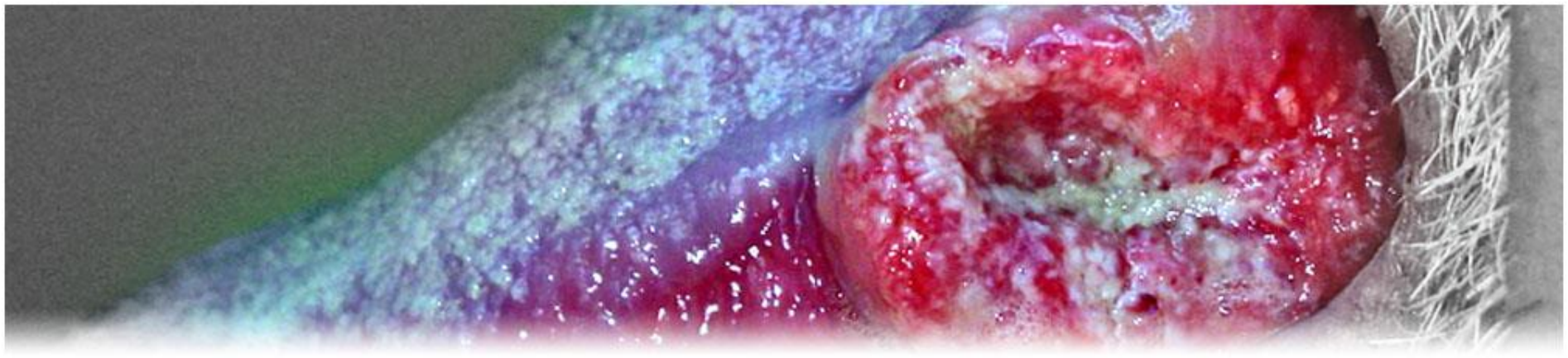
- Prokaryotic cells lack nuclei. Instead, their DNA molecules are found in the cytoplasm.
- Most prokaryotes contain a single, circular DNA molecule, or **chromosome**, that contains most of the cell's genetic information.





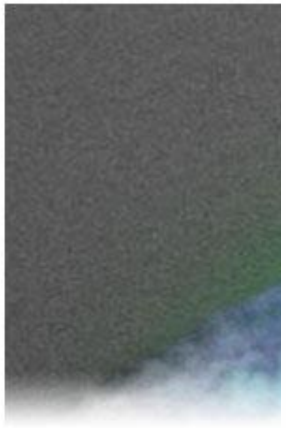
Eukaryotes

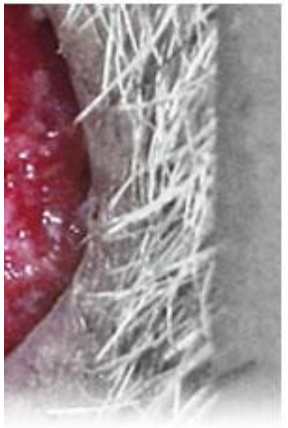
- The Cell Cycle is used for:
  - Growth and development (from fertilized egg to adult)
  - Repair or replacement of cells (replace cells that die from normal wear & tear or from injury)
  - Control size so nutrients can get in and waste can get out in a timely fashion
- Some cells die quickly and need to be replaced a lot (skin cells).
- Some cells never get replaced (nerve cells).
- Some organisms can regenerate whole body parts.

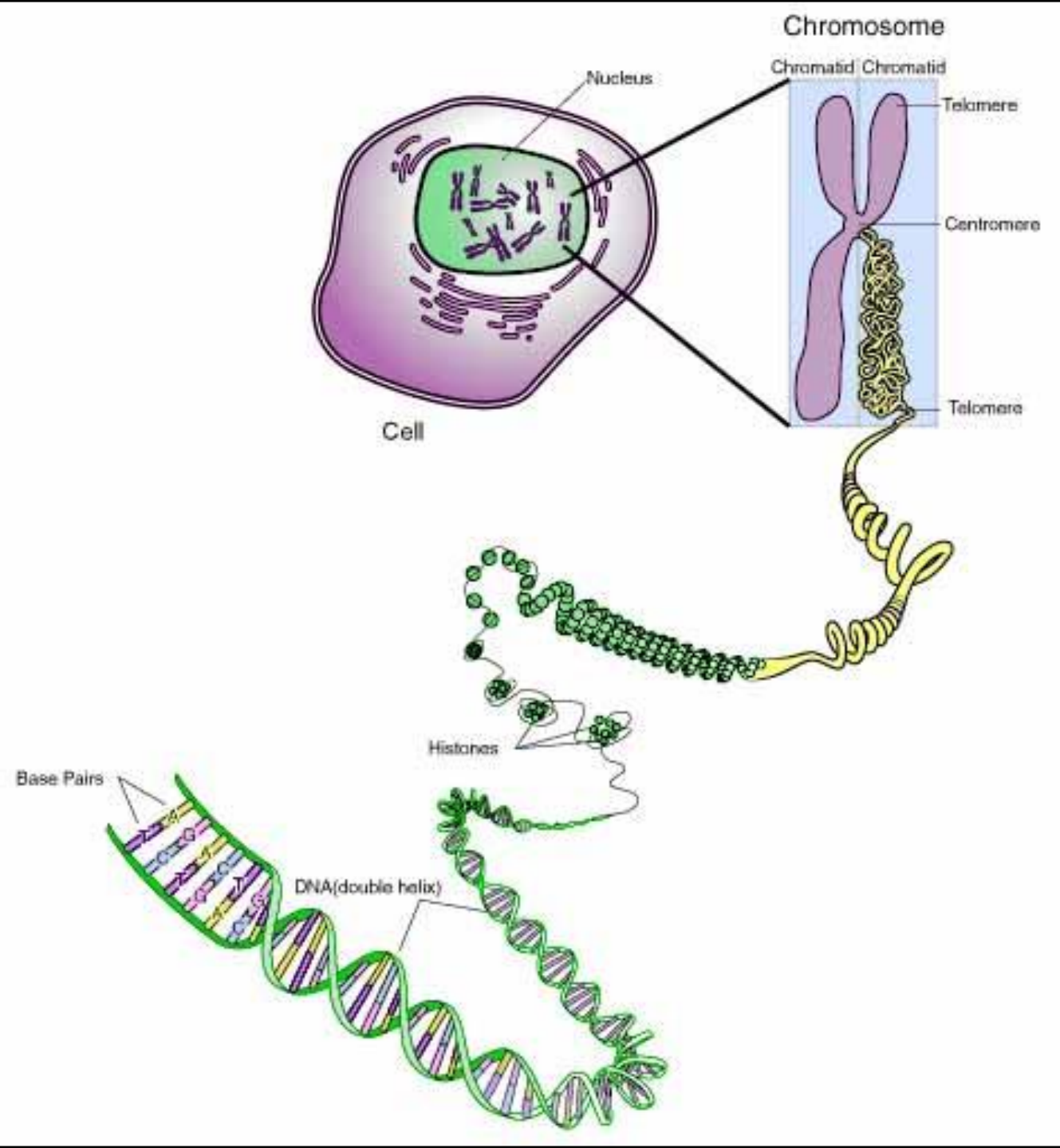


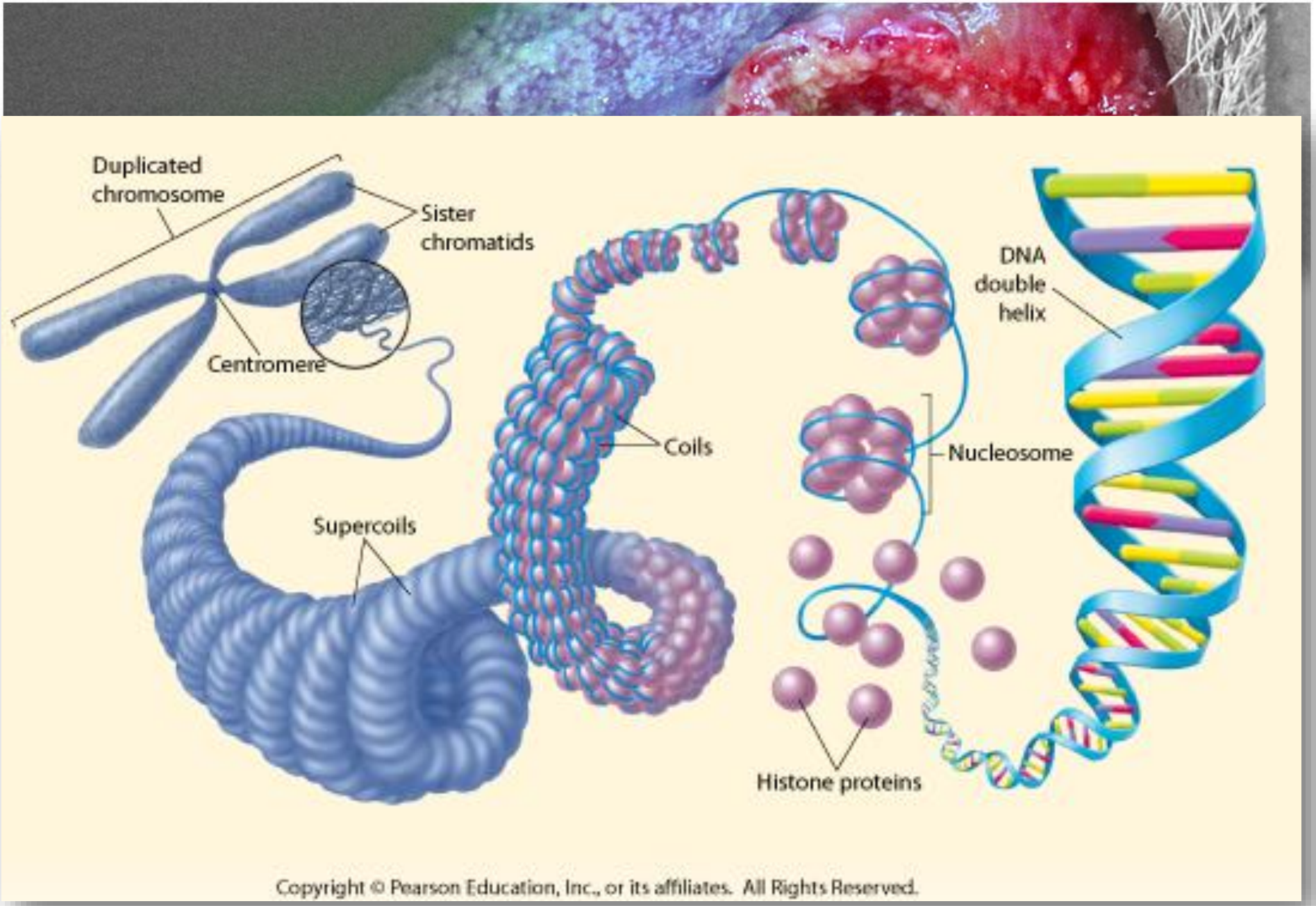
Chromosomes

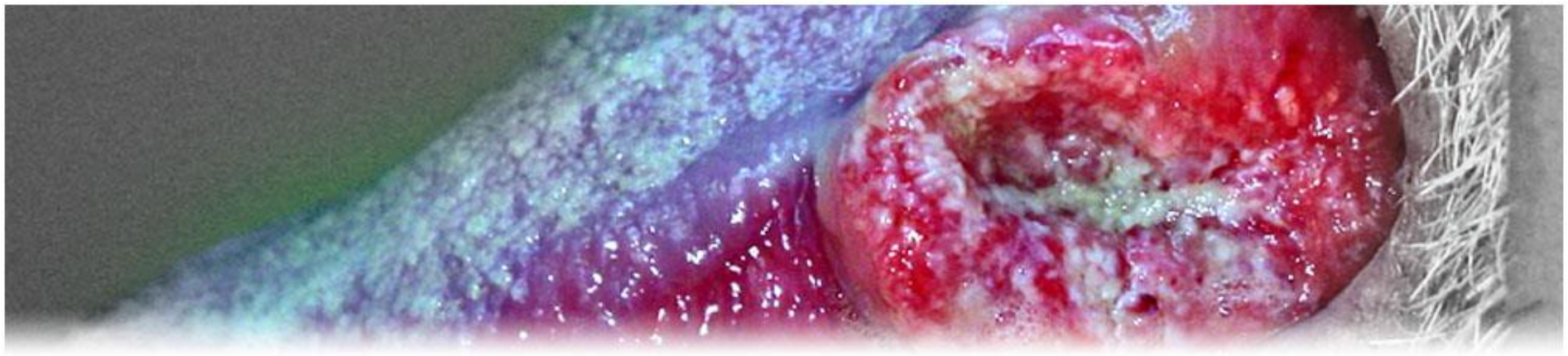
- In Eukaryotic cells, genetic information is passed from one generation to another by chromosomes.
  - Chromosomes are made of DNA and proteins.
  - The cells of every organism has a specific number of chromosomes, ex. human cells have 46 chromosomes. There are 2 sex chromosomes and 44 autosomes (chromosomes that do not determine the gender of an offspring)
  - They are not visible in most cells except during cell division because usually the DNA and protein molecules are spread throughout the nucleus, however during cell division they condense into compact, visible structures.



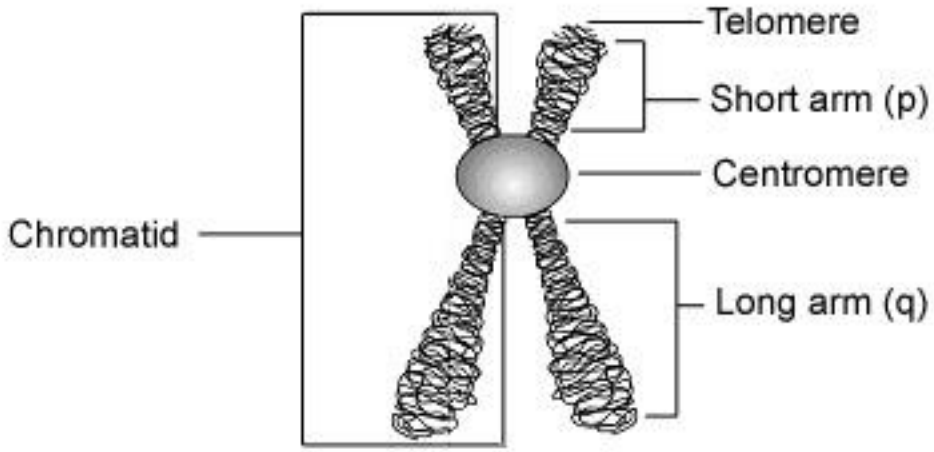


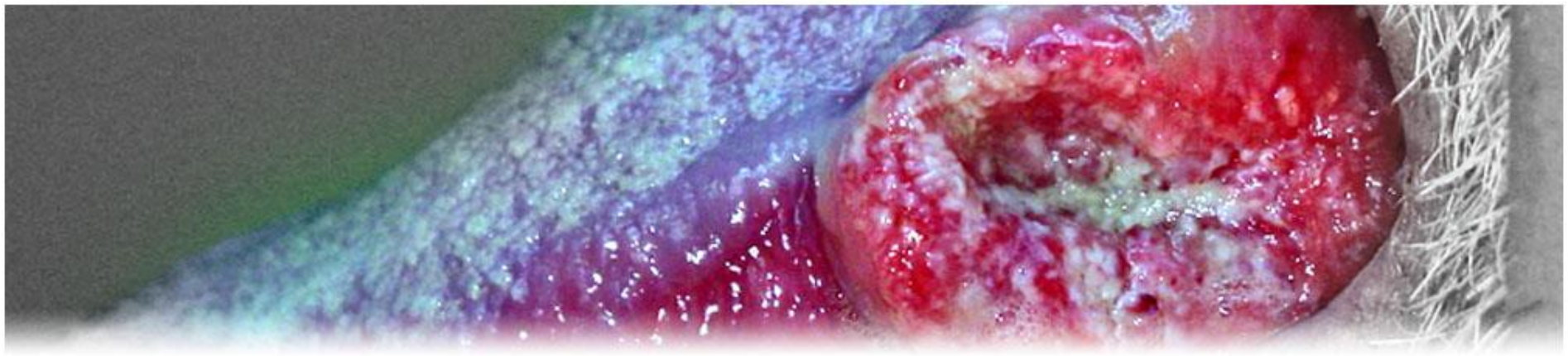

Chromosome
Chromatid
Chromatid
Nucleus
Telomere
Centromere
Telomere
Cell
Histones
Base Pairs
DNA(double helix)





