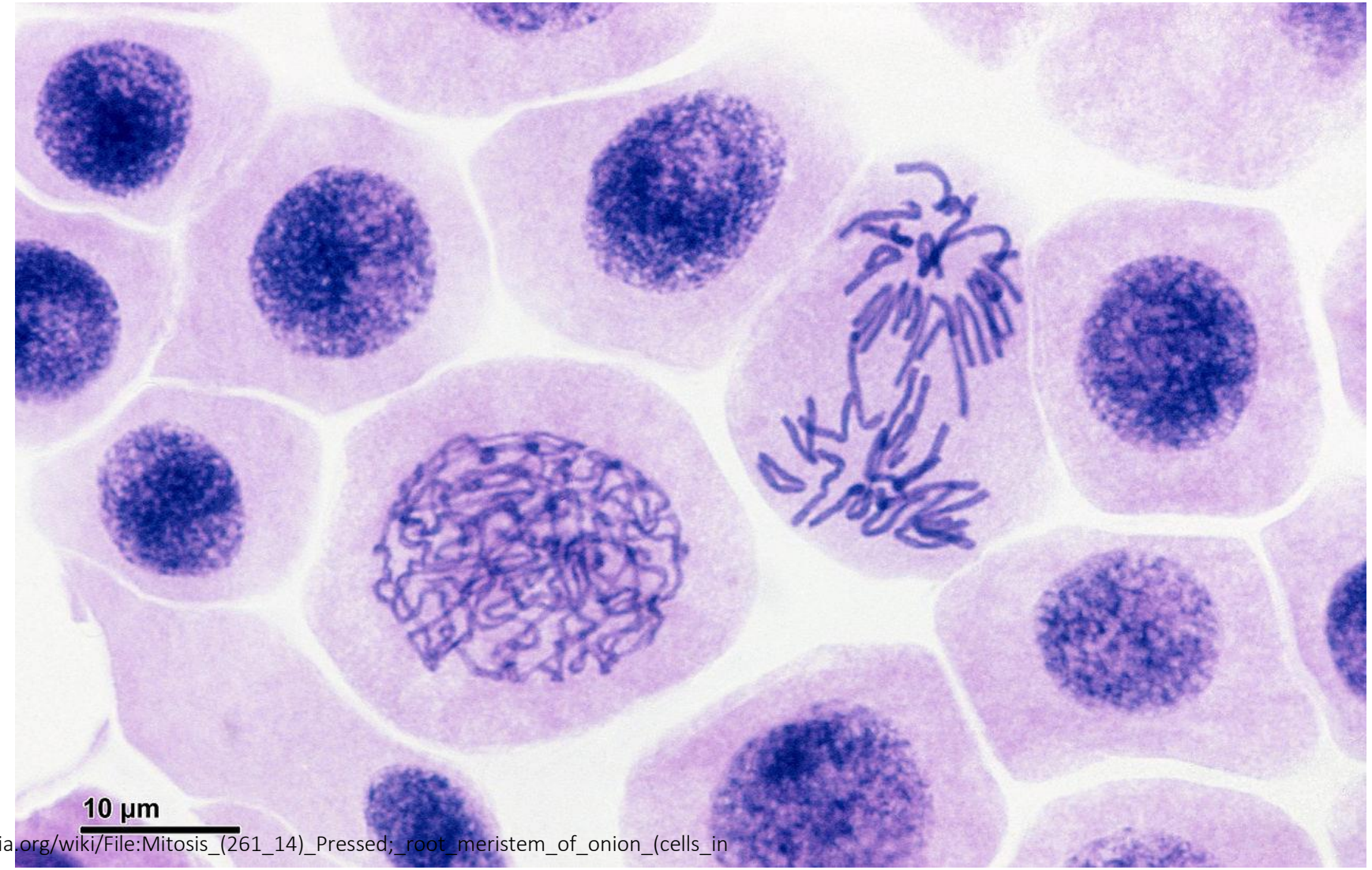
Today's class (L#3)– Cell Cycle, Mitosis & Start Meiosis



https://commons.wikimedia.org/wiki/File:Mitosis_(261_14)_Pressed;_root_meristem_of_onion_(cells_in_prophase,_anaphase).jpg

Reminder

Deadline for Dr. Pam Kalas' genetics survey (1%) is this Thursday night @ 11:59 pm

UBC SUS x GSS Mentorship Program

Seeking Mentorship?

What is the Mentorship Program?

The SUS x GSS Mentorship Program hopes to provide **academic and professional guidance** for first and second year students by connecting them with **upper year undergraduate and graduate mentors.**

Example Topics of Discussion

- Professional and graduate school
- Networking and interview skills
- Professional documents
- How to gain research experience (Volunteering, Co-op, Work Learn, Directed Studies)
- Course planning, study tips, and school-life balance
- Personal growth and development

Scan here to apply to be a mentee!

Due **Wednesday, January 25th, 11:59 pm PST**

MURC
MULTIDISCIPLINARY UNDERGRADUATE RESEARCH CONFERENCE

ROGERS

Peer Review Session

Presenter Applications due:

Jan 22nd at 11:59 pm

Visit students.ubc.ca/murc to apply!

Get valuable tips and feedback on your abstract before submitting them!

Join us online

Friday, Jan 20th

3-5pm

Register now!

THE UNIVERSITY OF BRITISH COLUMBIA
Centre for Student Involvement & Careers

Alumni Networking Night

Wednesday Feb 1

6 - 7:30 PM PST

Ever wondered what happens after grad? Want to meet professionals from diverse careers?

Register now for SCI Team's annual Alumni Networking Night to explore career options and the chance to connect with UBC BSc alumni!

SCI TEAM

sciteam.ubc.ca

UBC Faculty of Science

Tips & Tricks for Success #4

UBC researchers (Statistics Department) found that:

Students who use **recall/retrieval exercises** when studying perform significantly better on exams than students who depend solely on passive study habits.

Recall/Retrieval – answering questions (e.g. practice exams), flash cards, teaching others (e.g. study groups)

Passive – re-reading notes, re-writing notes, re-listening to lectures

Tips & Tricks for Success #5

A study by the same researchers found that, when studying, students who left **2 to 3 days before revisiting the same concept** performed significantly better on exams that students who revisited the concept every day.

The researcher told me that “students have to let their brain almost begin to forget” the concept before revisiting the concept….”

Last class, we discussed the following terms

Chromosomes - Types
- Autosomal chromosomes (1-22 in people)
- Sex chromosomes (e.g. X, Y)
- Homologous chromosomes

DNA
Genes and Alleles
Genome

Chromosome Structure:
- Centromere
- Arm
- Locus or Loci of genes
- Replicated and non-replicated chromosomes
  - Sister chromatids (of replicated chromosomes)
  - Non-sister chromatids of homologous chromosomes

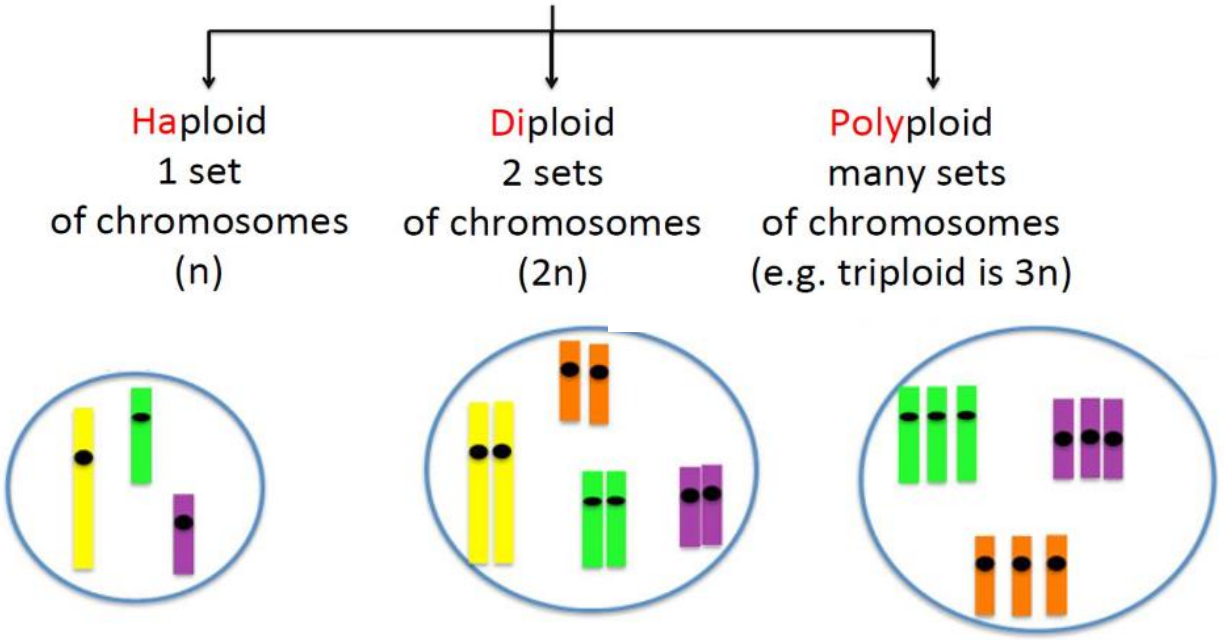
Terms to describe the genetics of a cell:

- Total chromosome number
- Ploidy
- Haploid number (n)