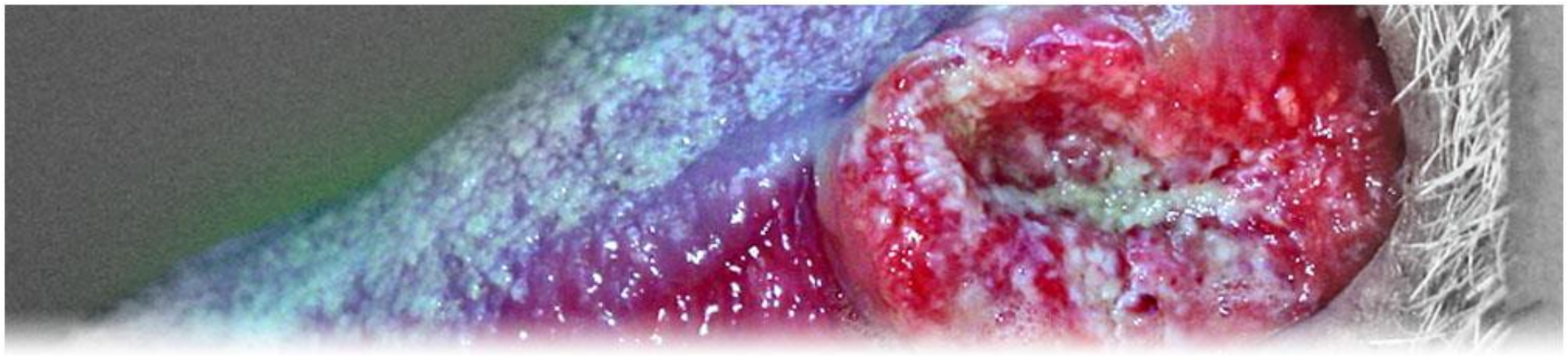
- Because of this, each chromosome consists of 2 identical "sister" **chromatids**
- During cell division, the chromatids separate
- Each pair of chromatids is attached at an area called the **centromere**



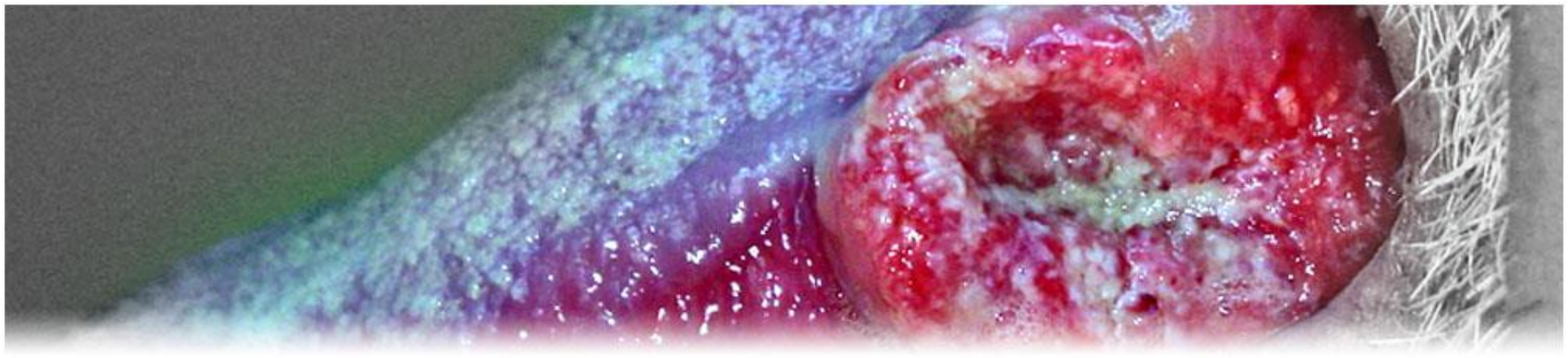


The Cell Cycle

- Is a series of events that cells go through as they grow and divide
- The cell cycle -all events between one cell division and the next
  - 2 basic steps: Interphase (G1, S, G2) and Mitosis (M)
  - **Interphase** is the period of the cell cycle between cell divisions
    - Consists of 4 phases:
      - 1. **G_1**
      - 2. **S phase**: chromosome replication or synthesis occurs
      - 3. **G_2** (BOTH G1 AND G2 are periods of intense growth and activity)
      - 4. **M phase**: mitosis and cytokinesis occurs here

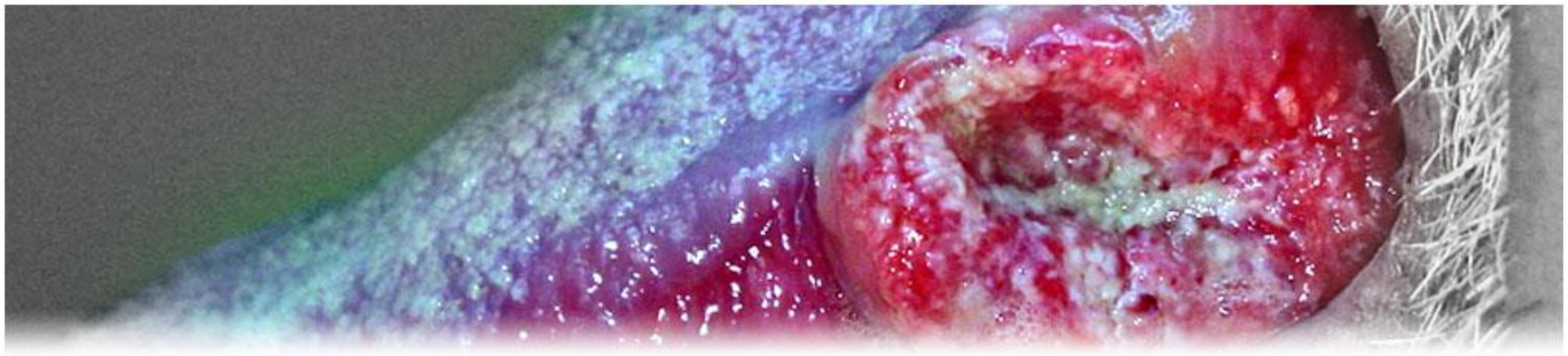


Introduction to the Cell Cycle



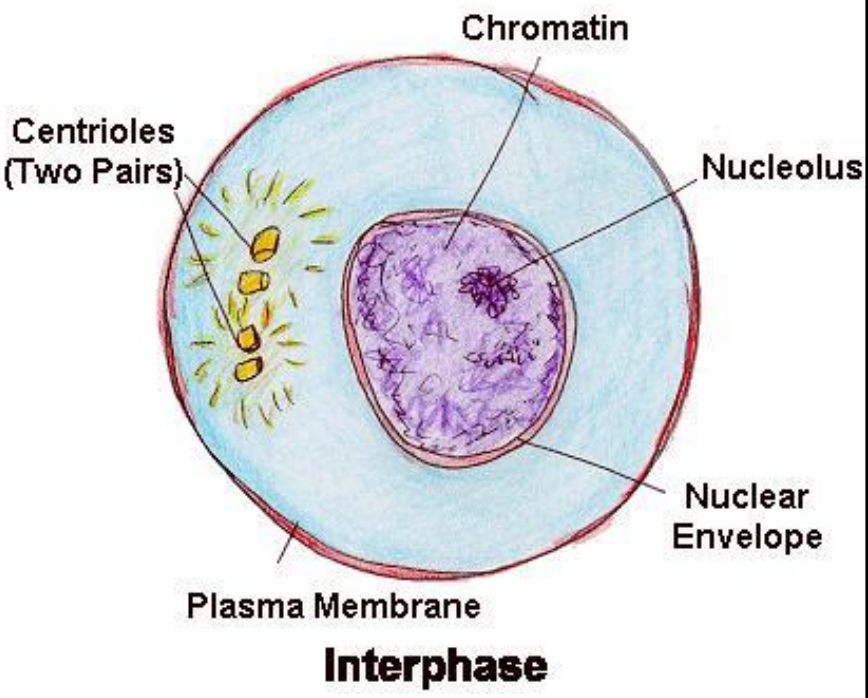
Interphase

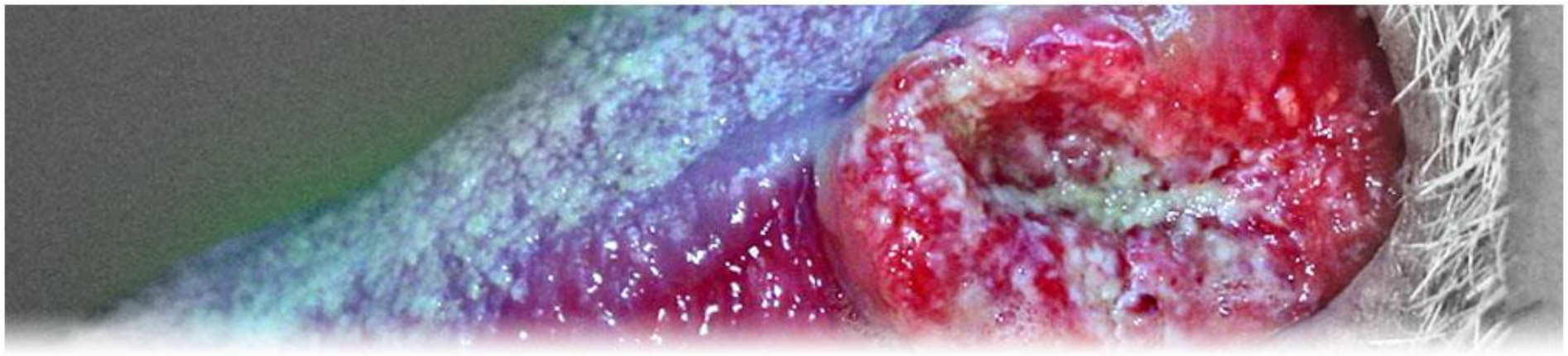
- **Interphase** is the period of the cell cycle between cell divisions



G1 Phase

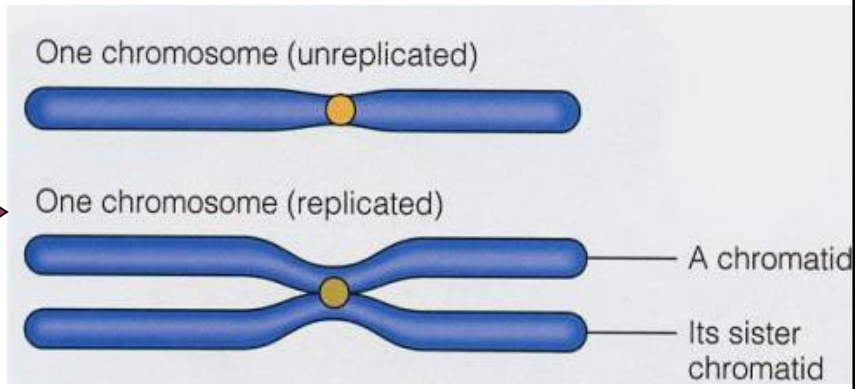
- First stage in Interphase: G1 (G=gap)
- Cell going through intense growth using lots of food and energy.
- DNA at this point is unwound and called **chromatin**

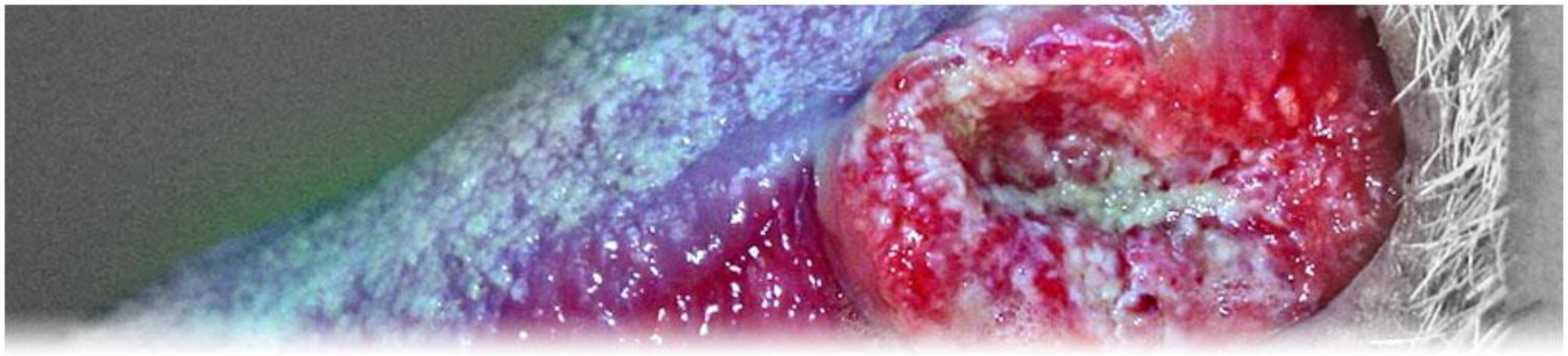




S Phase

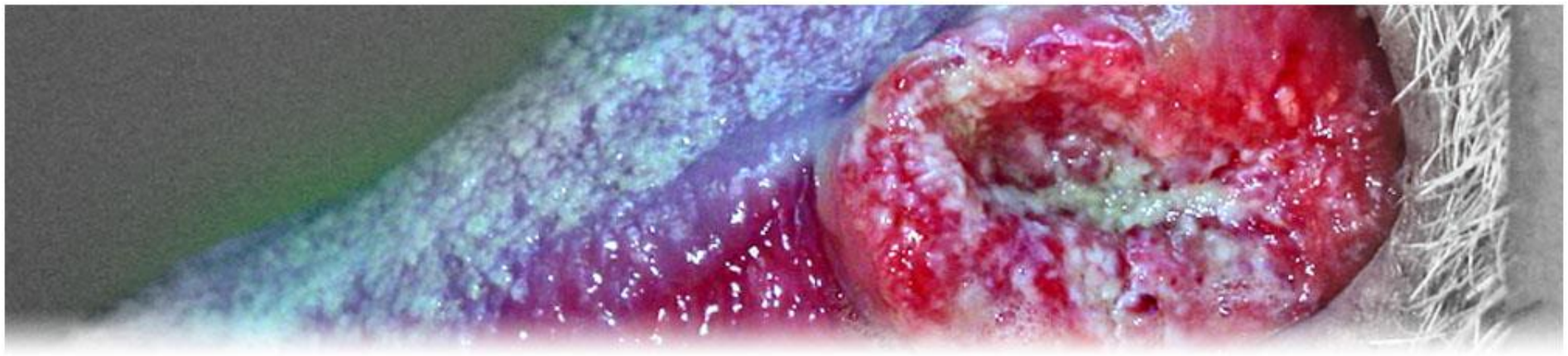
- Second stage in Interphase
- S = Synthesis phase.
- All DNA replicated during this phase→ cell has double the genetic material
- <u>Sister chromatid-</u> one of two identical parts of a replicated chromosome





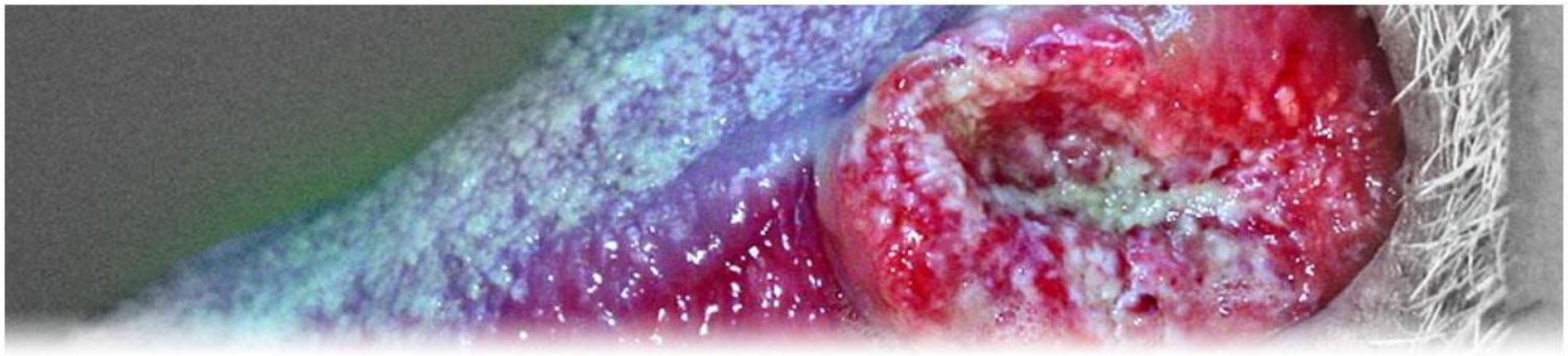
G2 Phase

- Third stage in Interphase
- G = gap
- Preparation for cell division
- Cell grows some more.
- Extra organelles are being made.

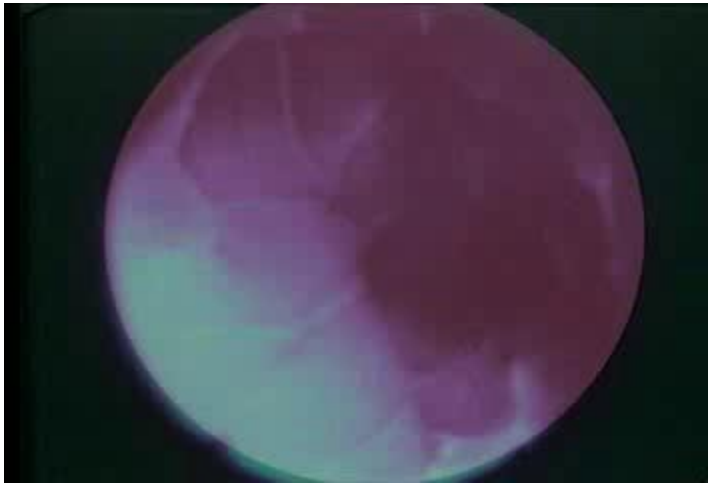


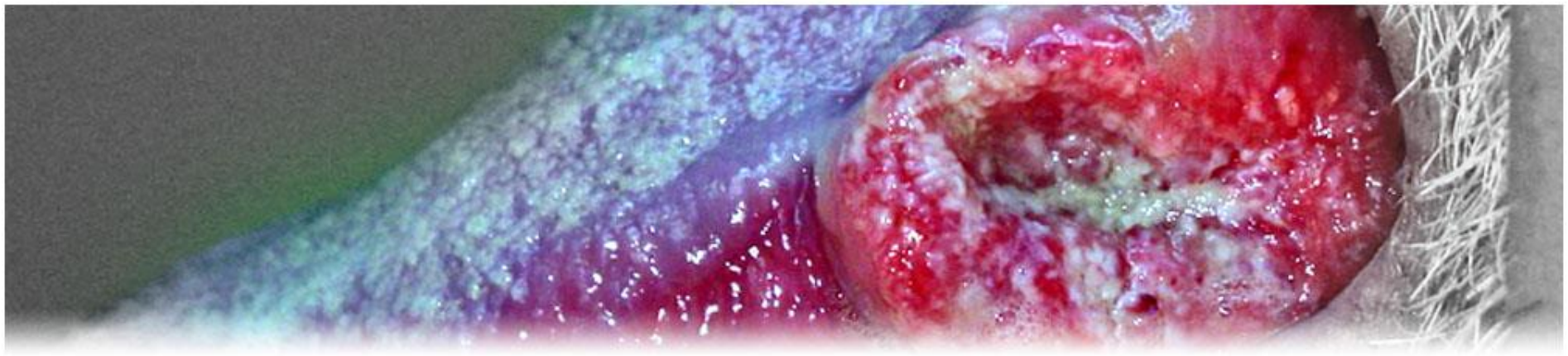
M Phase

- After Interphase (G1, S, and G2)
- M=Mitosis = Nuclear division.
- **MITOSIS IS ONLY THE DIVISION OF THE NUCLEUS DURING THE CELL CYCLE!!!**
- There are 4 mitotic steps:
  - 1. Prophase
  - 2. Metaphase
  - 3. Anaphase
  - 4. Telophase.



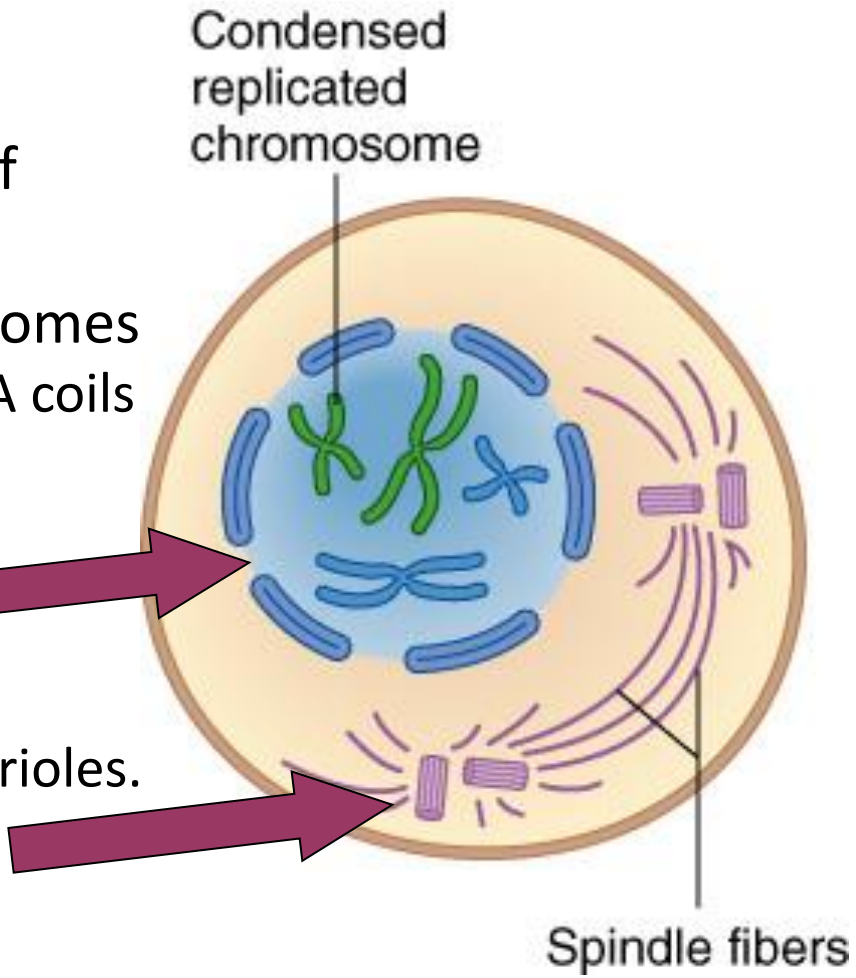
Introduction to Mitosis

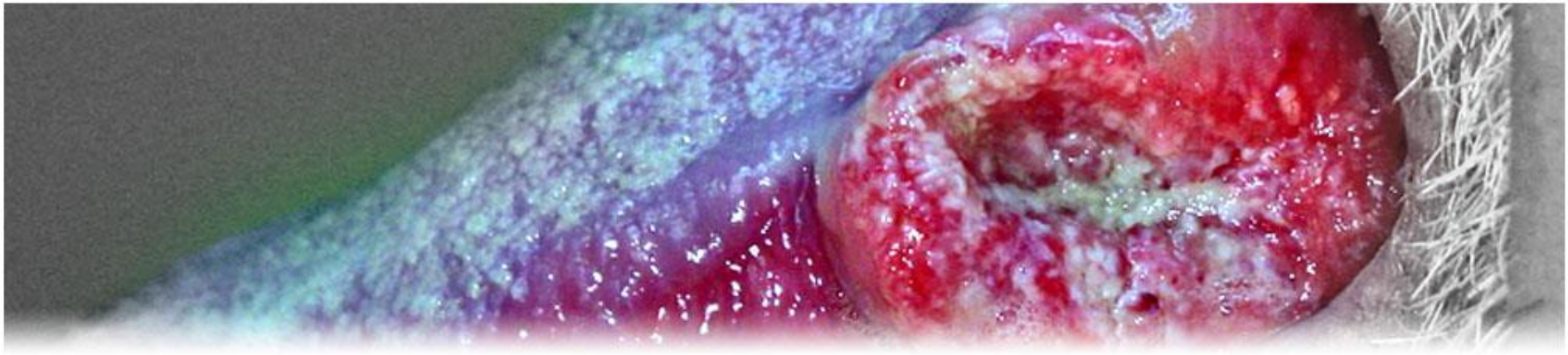




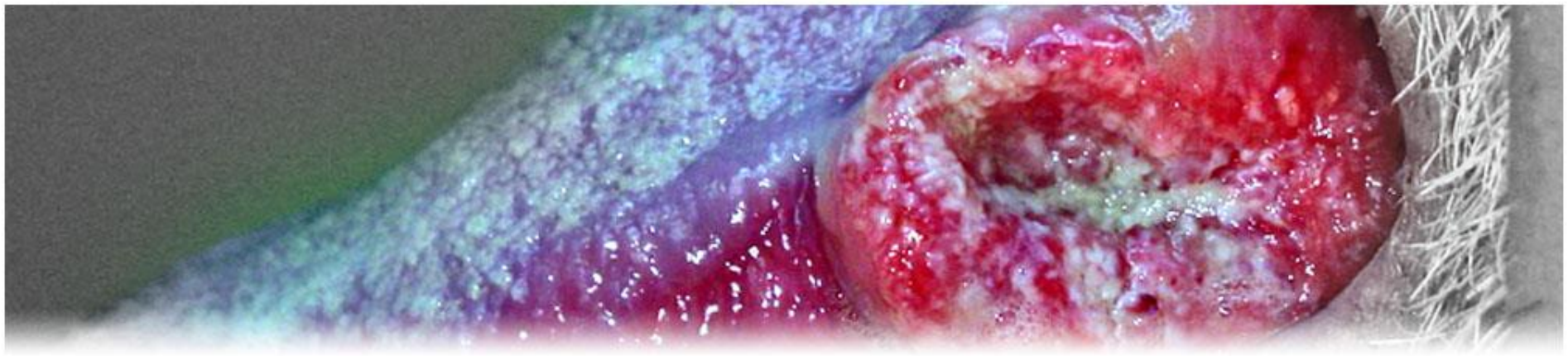
Prophase

- Is the first and longest phase of mitosis
- During this stage, the chromosomes become visible because the DNA coils up into visible chromosomes
- Nuclear envelope disappears.
- Spindle fiber forms from the centrioles.



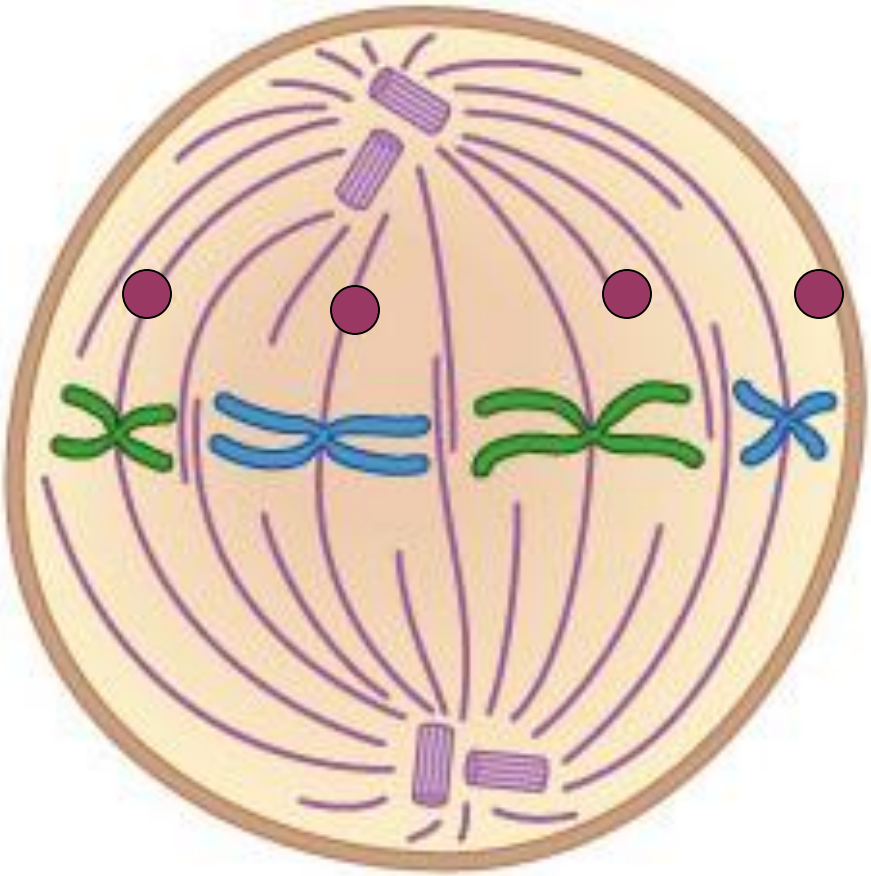


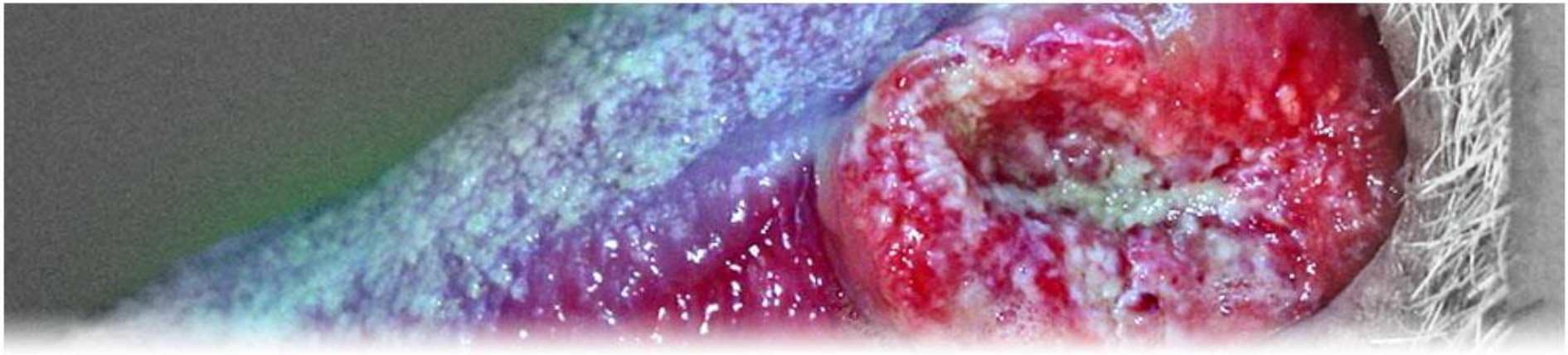
Prophase



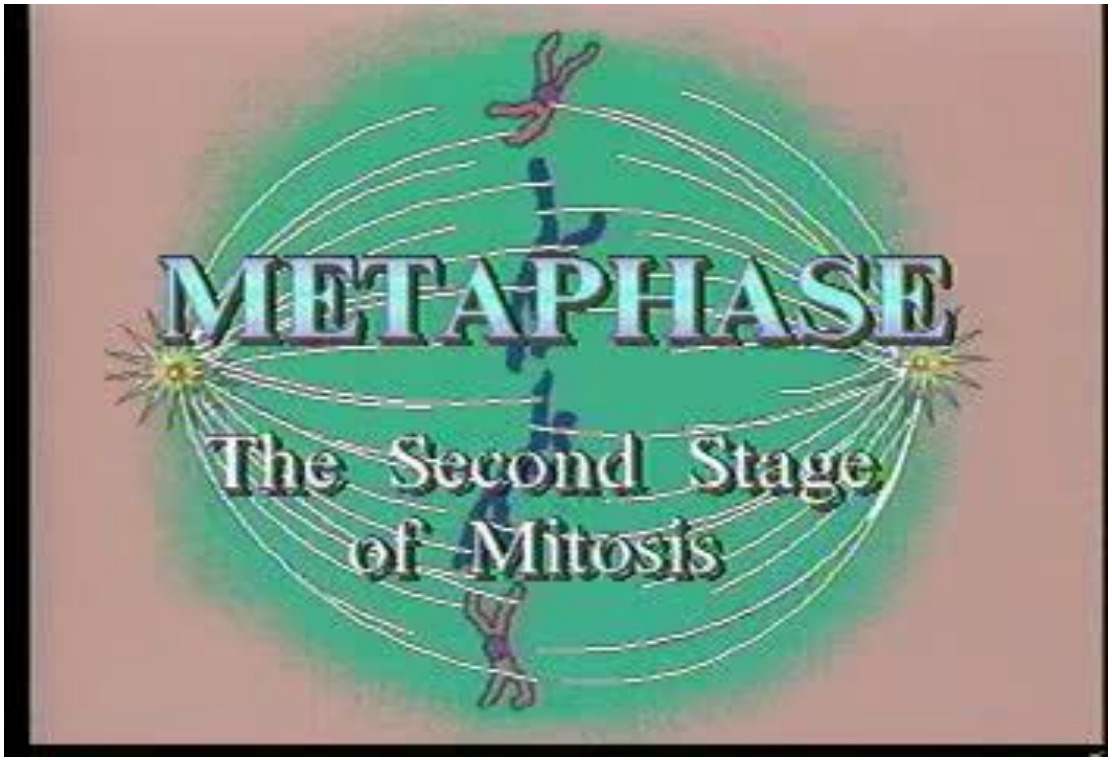
Metaphase

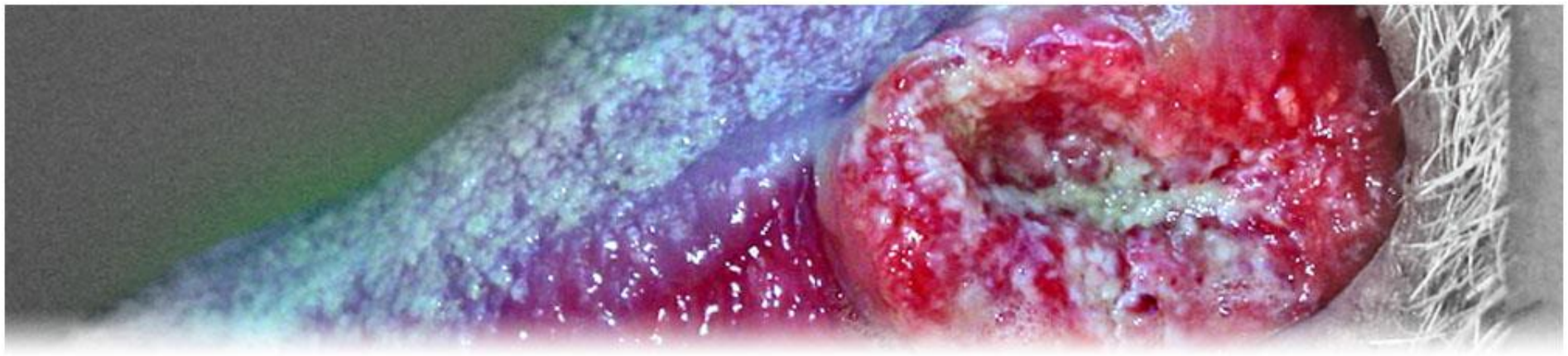
- 2nd phase of mitosis
- Chromosomes begin to line up at the equator of the cell.
- Spindle fibers attach to the **centromere** of each sister chromatid of the chromosome.