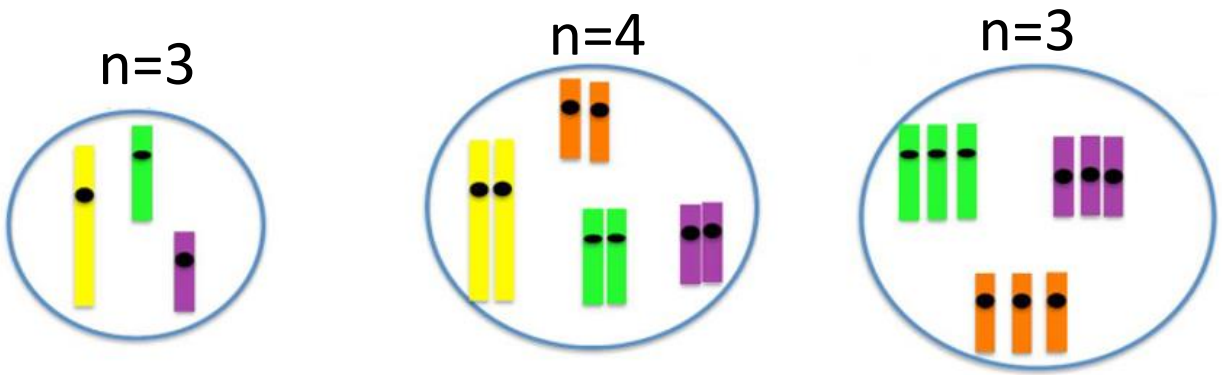
- Genotype
  - Homozygous
  - Heterozygous

When describing a cell

Ploidy = number of sets (or "copies") of chromosomes in the nucleus



Haploid number (n) = number of chromosomes in ONE complete set of chromosomes;
- or number of chromosomes in gamete



3n=9; so, haploid number (n) must be 3

2n=46; so, our haploid number must be 23

iClicker Question

What is the ploidy and haploid number of chromosomes in the cell shown below?

A. Diploid; 12
B. Diploid; 6
C. Diploid; 3
D. Haploid; 12
E. Haploid; 6

How would you write the notation for the genetic make-up of this cell?

Answer

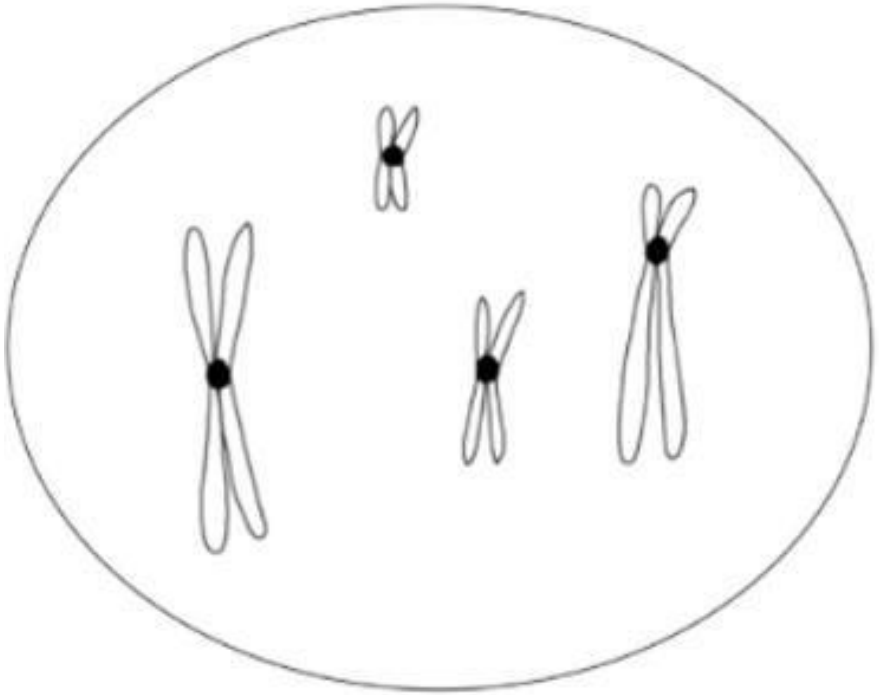
What is the ploidy and haploid number of chromosomes in the cell shown below?

A. Diploid; 12
B. Diploid; 6
C. Diploid; 3
D. Haploid; 12
E. Haploid; 6

How would you write the notation for the genetic make-up of this cell?

Explanation question to apply tip #5

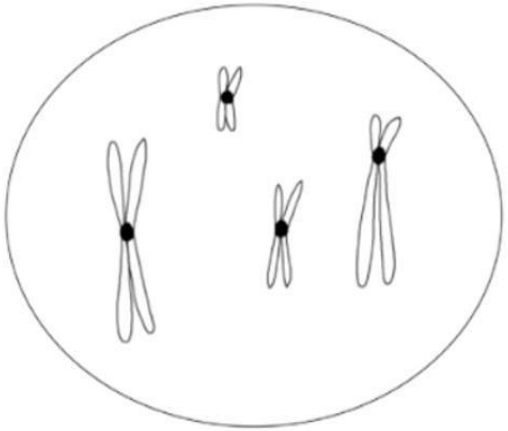
Your friend claims that the cell shown below is diploid. Is your friend correct? Explain why or why not.



2 minutes to answer question.

Example answer

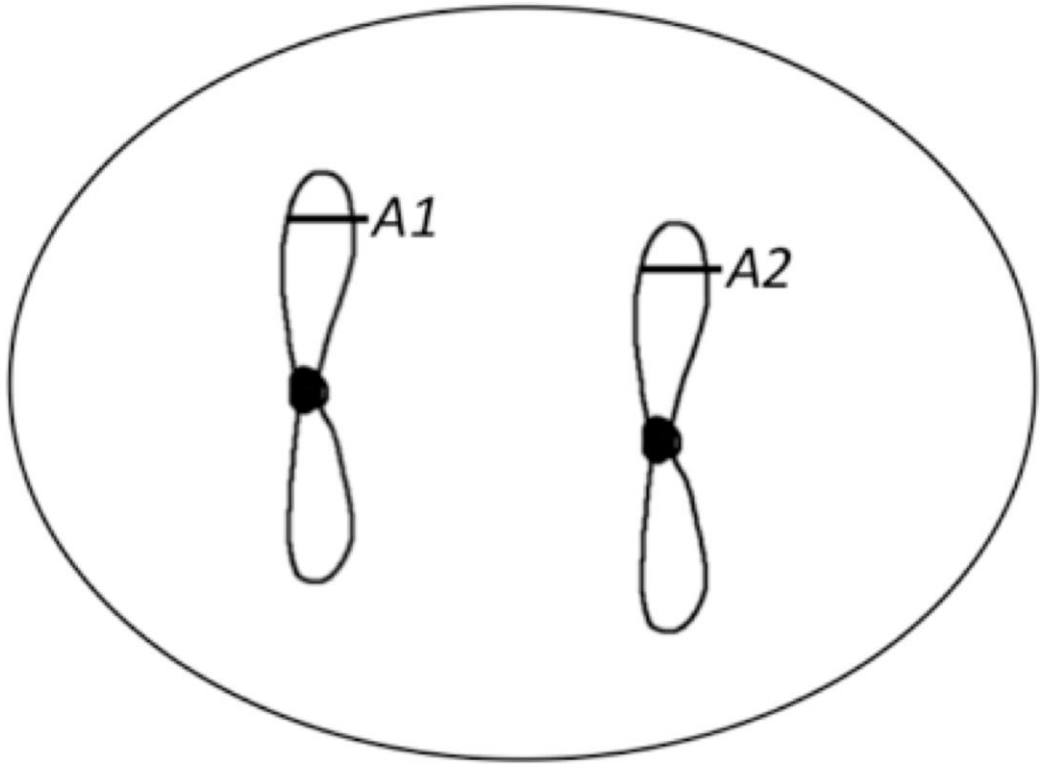
Your friend this the cell shown below is diploid. Is your friend correct? Explain why or why not.



My friend is incorrect. The cell is not diploid.

Diploid means that there are two of each type of chromosome in a cell. However, there is only one of each type of chromosome in this cell, as indicated by differences in size and centromere location. Therefore, this cell is haploid (1n=4), with replicated chromosomes, not diploid.