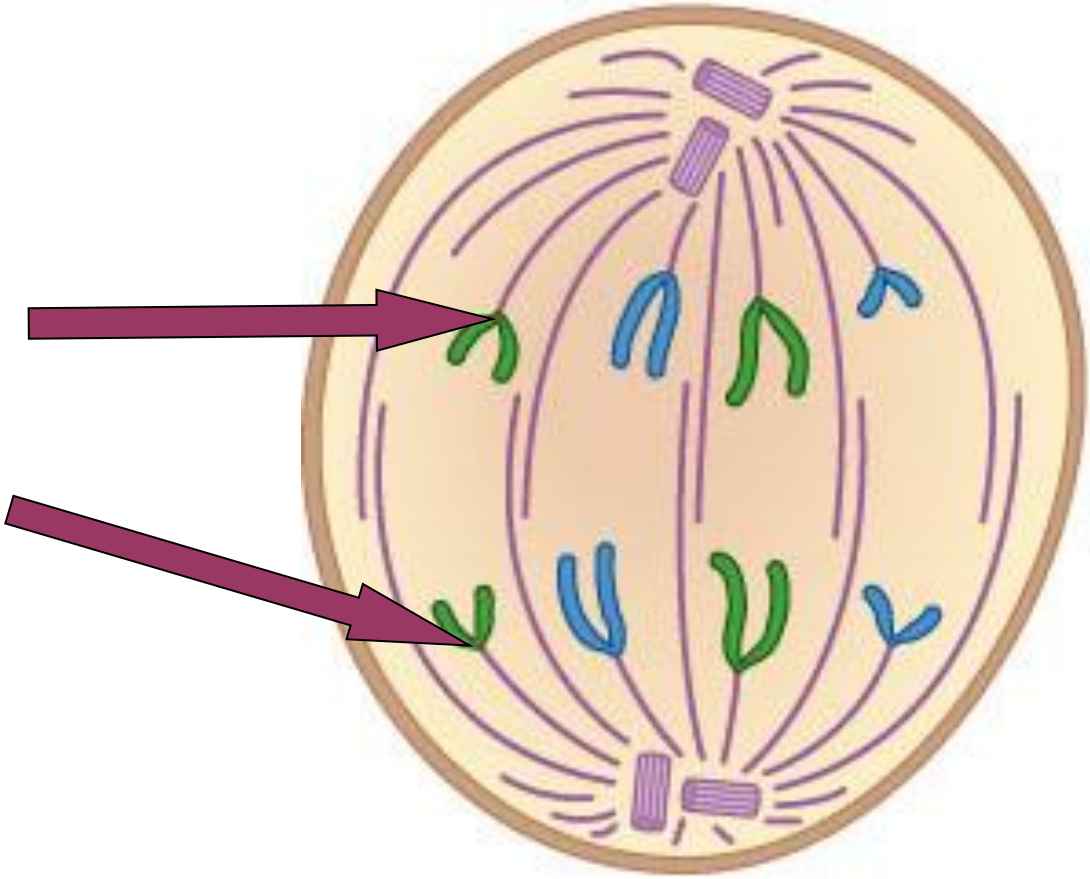
Metaphase

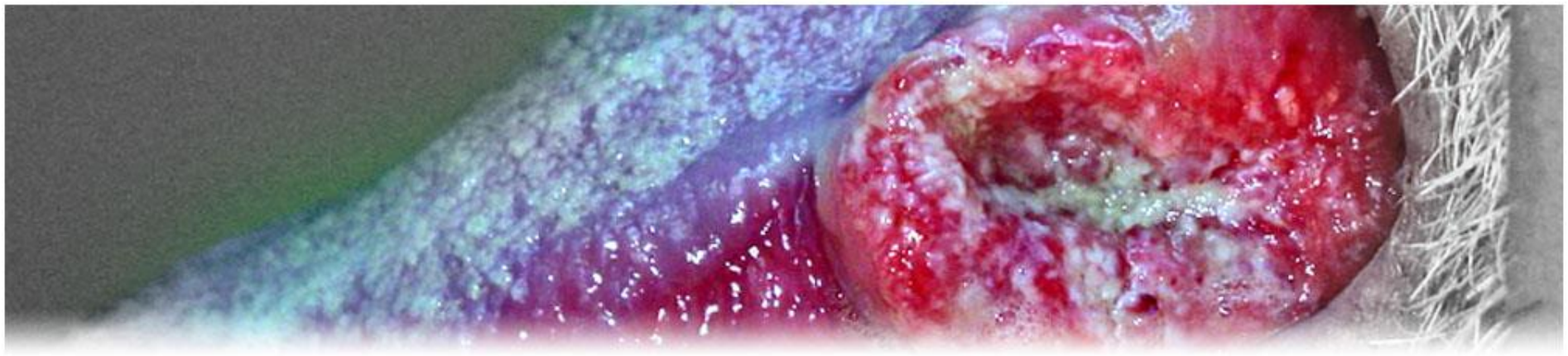




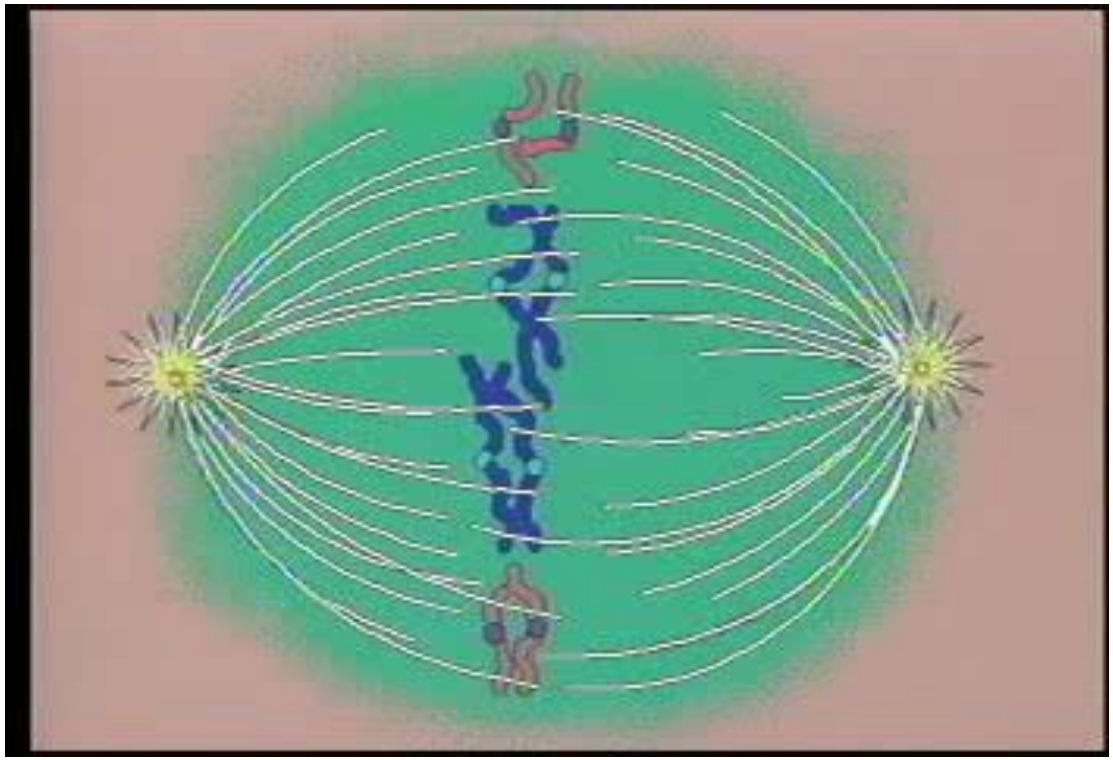
Anaphase

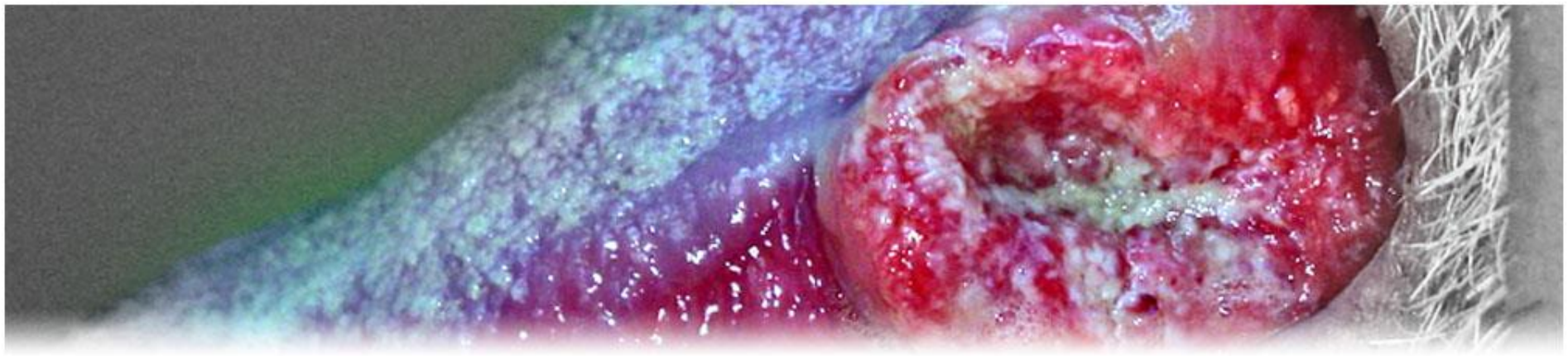
- 3rd stage of mitosis
- Spindle fibers begin to pull apart sister chromatids. Each is now a chromosome
- Spindle breaks down after this.





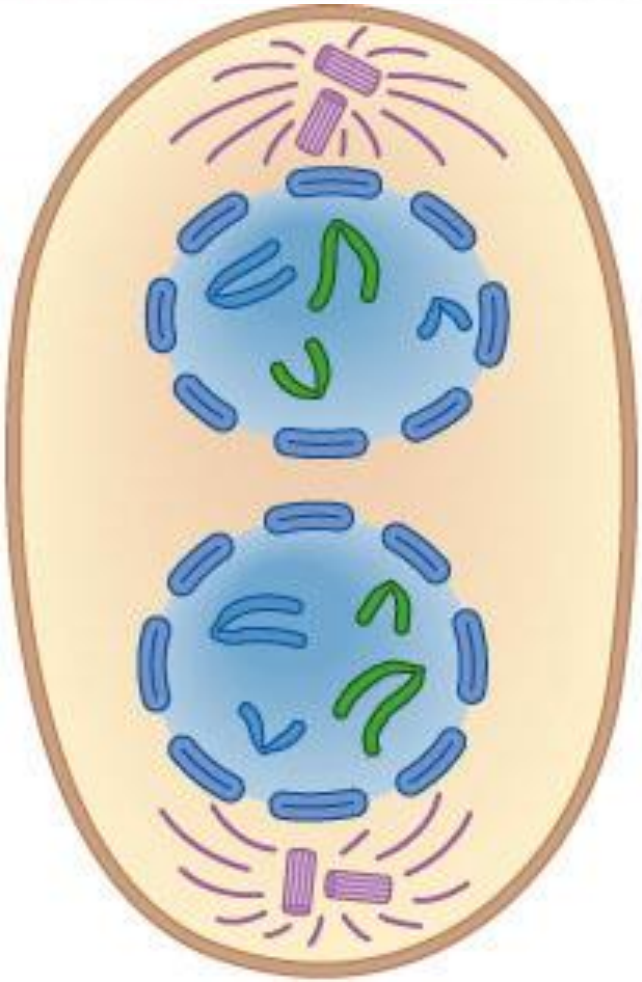
Anaphase

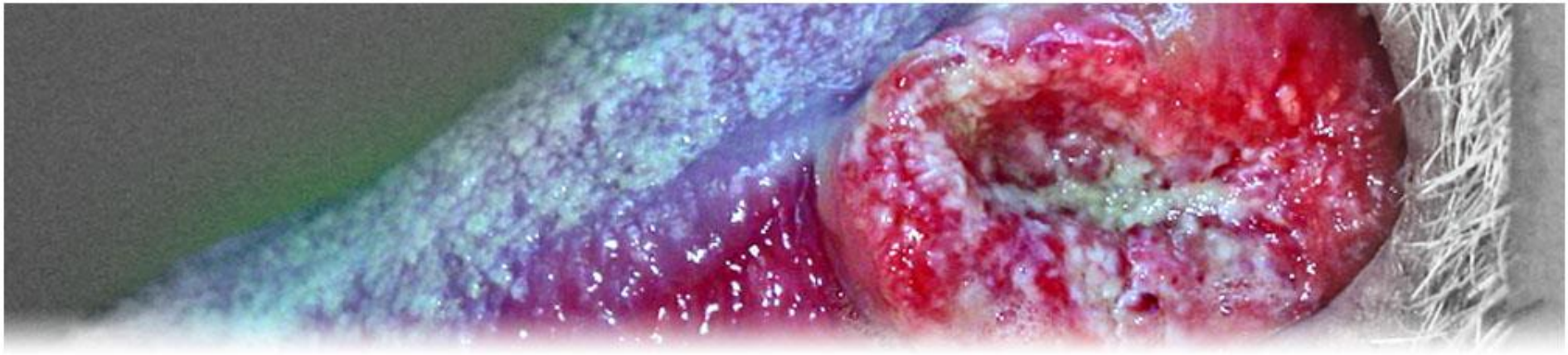




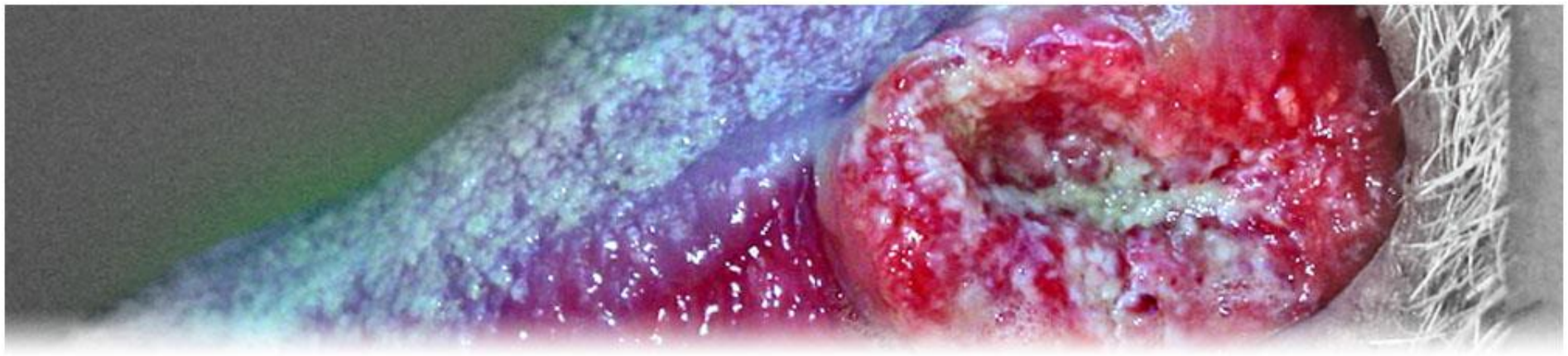
Telophase

- 4rth and final process of mitosis
- Each side now has a full set of chromosomes.
- Nuclear envelope will reform.
- Mitosis, NOT CELL DIVISION, is complete



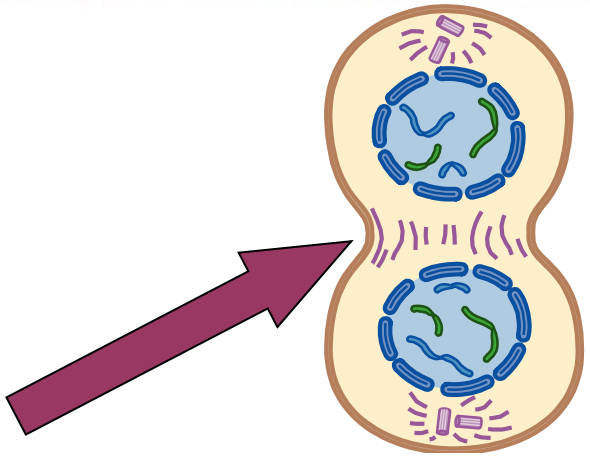


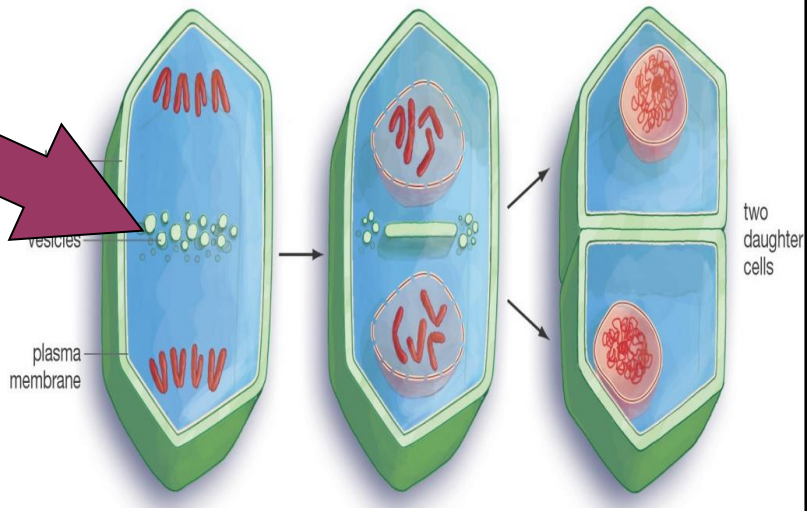
Telophase

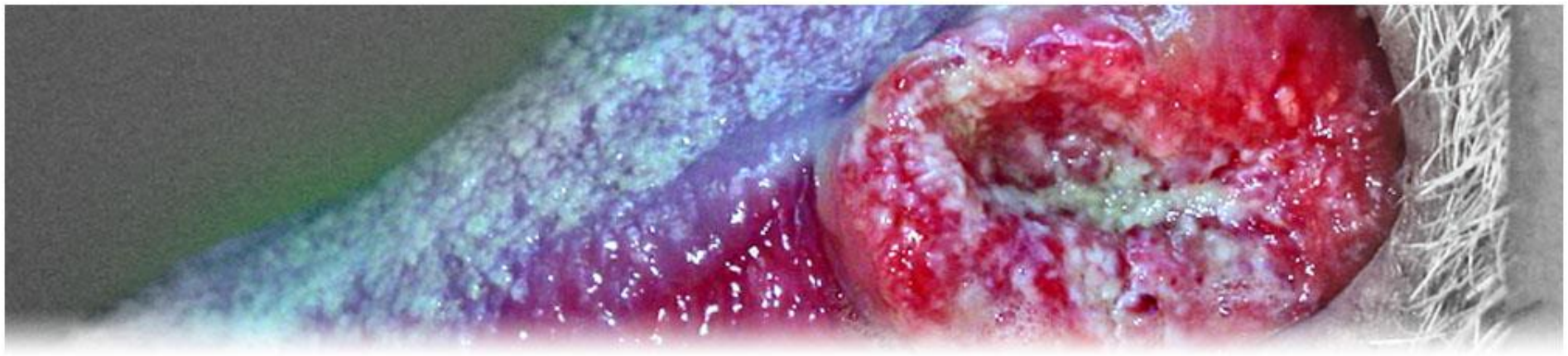


Cytokinesis

- "Cytokinesis"—division of cytoplasm at the end of the cell cycle which cleaves the cell in half.
- Animal cells form a cleavage furrow.
- Plant cells form a new cell plate that will become the cell wall.
- Formation of two, identical daughter cells with 46 chromosomes (2 sex chromosomes and 44 autosomes)

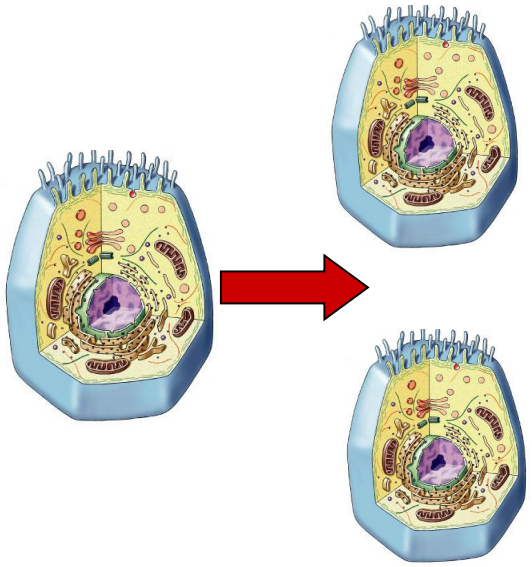


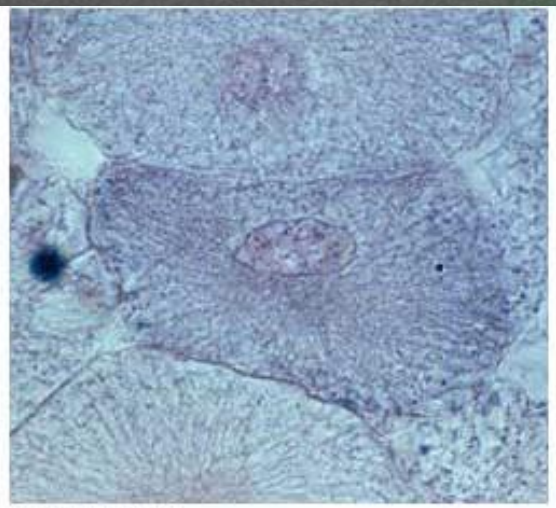




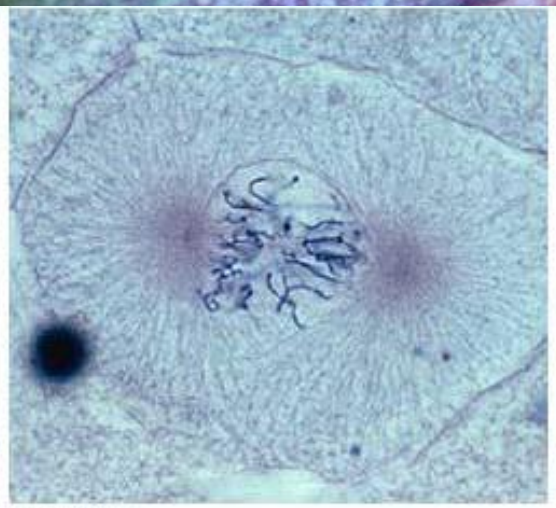
New "daughter" cells

- Get 2 exact copies of original somatic (body) cells
  - same DNA
  - "clones"
- A cell that contains both sets of homologous chromosomes is **diploid**, meaning "two sets."
- The diploid number of chromosomes is sometimes represented by the symbol **2N**.
- For the fruit fly, the diploid number is 8, which can be written as 2N = 8, where N represents twice the number of chromosomes in a sperm or egg cell.