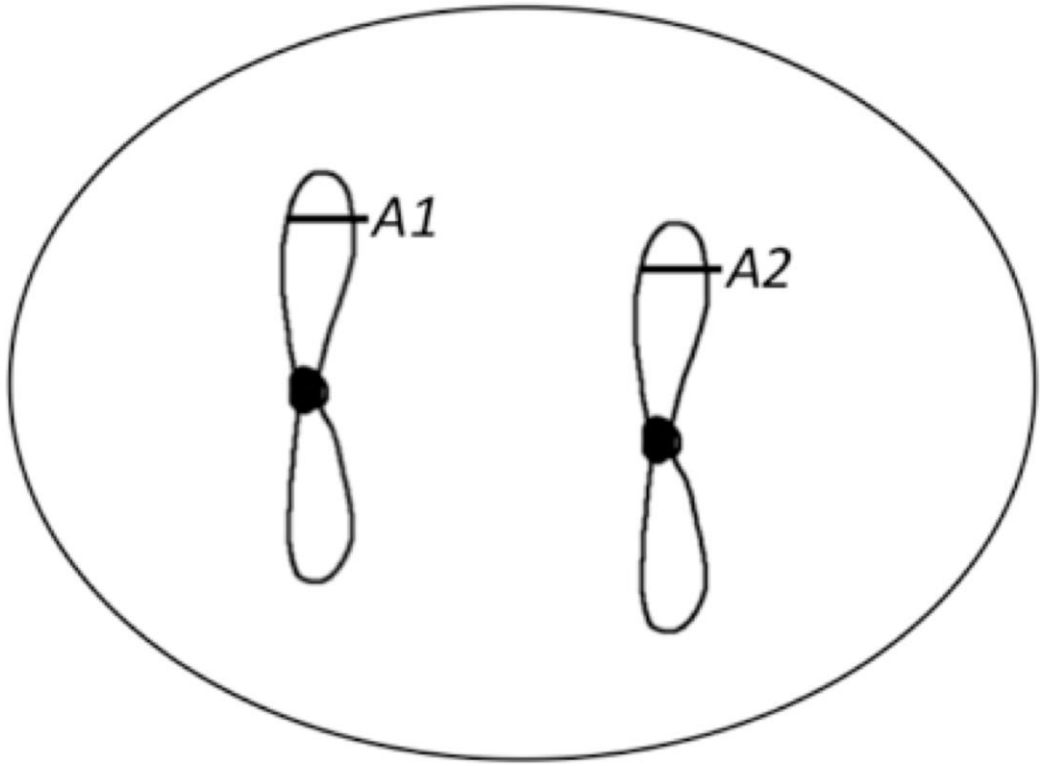
Question



Is this cell homozygous or heterozygous for the A gene?

A. Homozygous
B. Heterozygous
C. Not sure

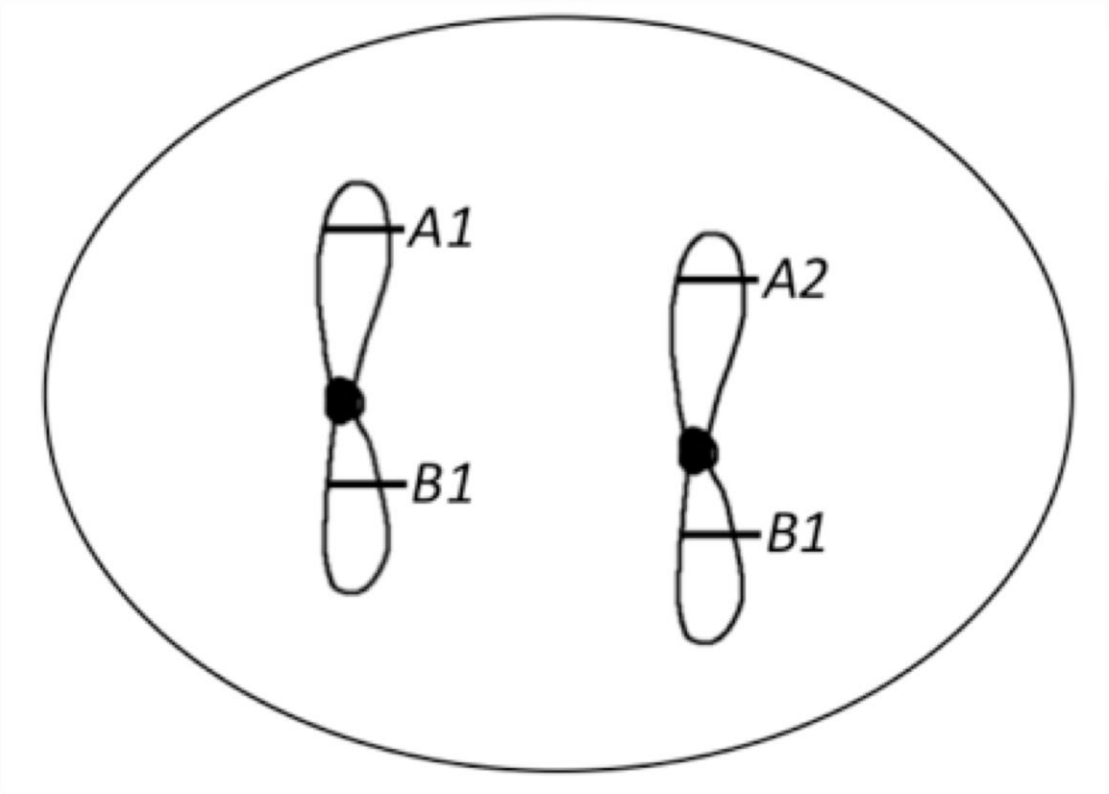
Answer



Is this cell homozygous of heterozygous for the A gene?

A. Homozygous
B. Heterozygous
C. Not sure

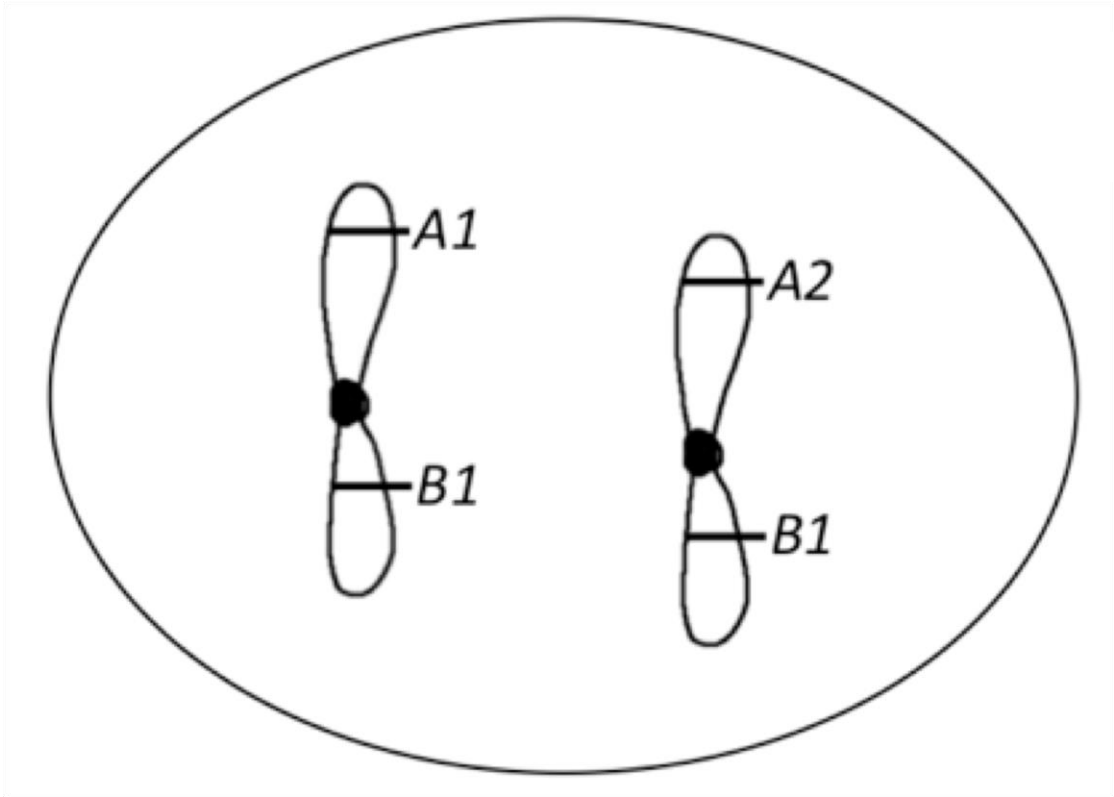
iClicker Question



Is this cell homozygous or heterozygous for the B gene?

A. Homozygous
B. Heterozygous
C. Not sure

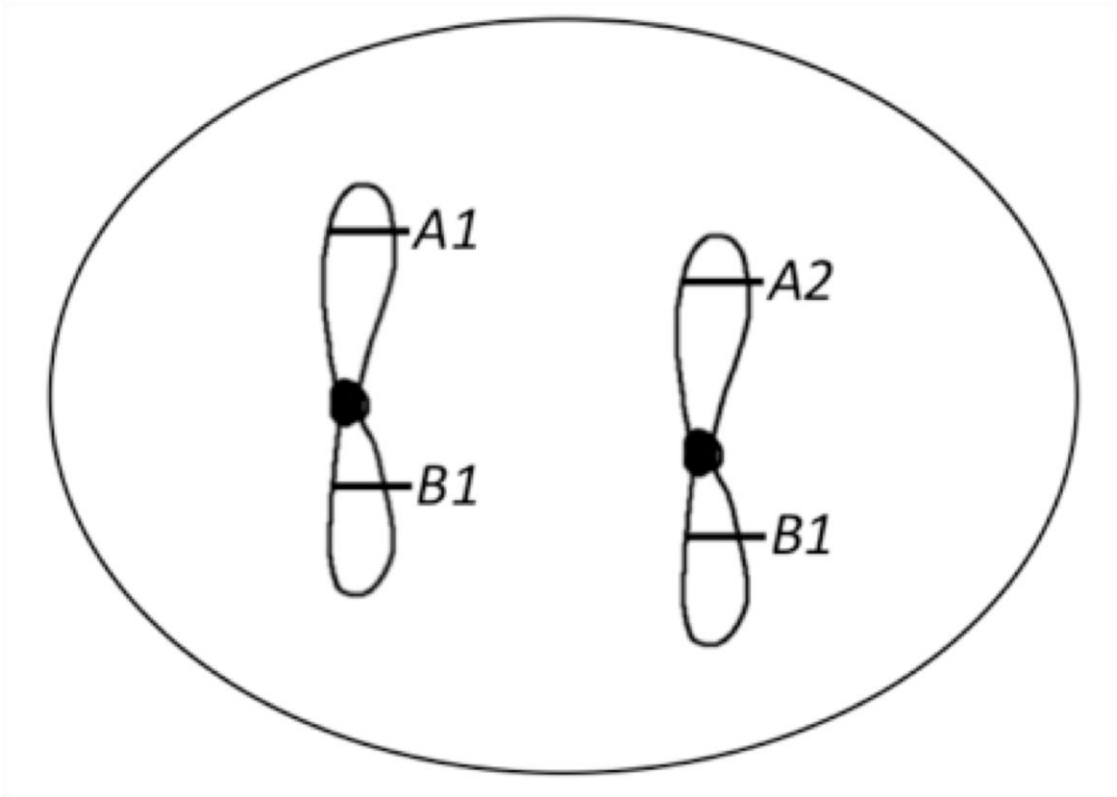
Answer



Is this cell homozygous or heterozygous for the B gene?