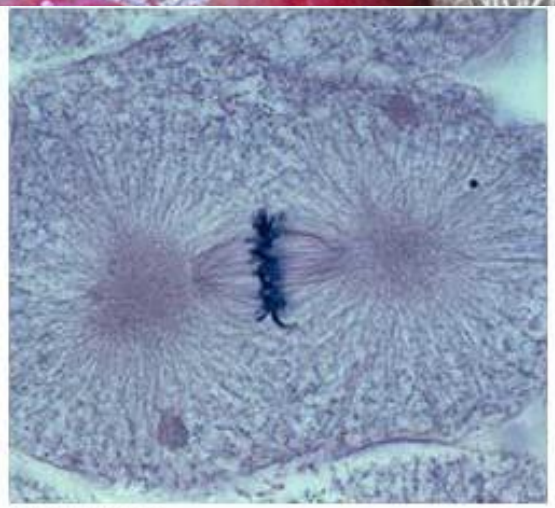




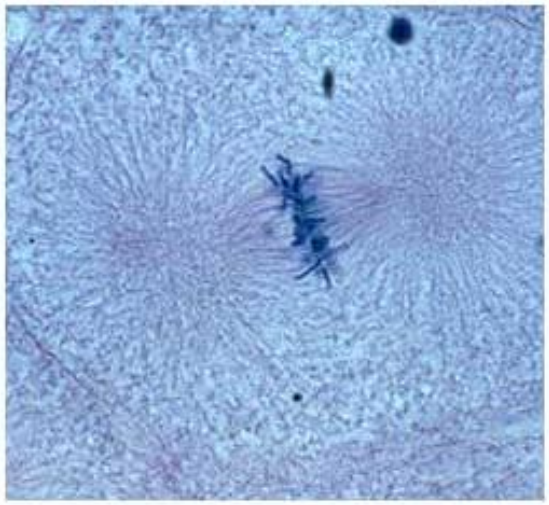
Interphase



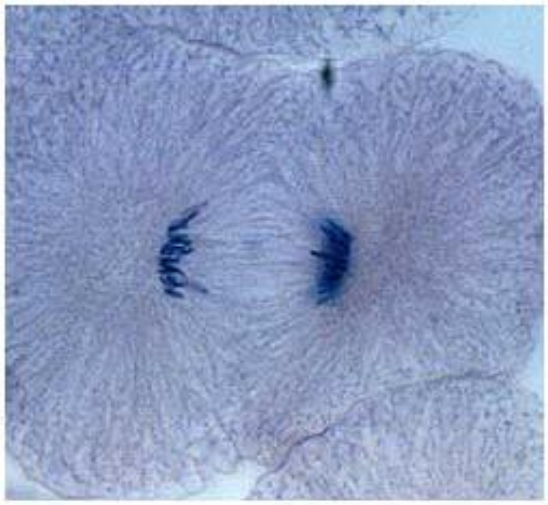
Prophase



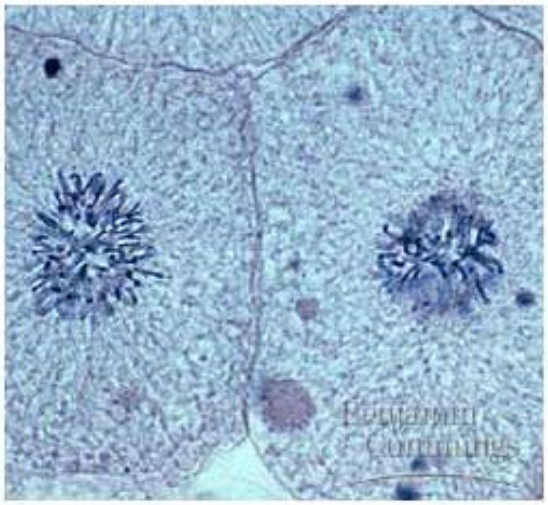
Metaphase



Anaphase

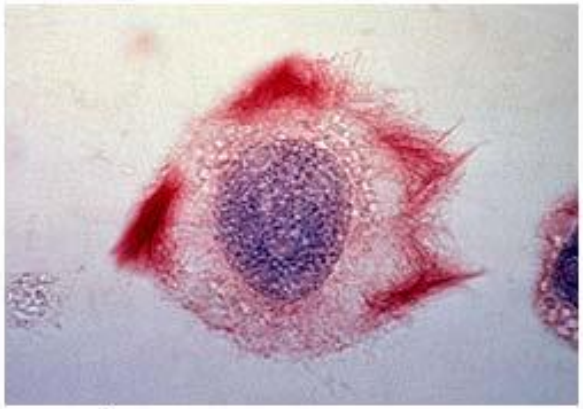


Early Telophase

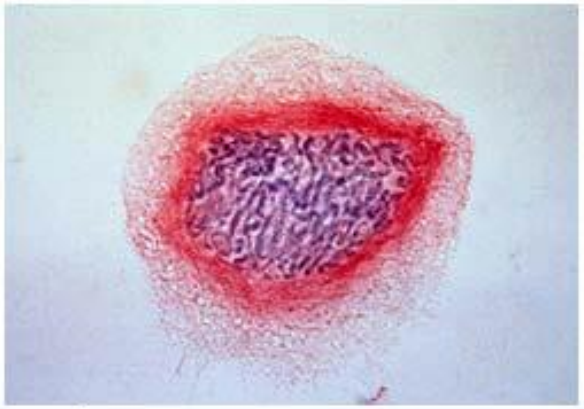


Late Telophase

Mitosis in whitefish embryo



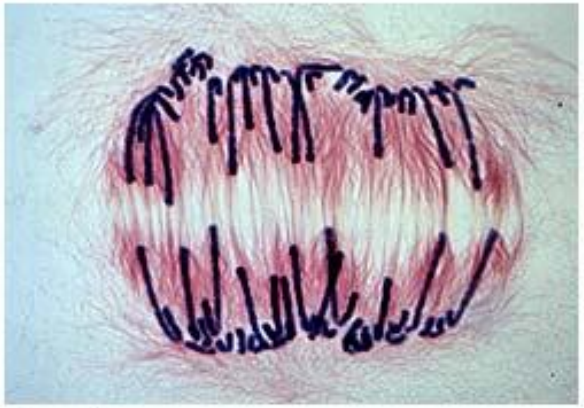
Interphase



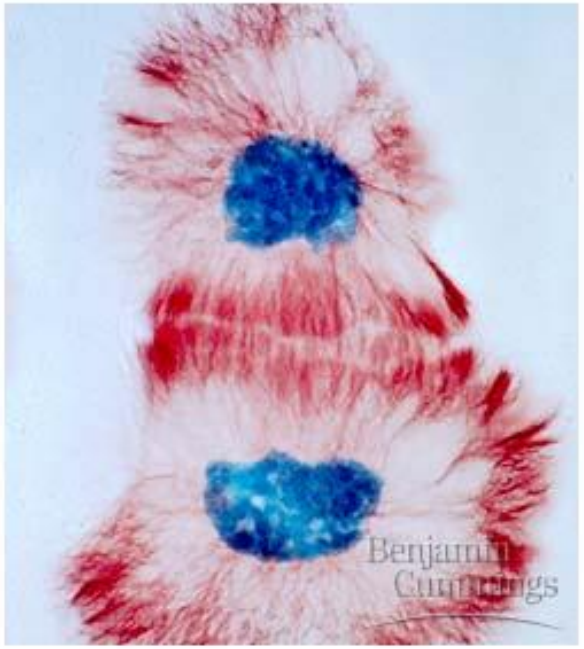
Prophase

Prometaphase

Metaphase

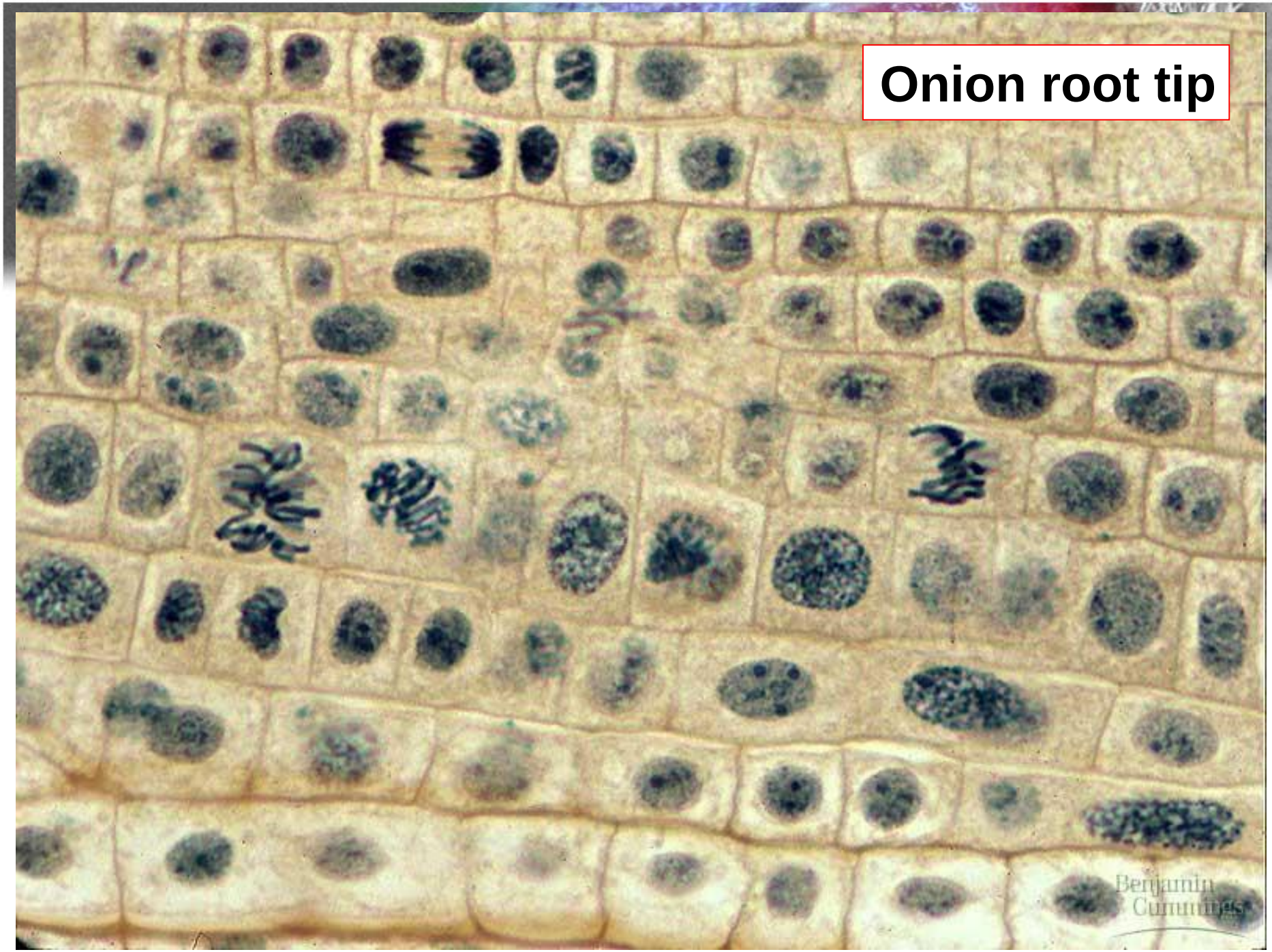


Anaphase

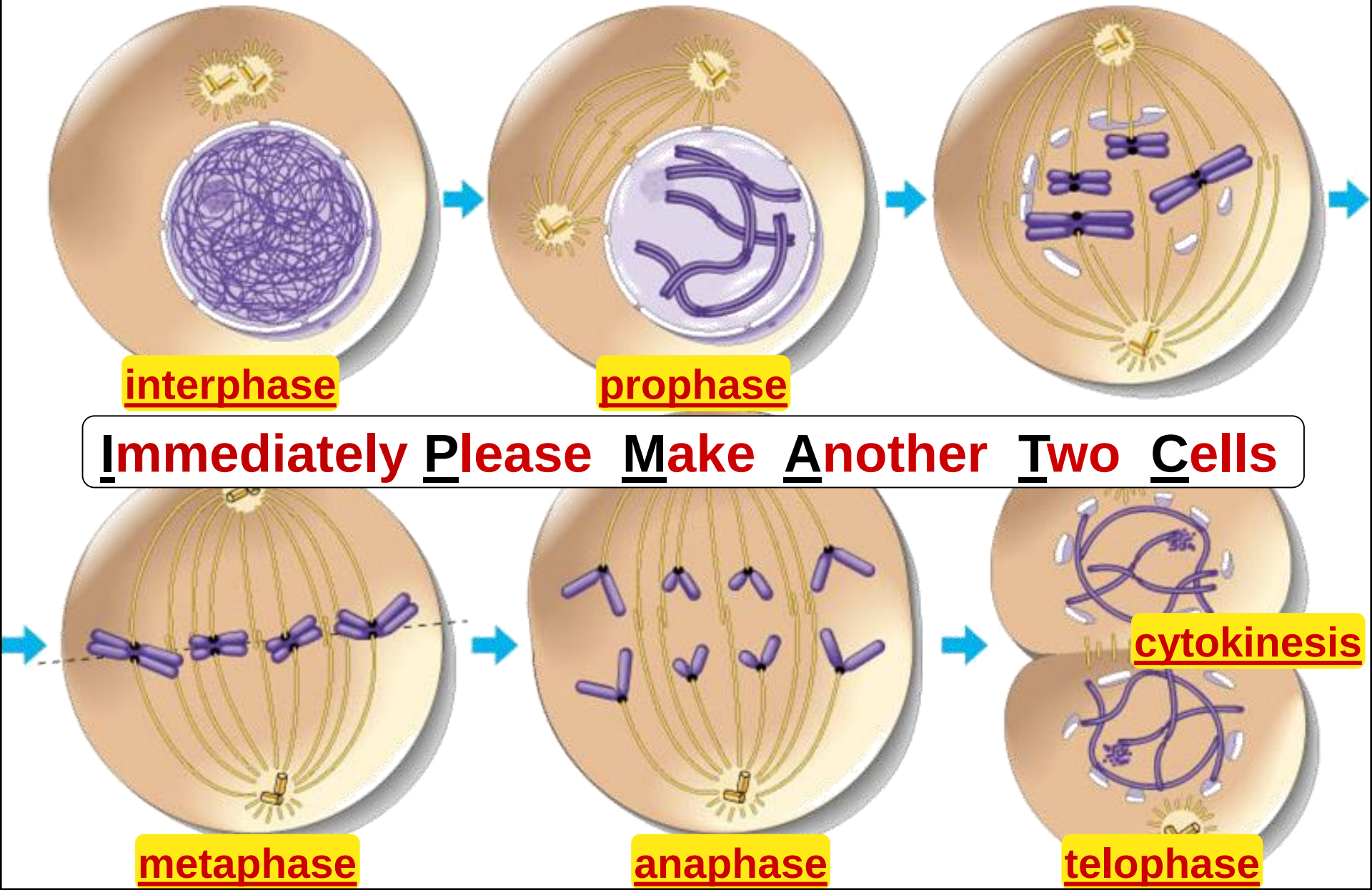


Telophase

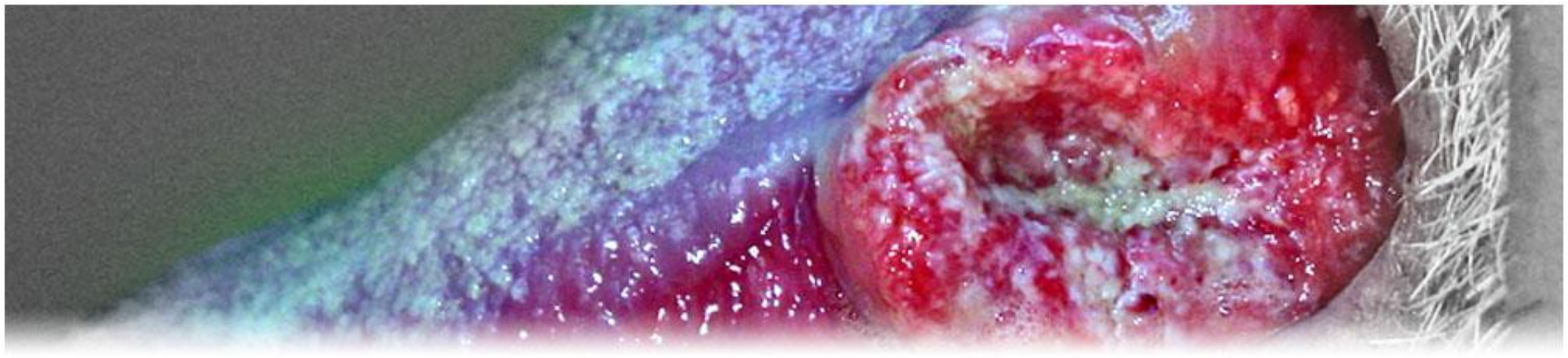
Mitosis in a plant cell


Onion root tip
Benjamin Cummings

Overview of the Cell Cycle

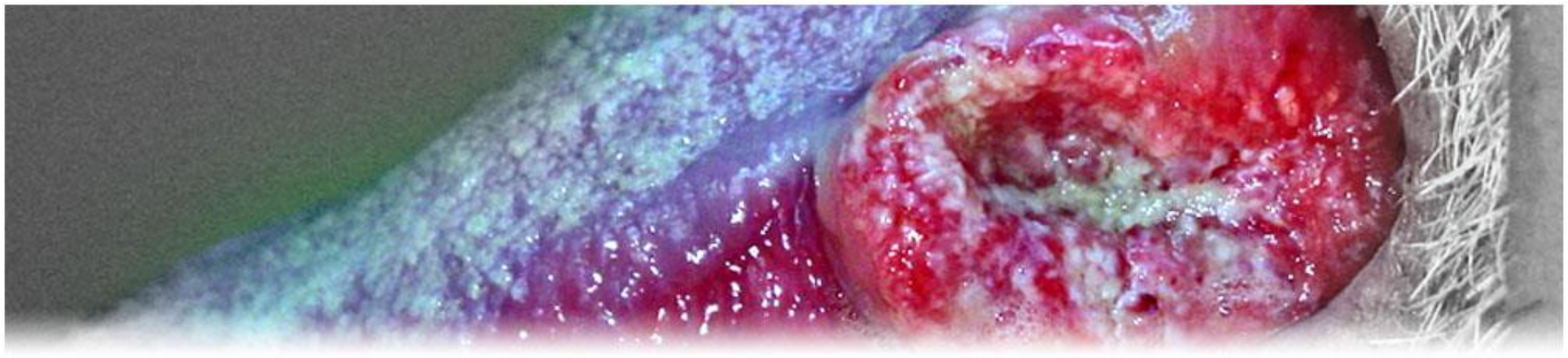


Immediately **P**lease **M**ake **A**nother **T**wo **C**ells

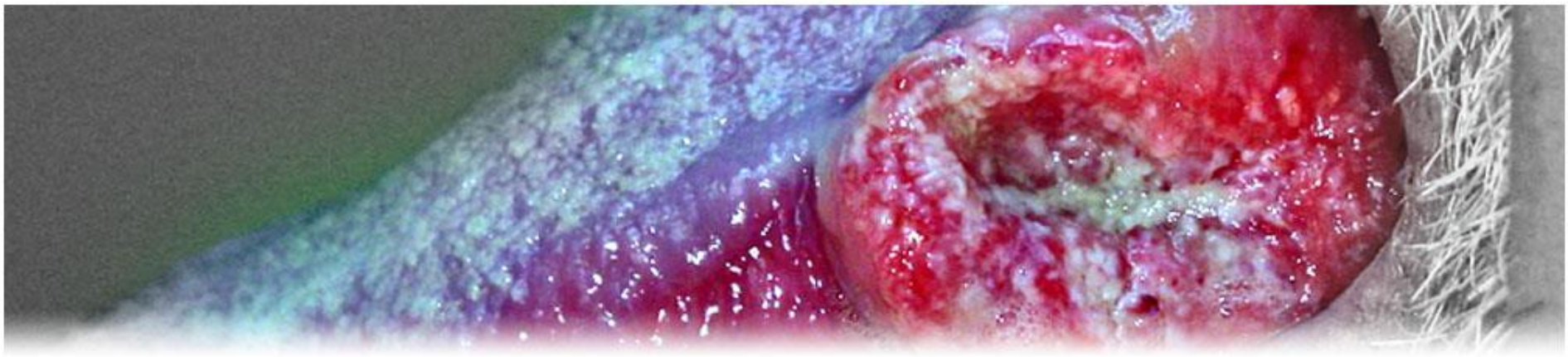


QUESTION AND ANSWER

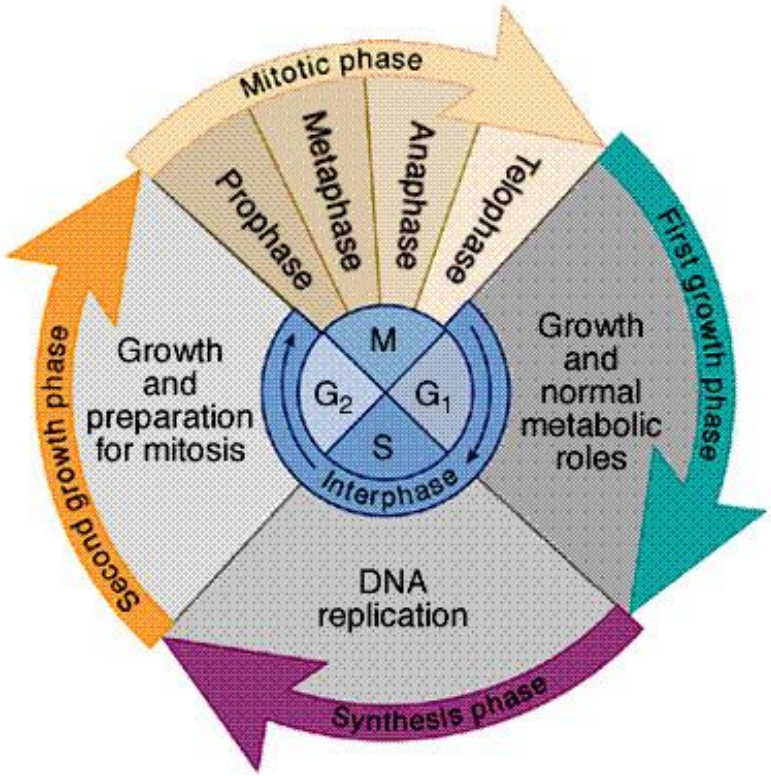
What events occur during each phase of the cell cycle?

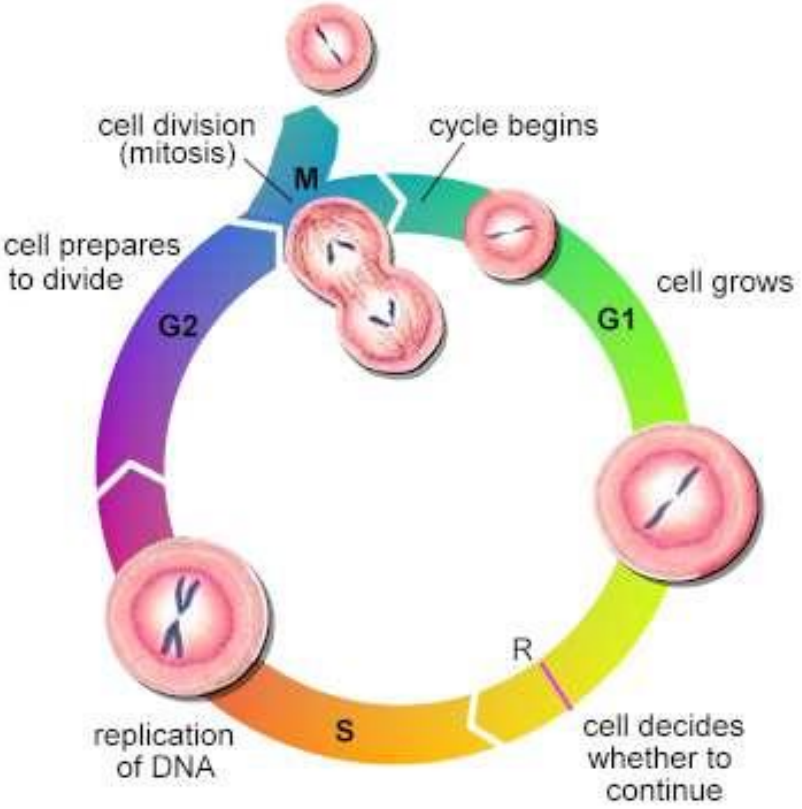


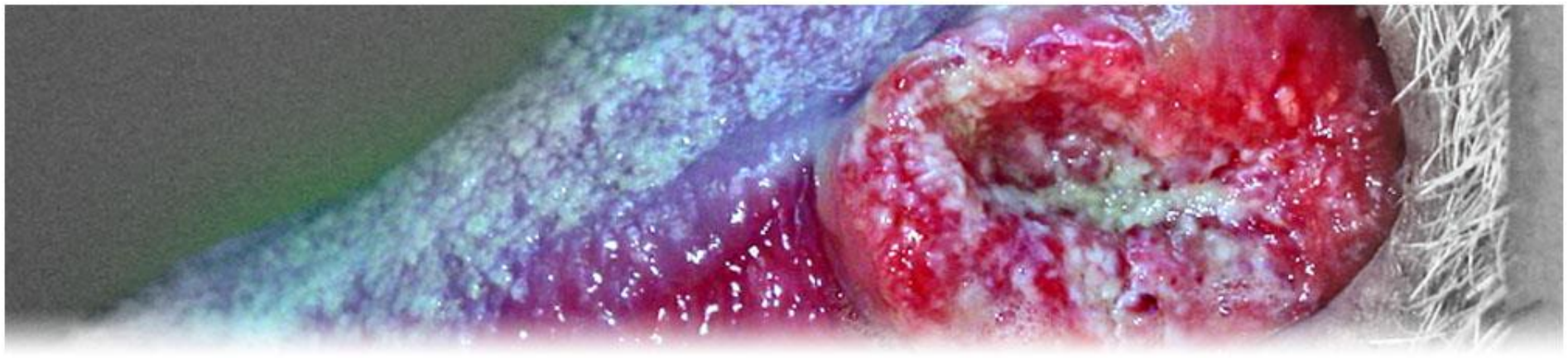
How do cancer cells differ from other cells?