A. Homozygous
B. Heterozygous
C. Not sure

Genotype notation



Only use upper and lower case notation, e.g. A/a if you know the alleles have a dominant/recessive relationship

In some worksheets, alleles of the same gene are separated by "/" and genes by a semicolon.

Notation: *A1/A2; B1/B1*

In some worksheets/questions there is no notation, e.g. It would also be acceptable to write: **A1A2B1B1**

Note – there are notations to indicate if two genes are located on the same chromosome; we will not be using that notation in BIOL121/

Genes & Chromosomes – Learning Objectives

You should be able to:

Identify homologous chromosomes based on structure (size, centromere position) and genetic loci.

Recognize or **describe:**

- autosome vs. sex chromosome
- unreplicated vs. replicated DNA
- number of DNA molecules vs chromosome number
- homologous chromosomes vs. sister chromatids
- sister chromatid vs non-sister chromatid
- cell ploidy (haploid, diploid, polyploidy)
- ploidy versus haploid number
- heterozygous genotype vs homozygous genotype

Diagram or **interpret** cells with different numbers of chromosomes and cells that differ in ploidy.

Please see Canvas > Learning Objectives

Phenotype

Phenotype = the observable and measurable characteristics of an organism.

Phenotype includes: morphological, biochemical, physiological, behavioural characteristics.

iClicker Question

Which of the following characteristics could be a phenotypic characteristic of an organism.

A. Body Length
B. Blood Type (e.g. B+)
C. Heart Rate
D. Migratory behaviour
E. All of the above

Answer

Which of the following characteristics could be a phenotypic characteristic of an organism.

A. Body length
B. Blood type (e.g. B+)
C. Heart Rate
D. Migratory behaviour
E. All of the above

These are all observable, measurable characteristics of an organism.

Phenotype

An individual's phenotype is determined by interactions between an individual's genotype and environmental factors.

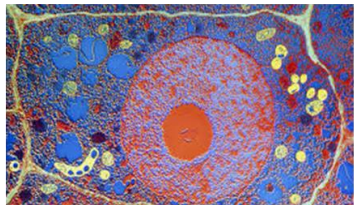
From Dr. Pam Kalas:

"Variation in phenotype amongst individuals is always due to interactions between:

- Genetic variation AND
- Variation in the environment, including:
  - Variation in the "internal" environment (e.g. differences in the physiological, cellular, molecular environment); and
  - Variation in the "external" environment (e.g. differences in exposure to stress, food availability)

Chance can also play a role."






Example: Environmental influence on sea star phenotypes

Color Polymorphism and Genetic Structure in the Sea Star *Pisaster ochraceus*

C. D. G. HARLEY,[1,*,†] M. S. PANKEY[2,*], J. P. WARES[2,*,‡], R. K. GROSBERG[2], AND M. J. WONHAM[3,§]

Dr. Chris Harley

- *Pisaster* has different colour phenotypes

Although colouration of other marine invertebrates is driven by genotype…

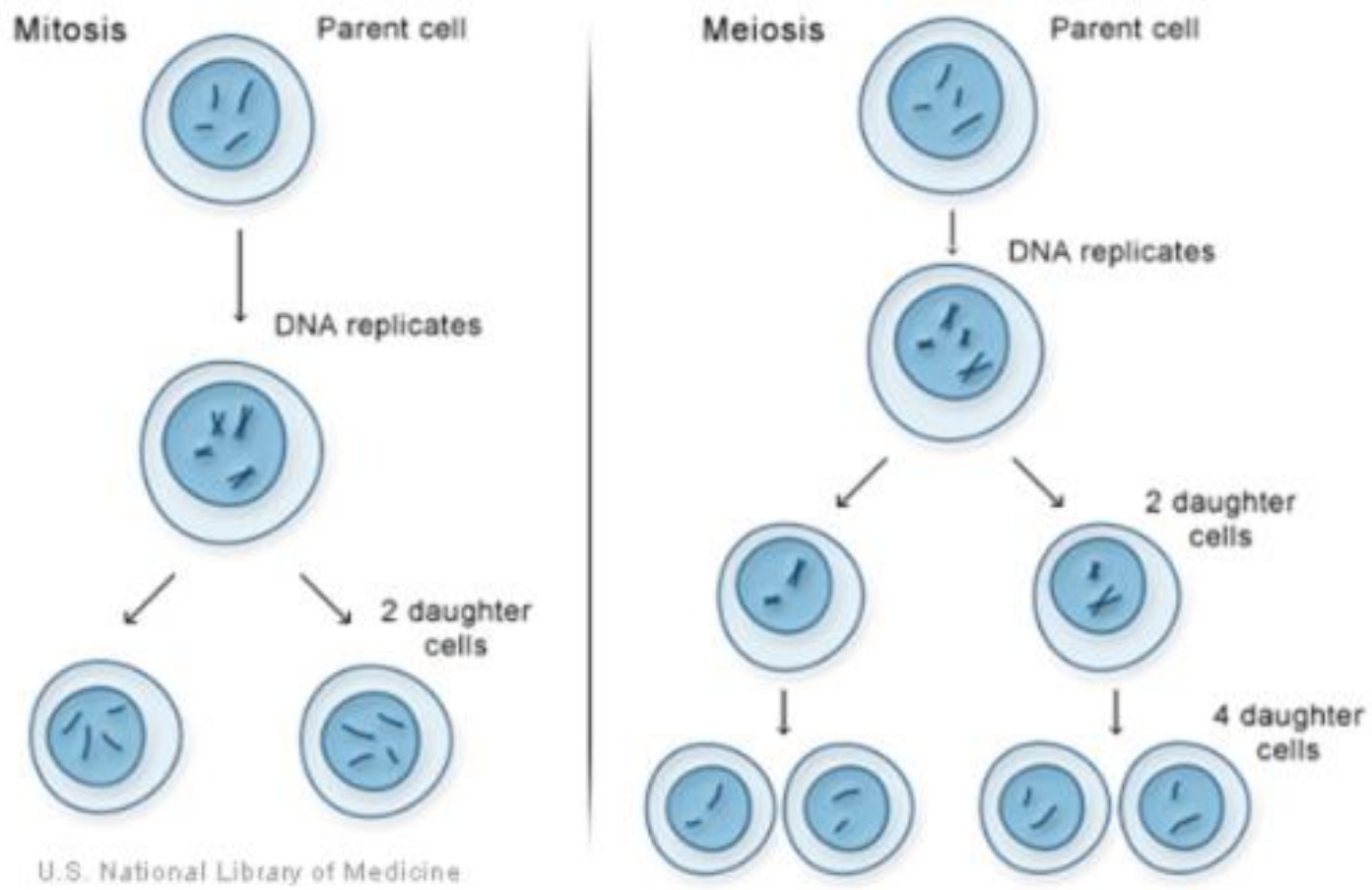
Pisaster colouration is also driven by diet!

Eats mostly mussels = orange or brown

Eats mostly barnacles = purple

Questions?

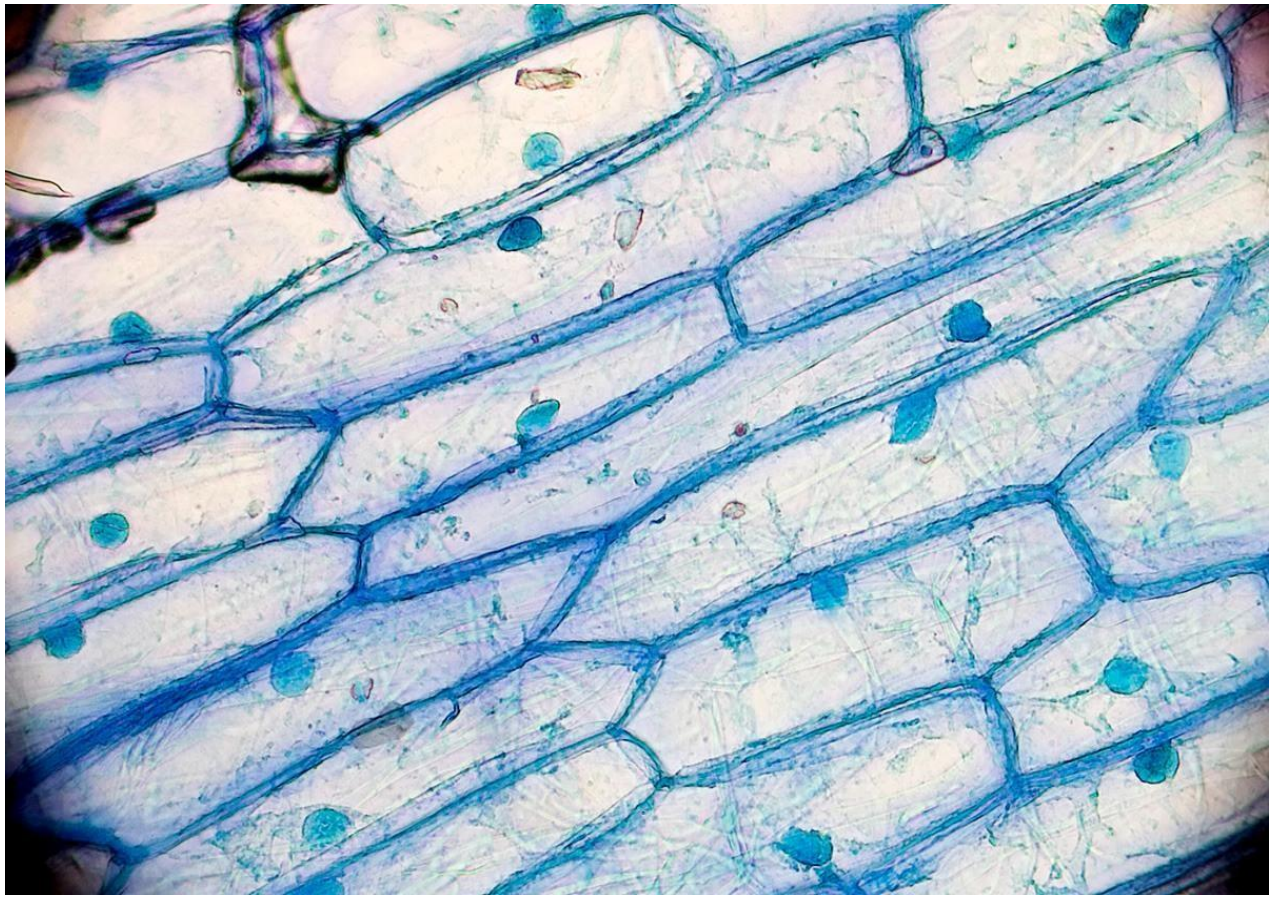
Mitosis & Meiosis



Credit: U.S. National Library of Medicine

According to cell theory

- All cells arise from pre-existing cells



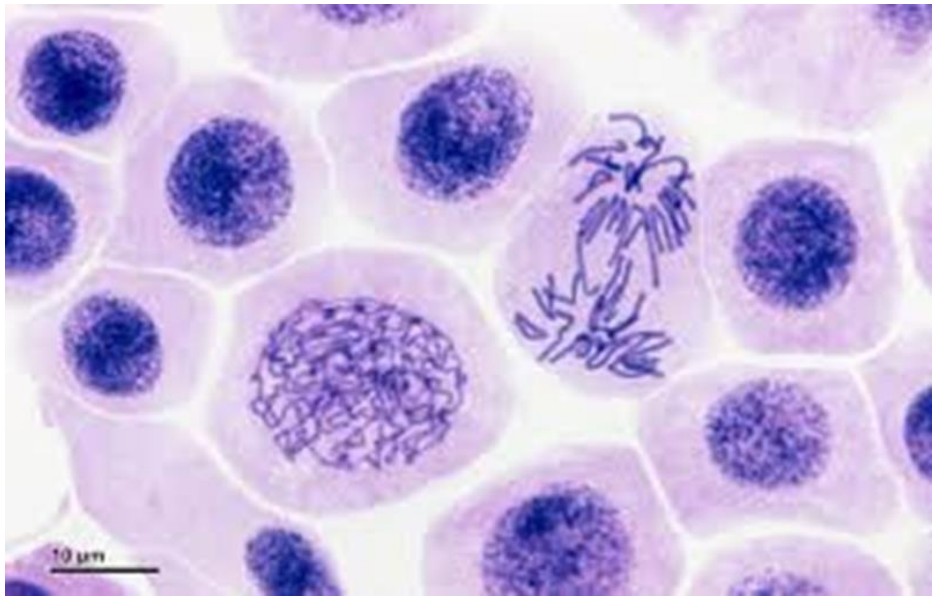
https://commons.wikimedia.org/wiki/File:Onion_Cells.jpg

New cells arise through cell division: 2 types

- Two types of cell division:

Mitosis + cytokinesis

Meiosis + cytokinesis



Mitosis & Meiosis = nuclear divisions

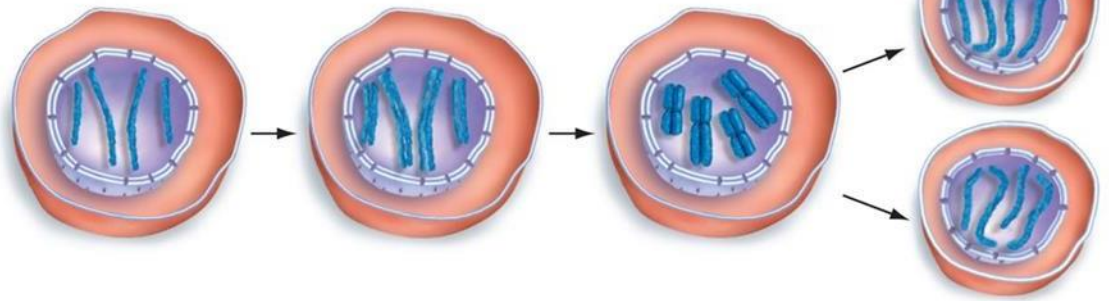
Cytokinesis = division of cytoplasm

Mitosis & Cytokinesis

- Goal – to produce 2 genetically identical daughter cells

2n=4, e.g. A1/A2

Parent cell



2n=4, A1/A2

2 genetically identical daughter cells

2n=4, A1/A2

One round of nuclear division

Why would you want your somatic cells to be able to undergo mitosis?

Without mitosis (and cytokinesis)

- All organisms (including you) would be single celled;
- You could not grow
- Dead and damaged cells and worn out cells could not be replaced;

https://en.wikipedia.org/wiki/Zygote

Table 4.1.1: Life Span of Cells in Selected Organs of the Human Body

Data after KLIMA 1967, RUCKER 1967

Organ	Average life span (days)
Stomach (pylorus)	1.8– 1.9
Stomach (cardia)	9.1
Small intestine	1.3– 1.6
Liver	10.0– 20.0
Large intestine	10.0
Rectum	6.2
Anus	4.3
Trachea	47.5
Lungs (alveoli)	8.1
White blood cells	1.0– 3.0
Red blood cells	120.0
Bladder	64.0
Epidermis	
Lips	14.7
Soles	19.1
Abdominal skin	19.4
Ear	34.5
Nervous system	No regeneration

Note – red blood cells and (most) white blood cells cannot divide – not testable

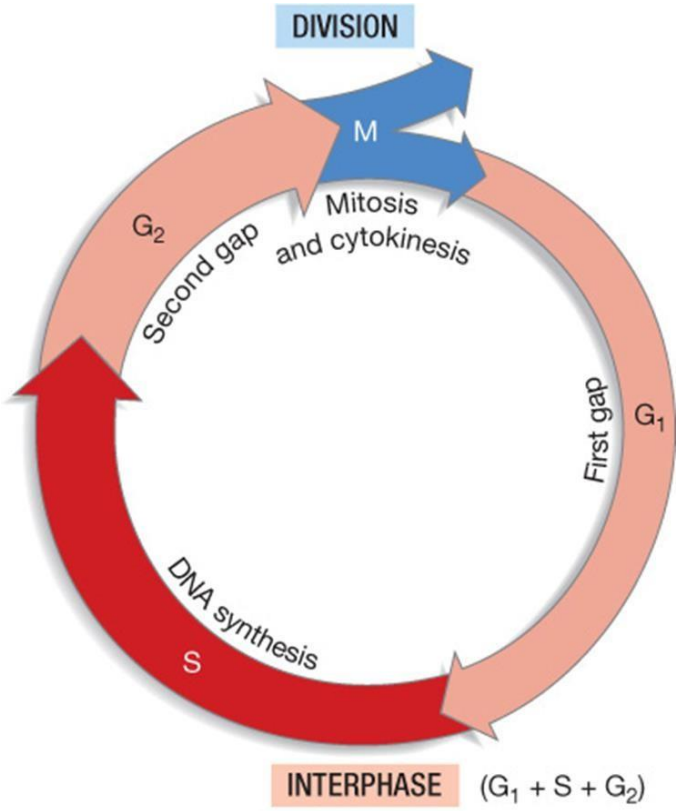
https://bionumbers.hms.harvard.edu/bionumber.aspx?s=n&v=2&id=101940