Overall Cell Cycle Process

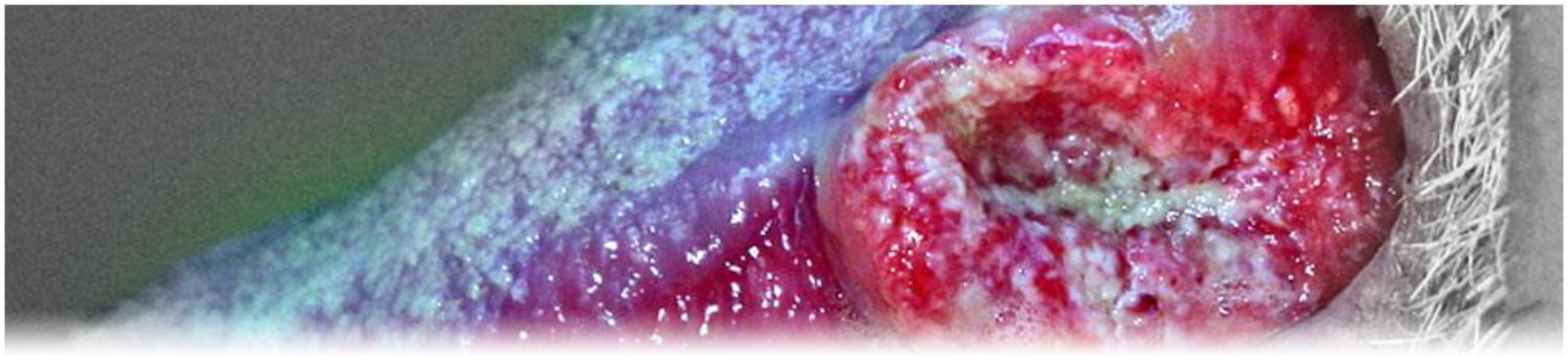






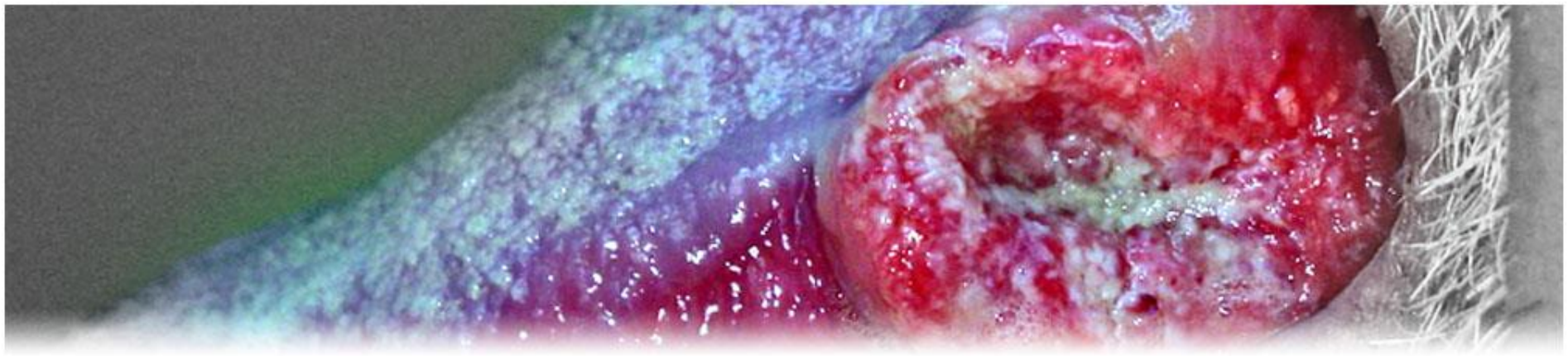
Regulation of the Cell Cycle

- Cell division controlled by certain proteins called **cyclins**
- When cells come in contact with other cells, they stop growing. Molecules found on the surfaces of neighboring cells often have the opposite effect, causing cells to slow down or stop their cell cycles. This prevents excessive cell growth.
- Cancer cells don't respond to the cyclin signals which results in uncontrolled growth (tumors)



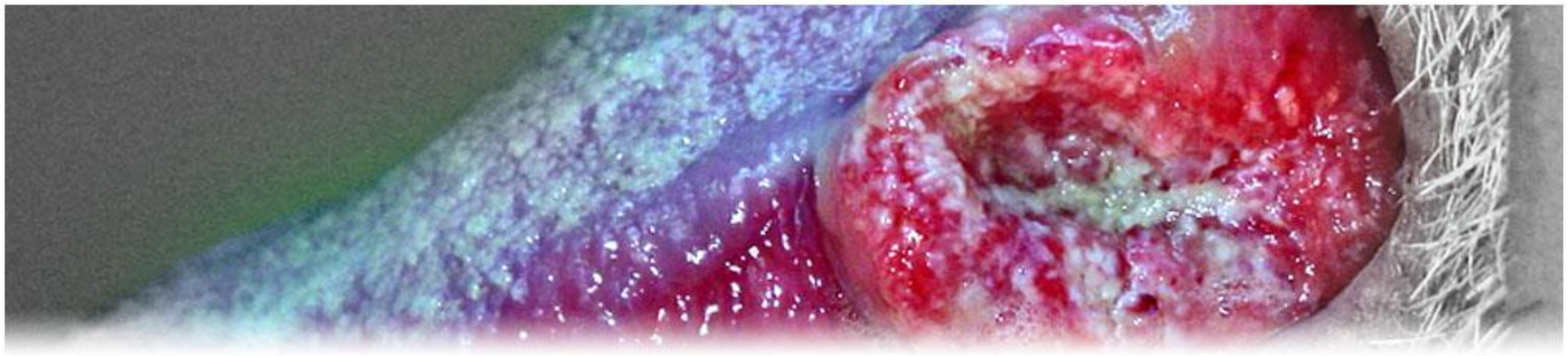
Uncontrolled cell growth

- Cancer is a disorder in which some of the body's own cells lose the ability to control growth
- **Cancer cells don't respond to the cyclin signals---** they do not respond to the signals that regulate the growth of most cells so they divide uncontrollably and form masses of cells called tumors that can damage surrounding tissues
- Benign tumors stay intact
- Malignant tumors spread throughout body (metastasize)



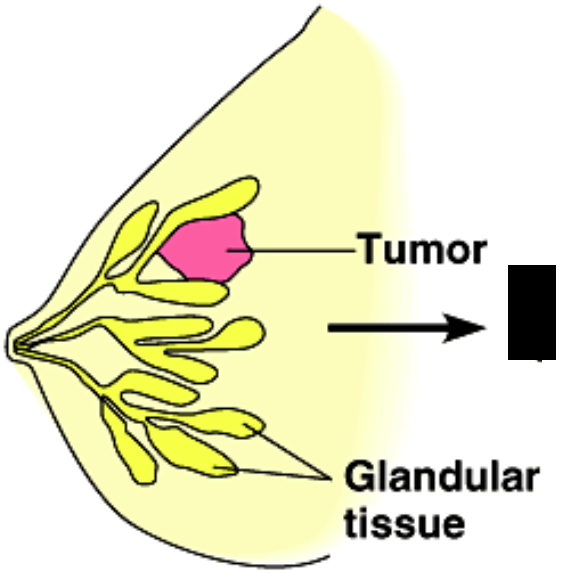
Cancer

- A defect in a gene called **p53** is common among many cancer cells
- P53 normally halts the cell cycle until all the chromosomes have been properly replicated however, damaged or defective p53 genes cause the cells to lose information needed to respond to signals that would normally control their growth.
- It starts with a single cell that loses its control mechanisms due to a genetic mutation. That cell starts dividing without limit, and eventually kills the host.

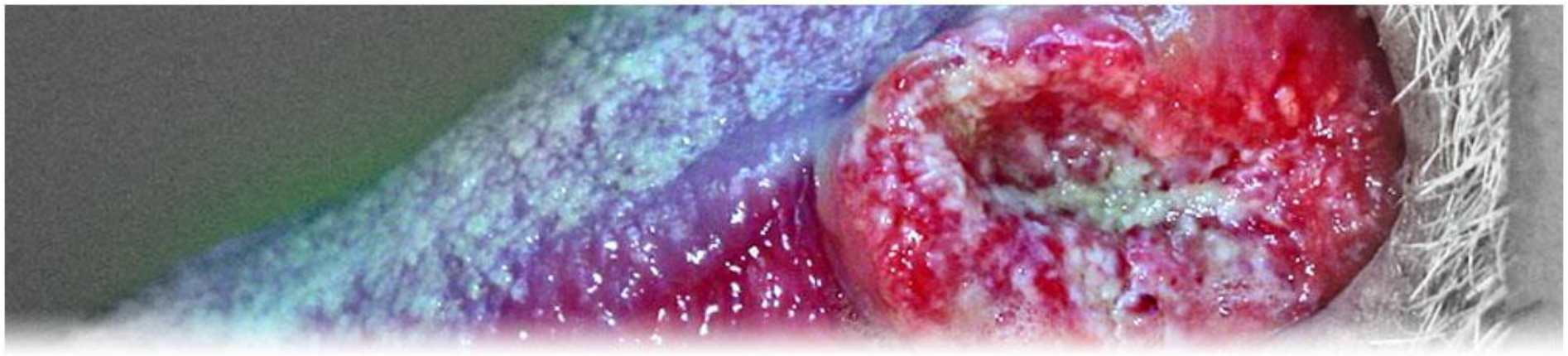


When is mitosis a BAD thing

- When cells reproduce & they are not needed
  - these cells take over organs, but don't do the right job
  - they just keep making copies
  - cancer
    - damages organs

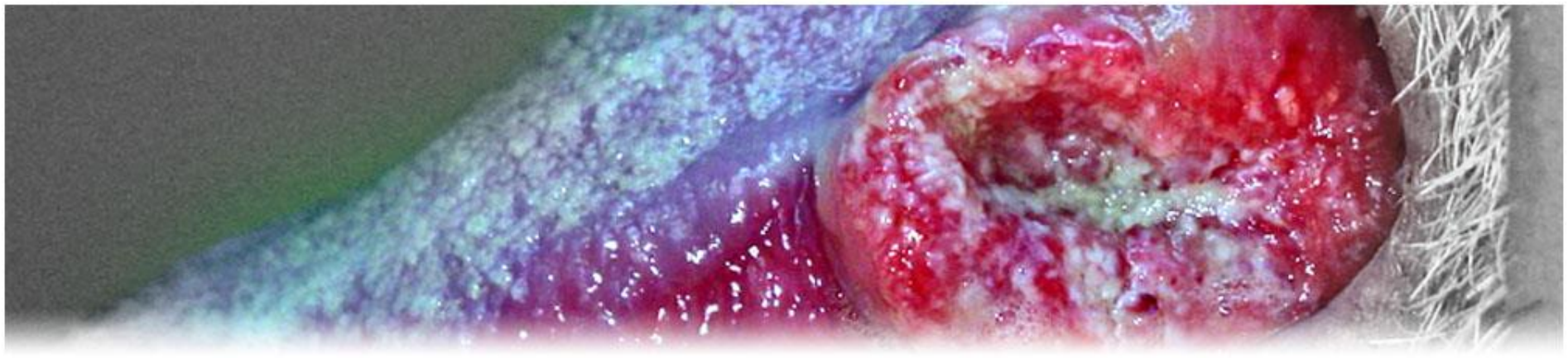


❶ A tumor grows from a single cancer cell.



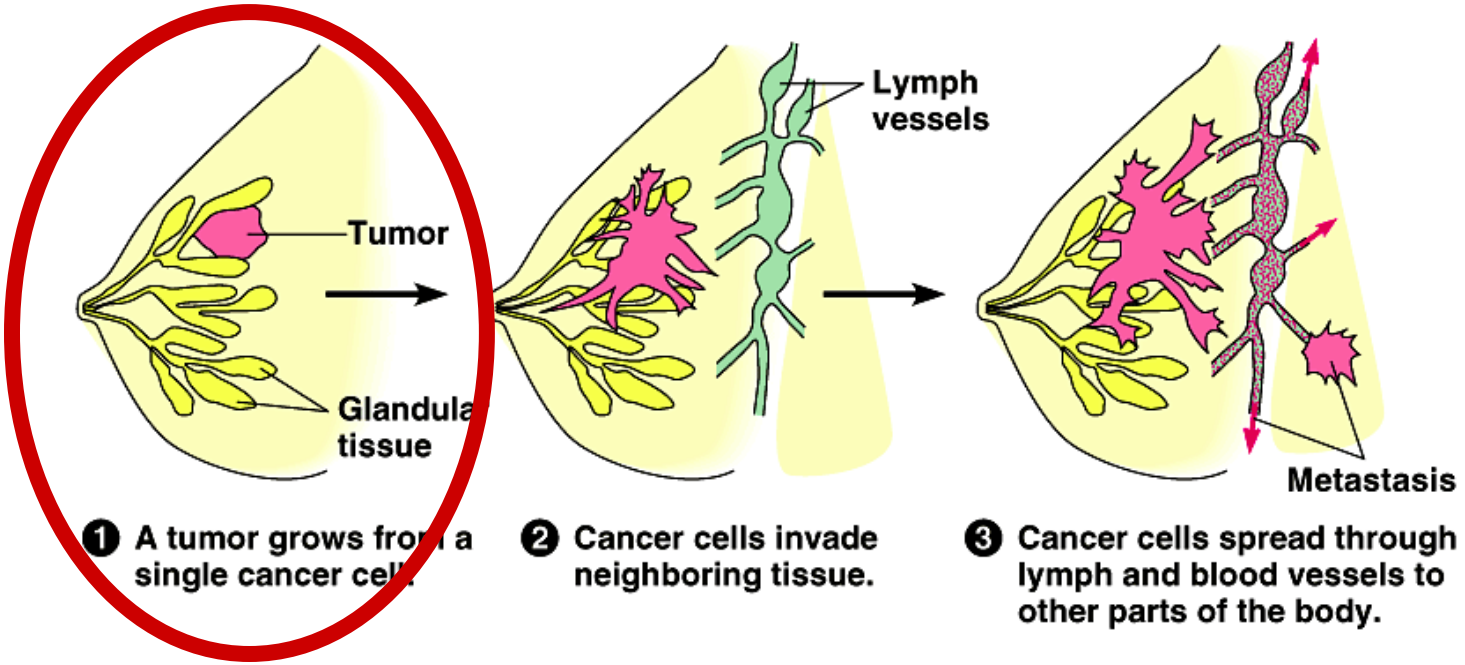
Why would cells just make copies?

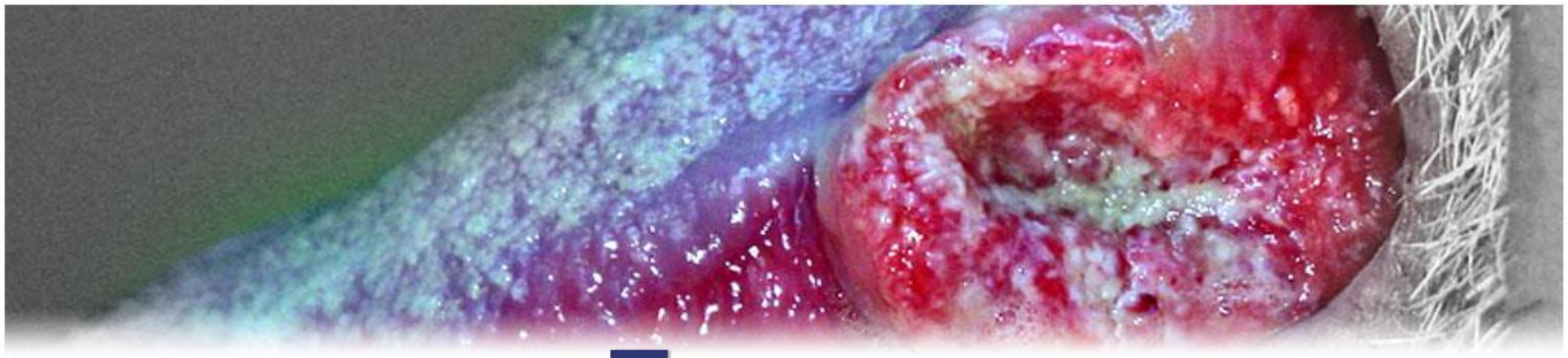
- If DNA gets damaged, cells stop listening to correct instructions
  - mutations
- Causes of mutations:
  - **UV radiation**
  - **chemical exposure**
  - **radiation exposure**
  - **heat**
  - **cigarette smoke**
  - **pollution**
  - **age**
  - **genetics**