The Cell Cycle

- Mitosis is part of the cell cycle

- Cell cycle is defined as an ordered sequence of events that a cell goes through between one cell division and the next. (not testable)

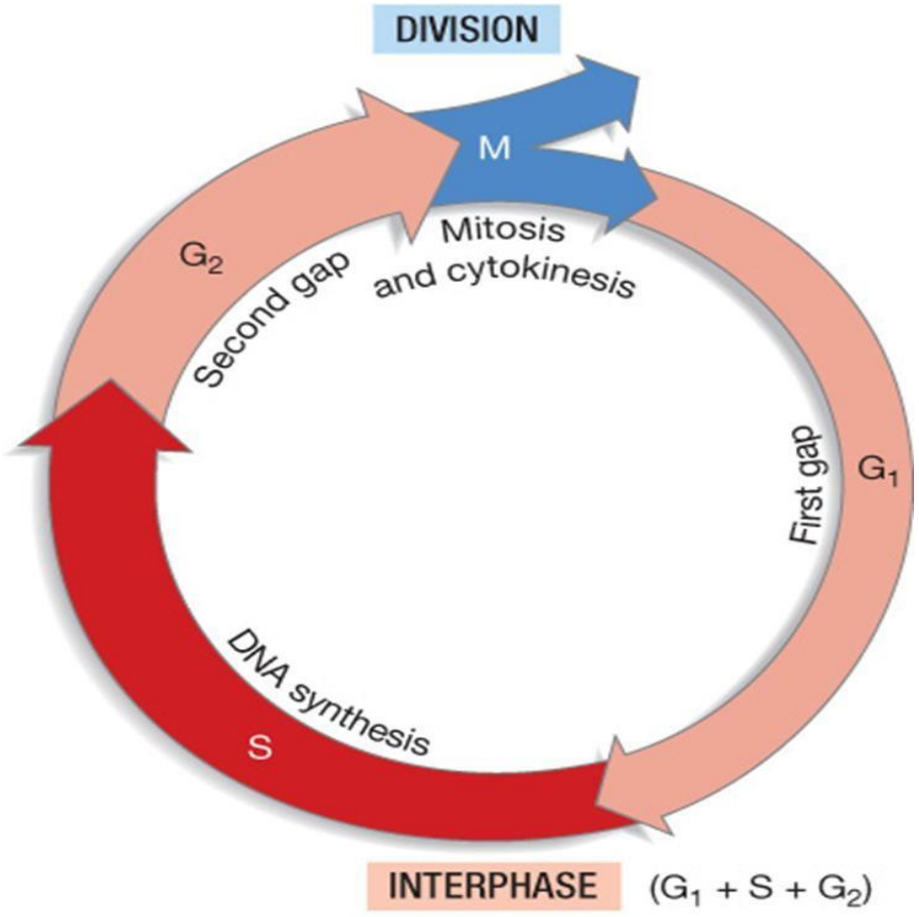
- Cell cycle has two major phases: Interphase and M phase = Mitosis + Cytokinesis



Interphase

- Interphase = longest part of a cell's life.

- 3 stages to Interphase: G1 phase
  S phase
  G2 phase

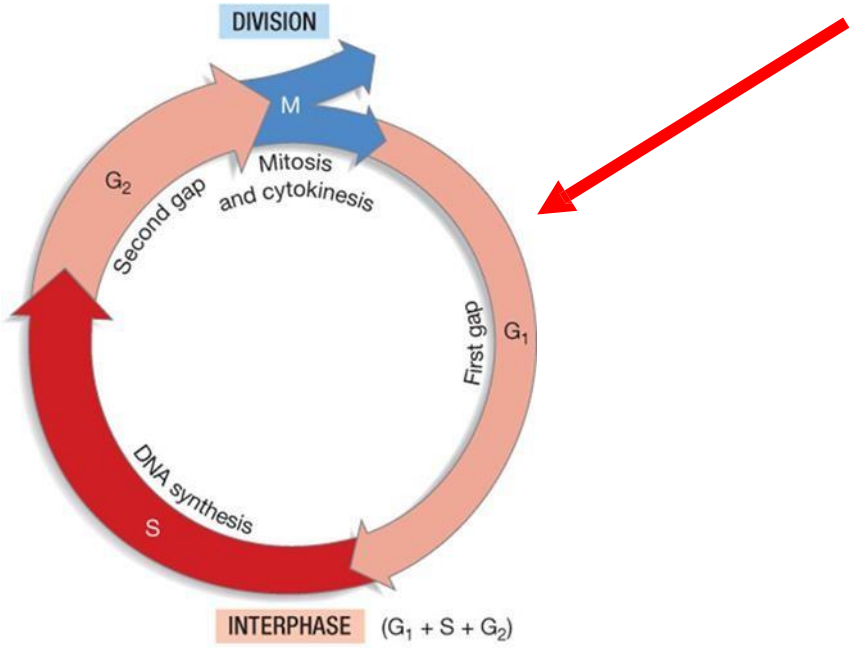


G1 phase or Gap 1 Phase

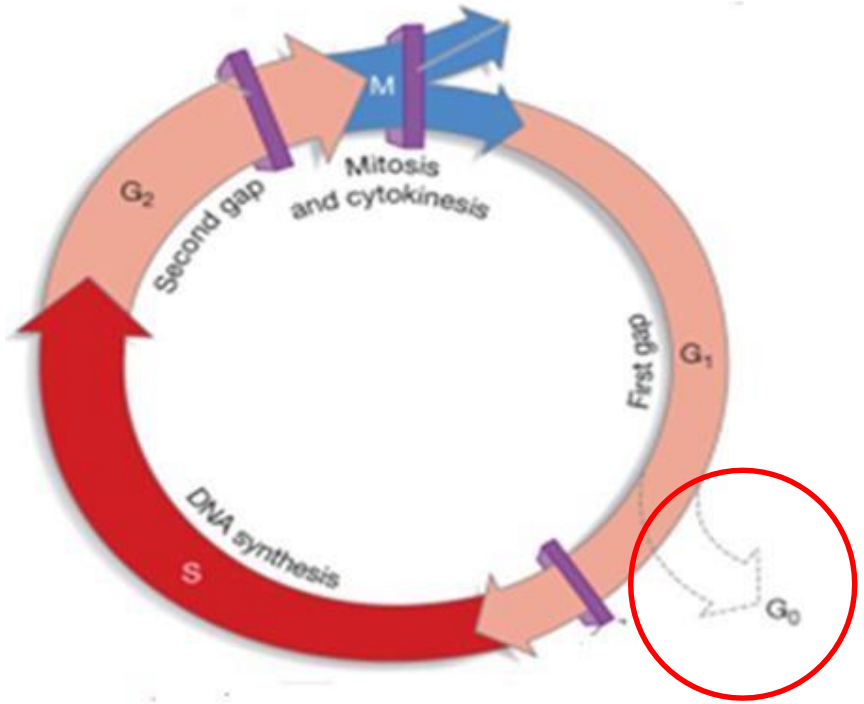
In G1 the cell is performing its functions, e.g. being a liver cell or skin cell.

If cell the signaled to start dividing, cell begins to prepare by:

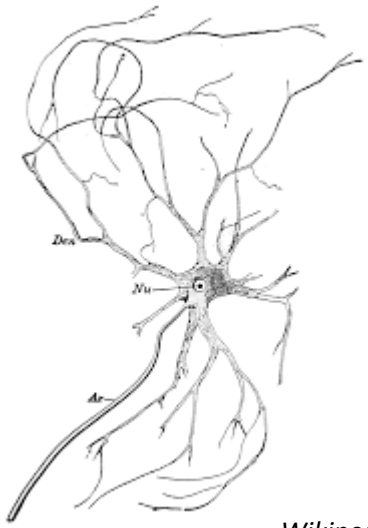
- growing
- duplicating organelles
- accumulating nucleotides
- obtains energy reserves



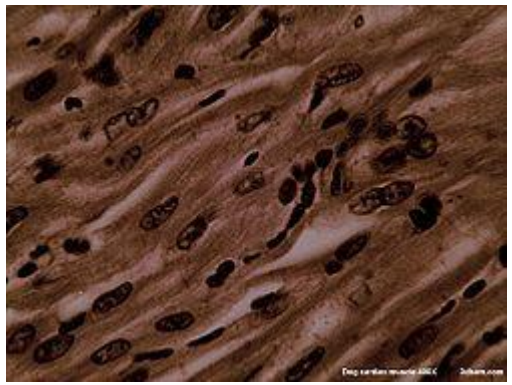
If a cell is not going to divide it can enter Go phase



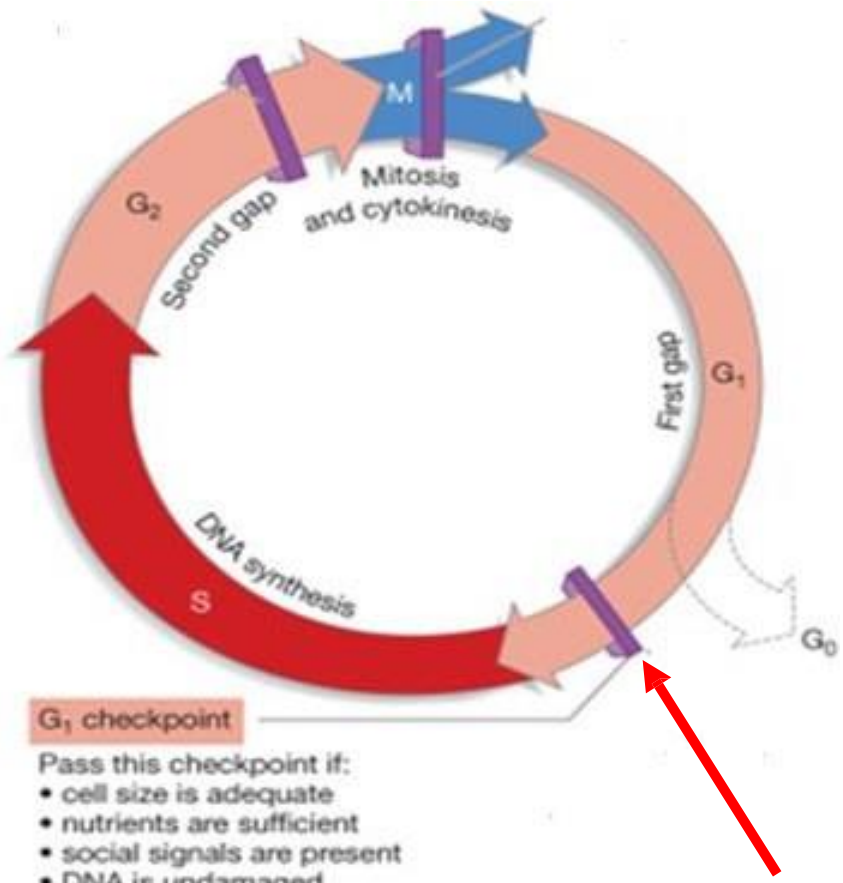
- Performs main function indefinitely
- e.g., neurons, muscles cells in your heart are in $G_o$phase.



Wikipedia



G1 Checkpoint (not testable)



Before the cell can enter the next phase (S phase), the cell must pass checkpoint 1.

- Is the cell size adequate?
- Nutrients/cytoplasm sufficient?
- DNA undamaged?
- Social signals present (go ahead)?

The G1 checkpoint is when a cell irreversibly commits to the cell division process.

Many types of cancers involve defects in the G1 checkpoint, i.e. cells begin dividing in the absence of the “go ahead” signal.

11.14

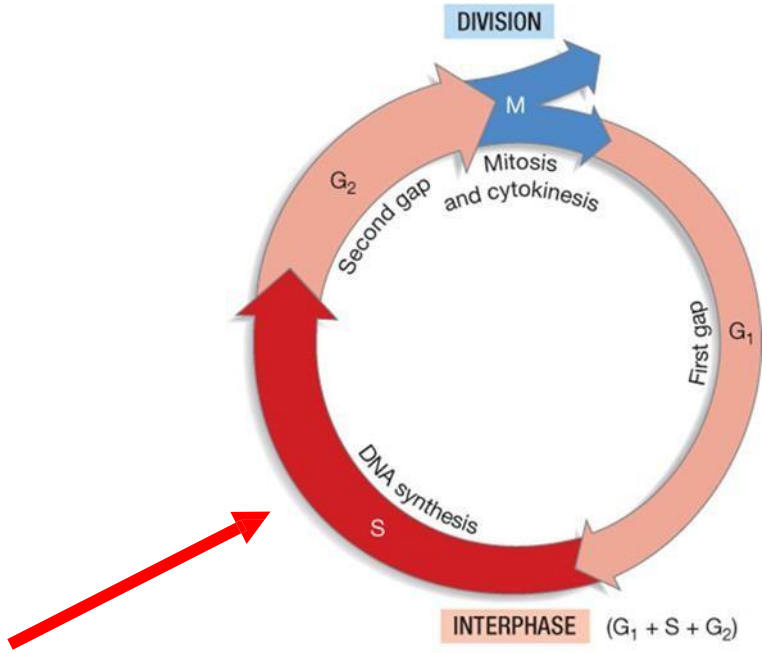
Fun fact: Not testable

- In humans, the DNA itself signals that it has been damaged by increasing the activity of certain genes, including the tumor suppressor gene p-53
- p-53 gene sometimes called “the guardian of the genome” – determines whether the cell can continue into S-phase to protect the genome from a proliferation of damaged DNA.

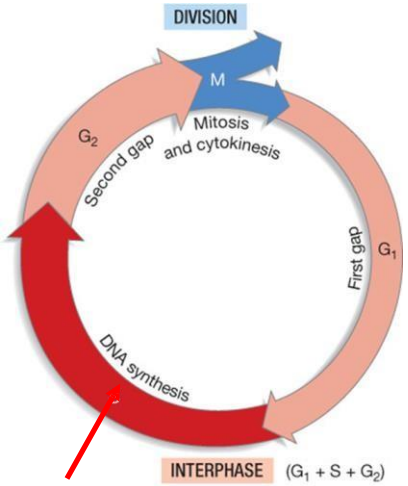
S phase

S= Synthesis

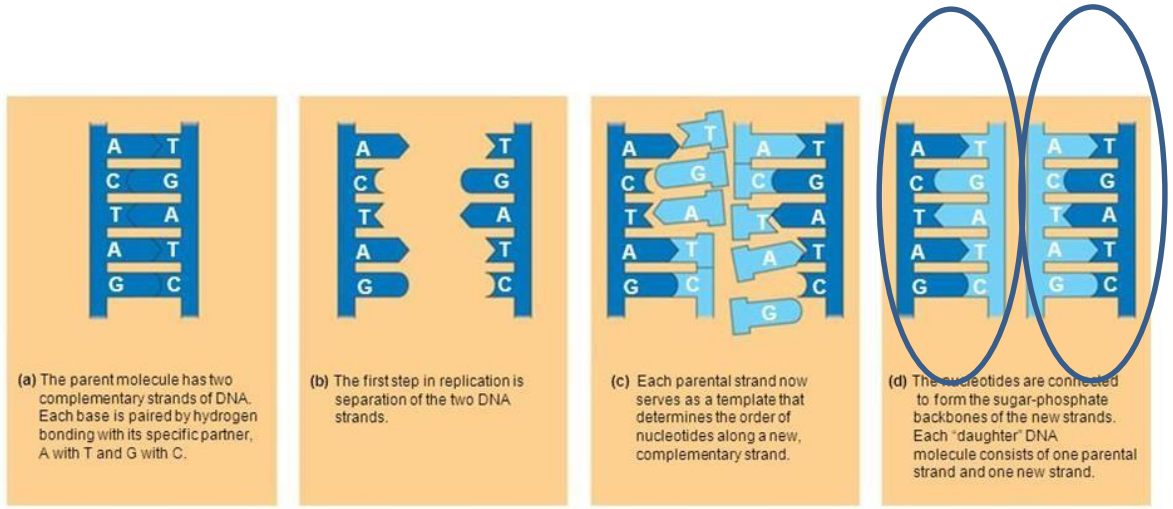
- This is when the DNA replicates (sister chromatids are formed)



S-stage

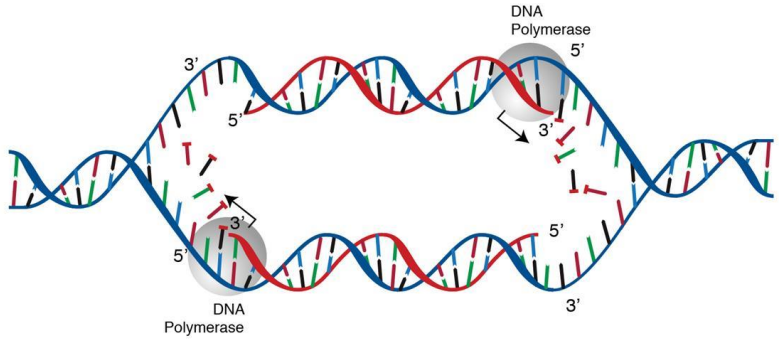


Sister chromatids



Replicated chromosome

Consists of two copies of the same chromosome.



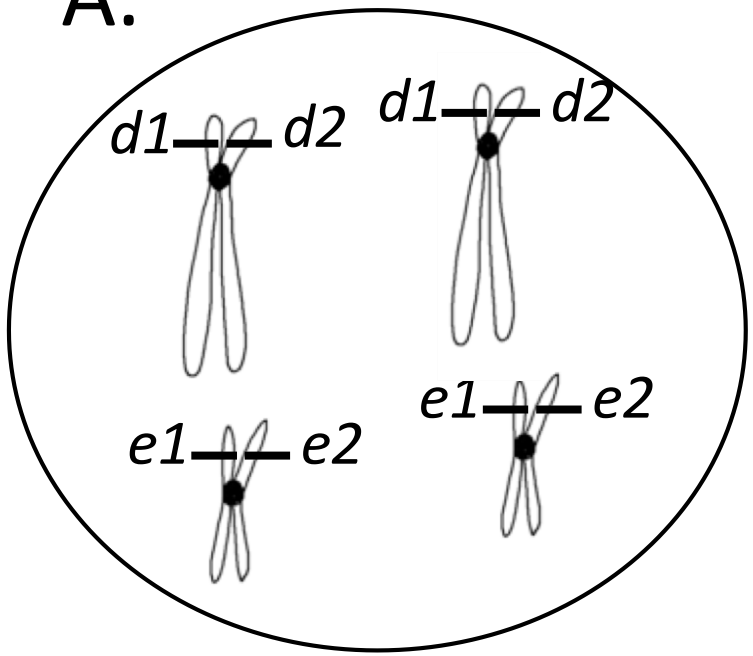
https://www.genome.gov/genetics-glossary/DNA-Replication

This is called semi-conservative DNA replication because each daughter DNA molecule consists of **one old strand and one new** strand.