Tumors

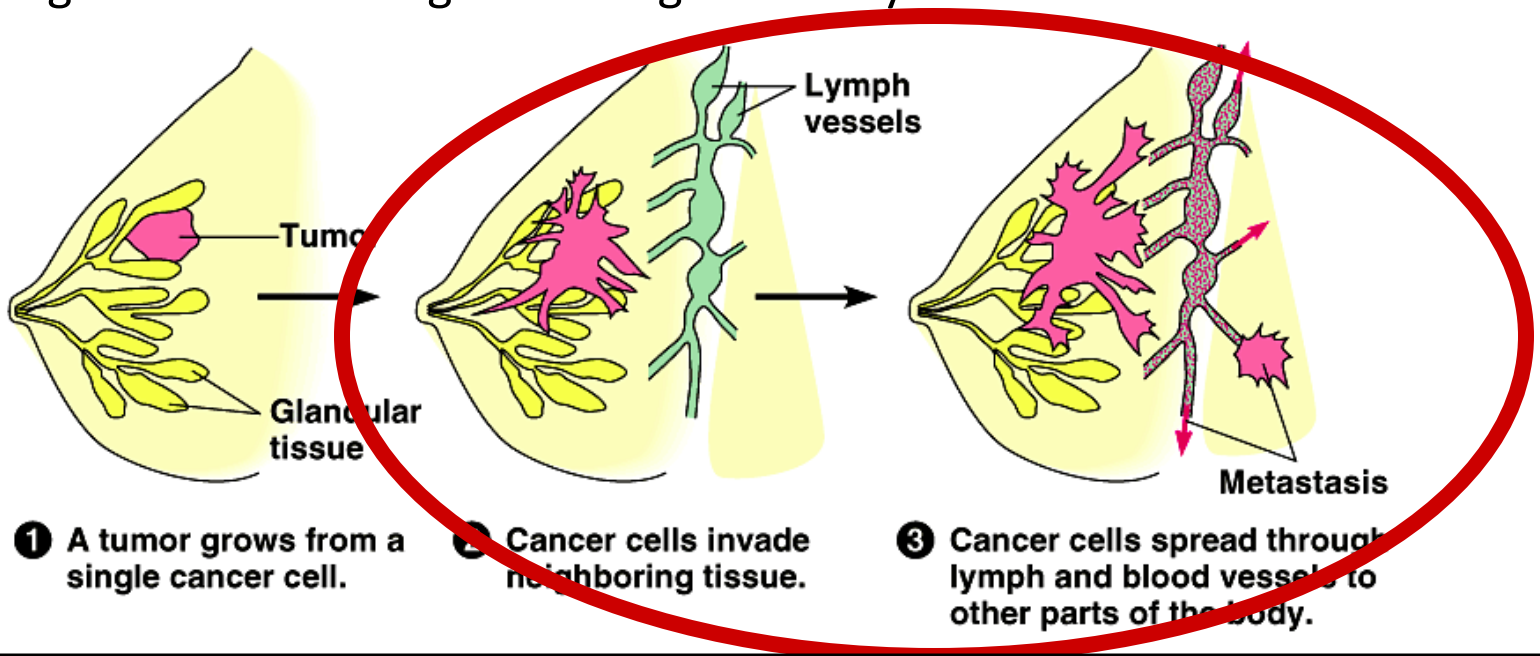
- Benign tumor
  - abnormal cells remain at original site as a lump
  - most do not cause serious problems & can be removed by surgery

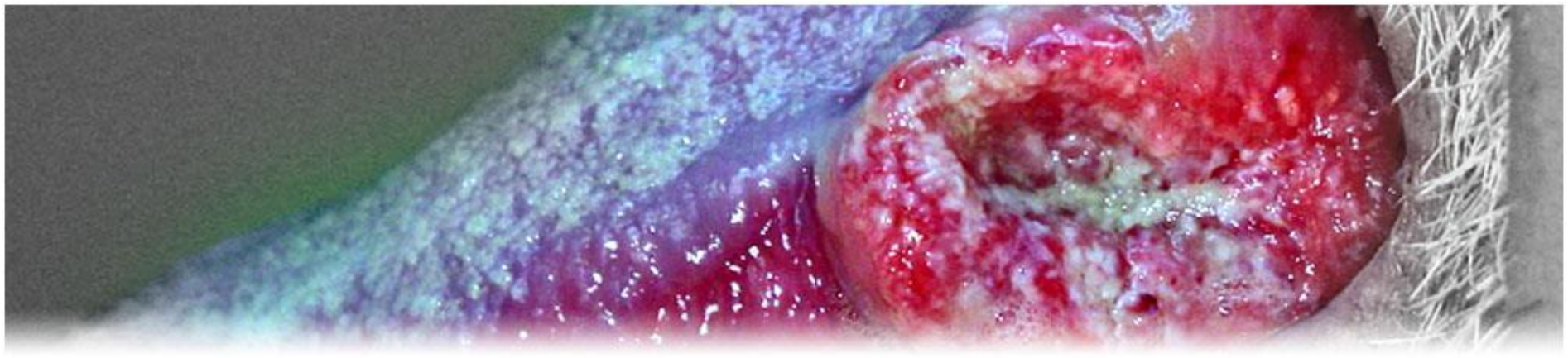




Tumors

- Malignant tumor
  - cells leave original site
    - carried by blood system to other tissues
    - start more tumors
  - damage functions of organs throughout body





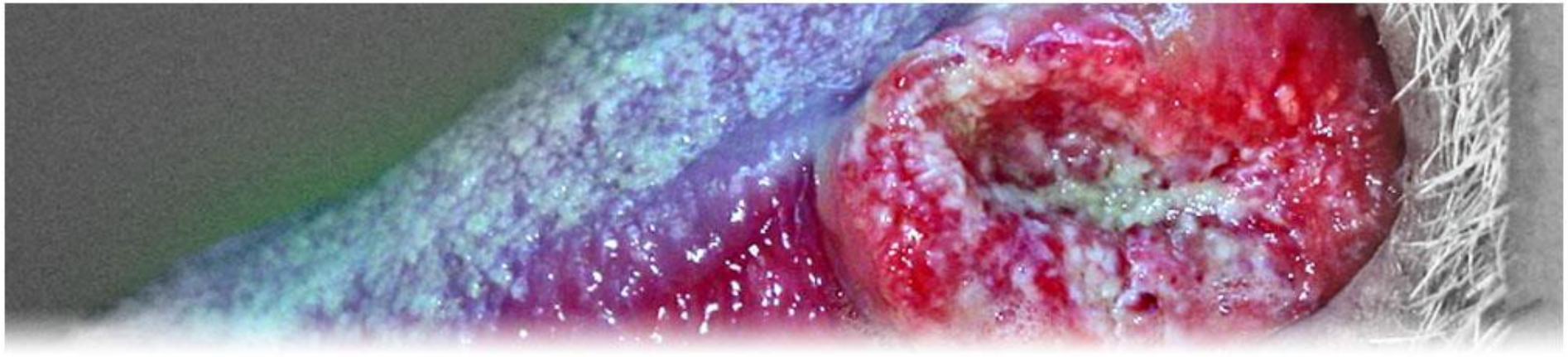
Cancer Treatment

- Two basic treatments: surgery to remove the tumor, and radiation or chemicals to kill actively dividing cells.
- It is hard to remove all the tumor cells. Tumors often lack sharp boundaries for easy removal, and metastatic tumors can be very small and anywhere in the body.
- Radiation and chemotherapy are aimed at killing actively dividing cells, but killing all dividing cells is lethal: you must make new blood cells, skin cells, etc. So treatment must be carefully balanced to avoid killing the patient.
- Chemotherapy also has the problem of natural selection within the tumor. If any of the tumor cells are resistant to the chemical, they will survive and multiply. The cancer seems to have disappeared, but it comes back a few years later in a form that is resistant to chemotherapy. Using multiple drugs can decrease the risk of relapse: it's hard for a cell to develop resistance to several drugs at the same time.

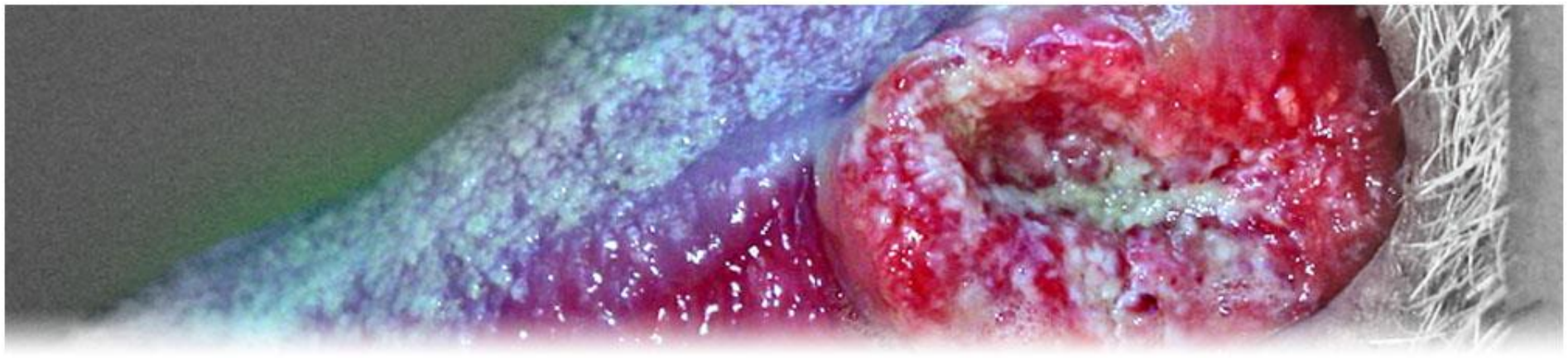
Treatments for cancers

- Treatments kill rapidly dividing cells
  - chemotherapy
    - poisonous drugs that kill rapidly dividing cells
  - radiation
    - high energy beam kills rapidly dividing cells

side effects

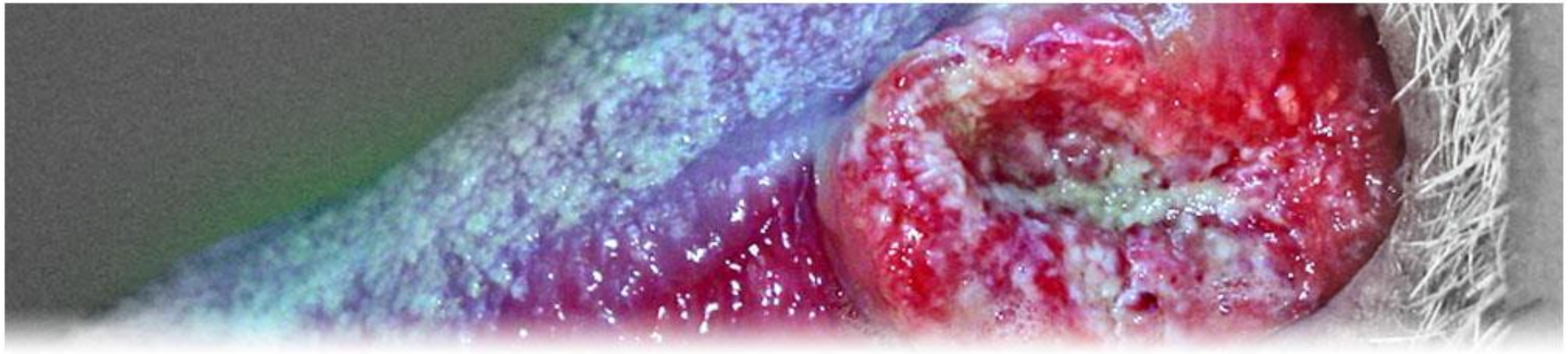


Cancer

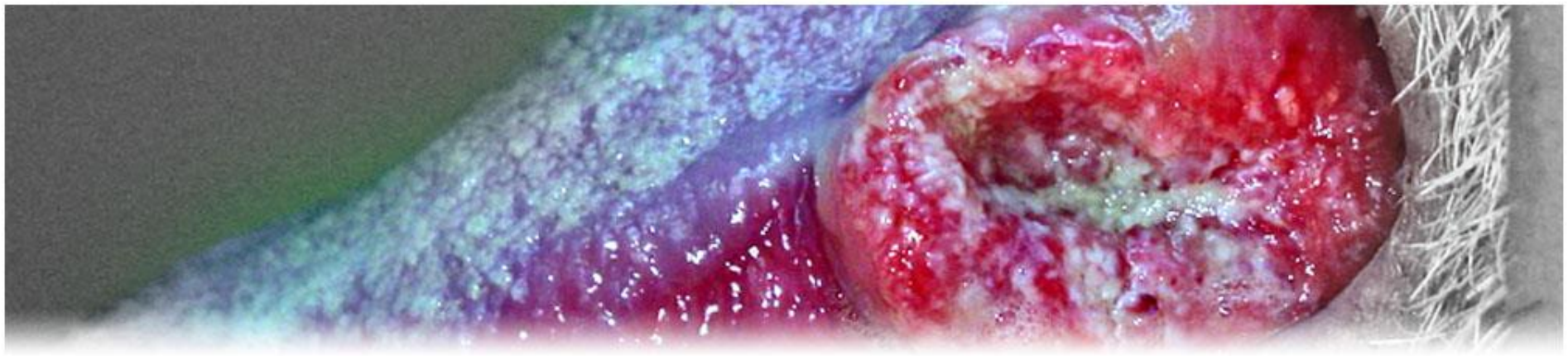


QUESTION AND ANSWER

How do cancer cells differ from other cells?

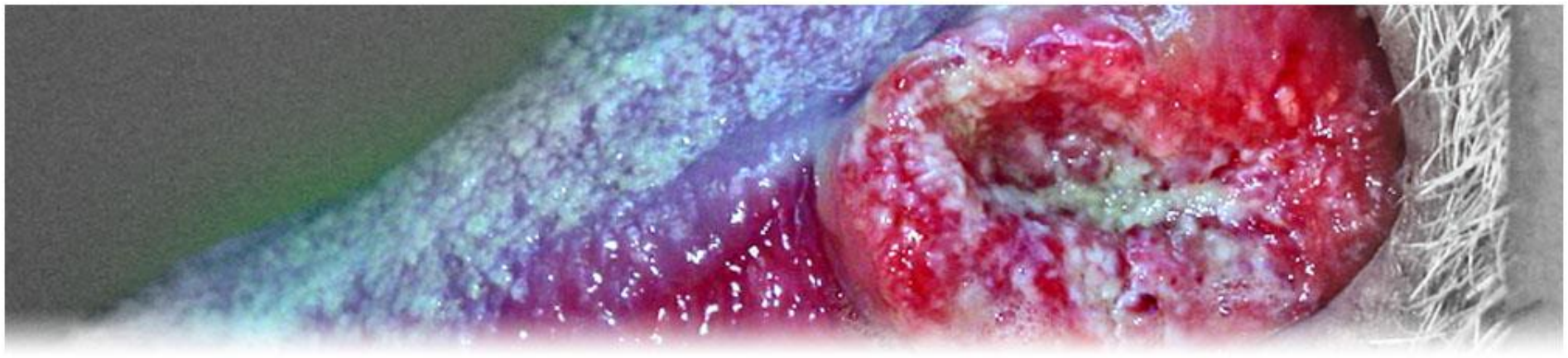


What are stem cells?



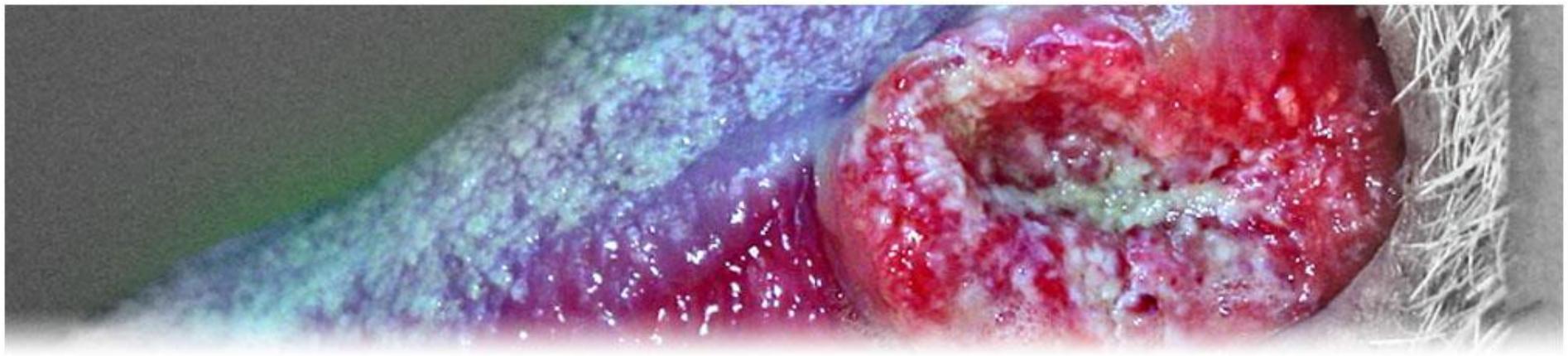
Cell differentiation

- Organisms start life as an embryo and during this developmental process cells become more and more differentiated and specialized for particular functions.
  - The process by which cells become specialized is known as **differentiation**
  - During the development of an organism, cells differentiate into many types of cells.
  - The unspecialized cells from which differentiated cells develop are known as **stem cells**
    - Therefore stem cells are cells with the potential of developing into other cell types



QUESTION AND ANSWER

What are stem cells?



Essential Question

- How does a cell produce a new cell?