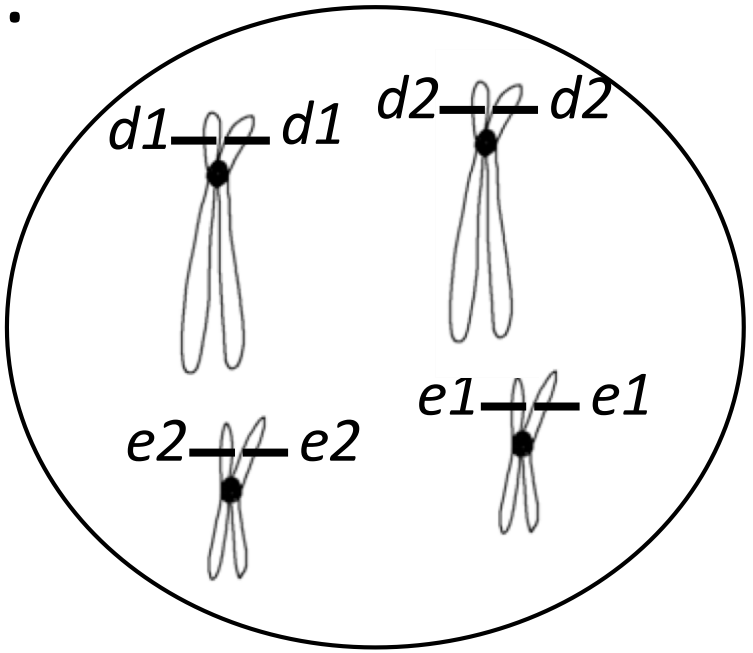
iClicker Question

Suppose an individual has the genotype d1/d2; e1/e2.
What should their chromosomes look like immediately after DNA replication?

A.



B.



Answer

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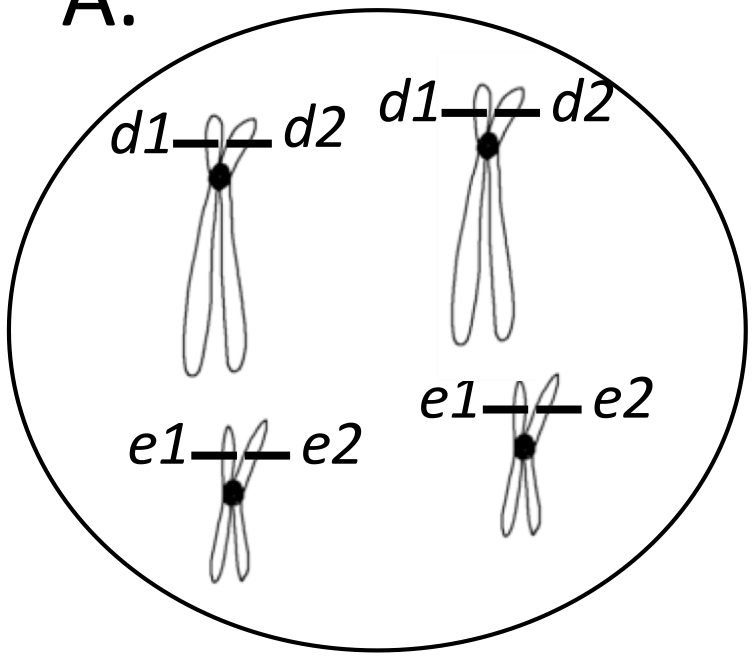
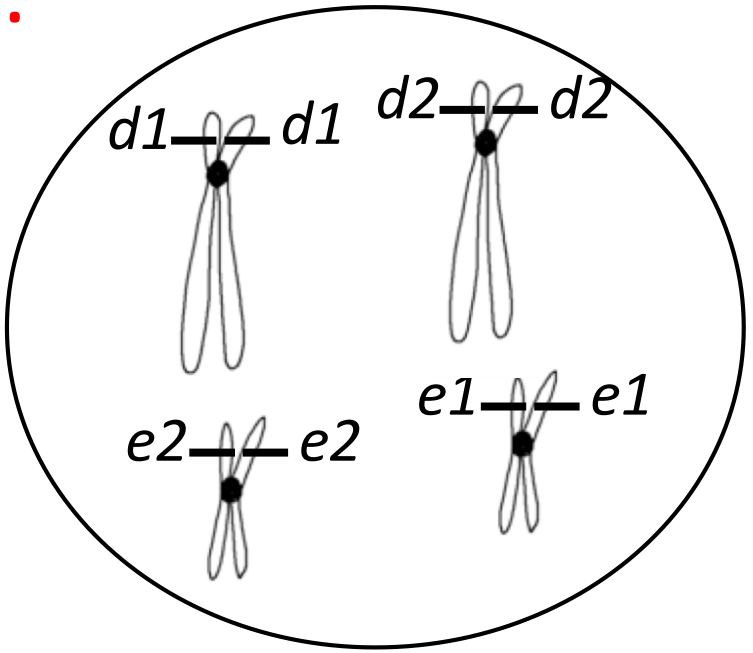


B.



iClicker Question

Students in Dr. Jennifer Klenz's genetics class (Biol 234) were asked to draw two replicated homologous chromosomes <u>just after DNA replication</u>. One homolog carries the B2 gene and one homolog carries the B5 gene. Which diagram is correct?

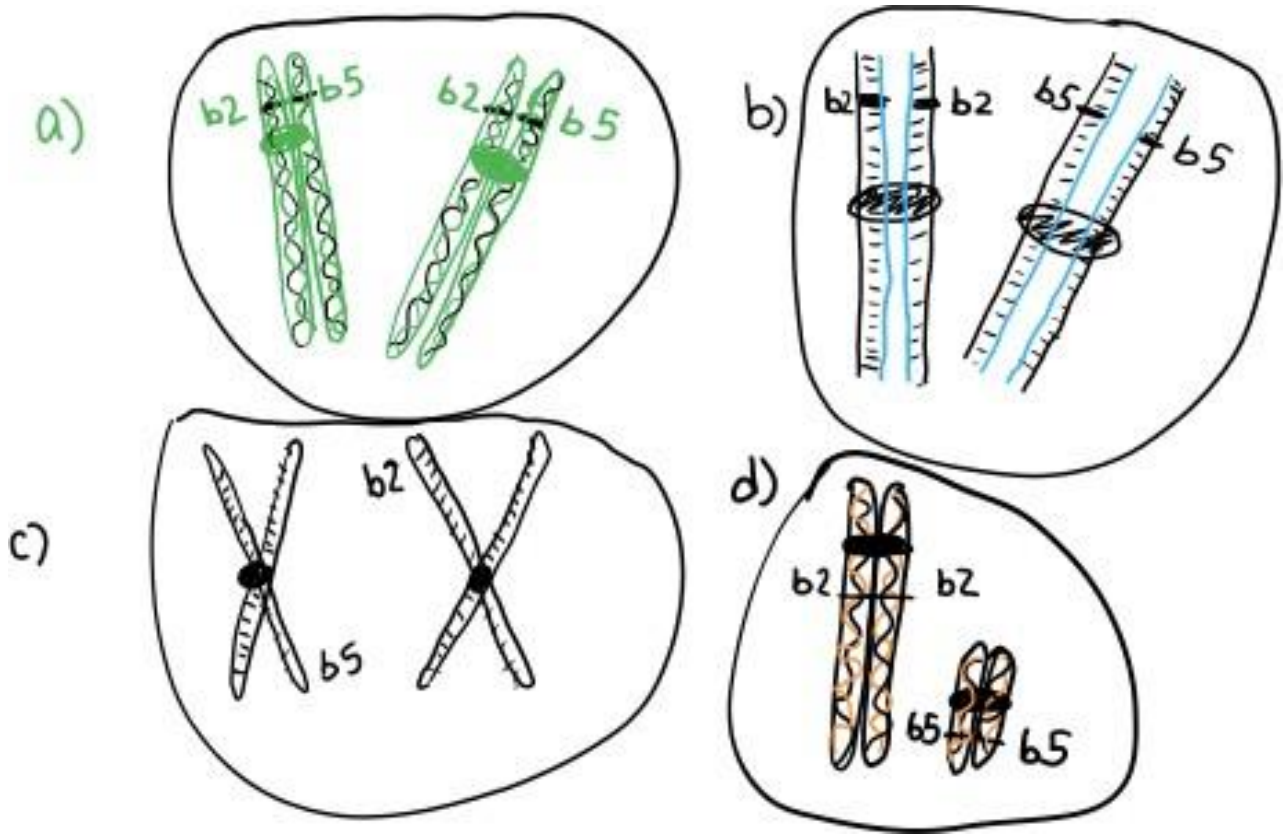
A. = a

B. = b

C. = c

D. = d

E. = not sure



Answer

Students in Dr. Jennifer Klenz's genetics class (Biol 234) were asked to draw two replicated homologous chromosomes just after DNA replication. One homolog carries the B2 allele and one homolog carried the B5 allele. Which diagram is correct?

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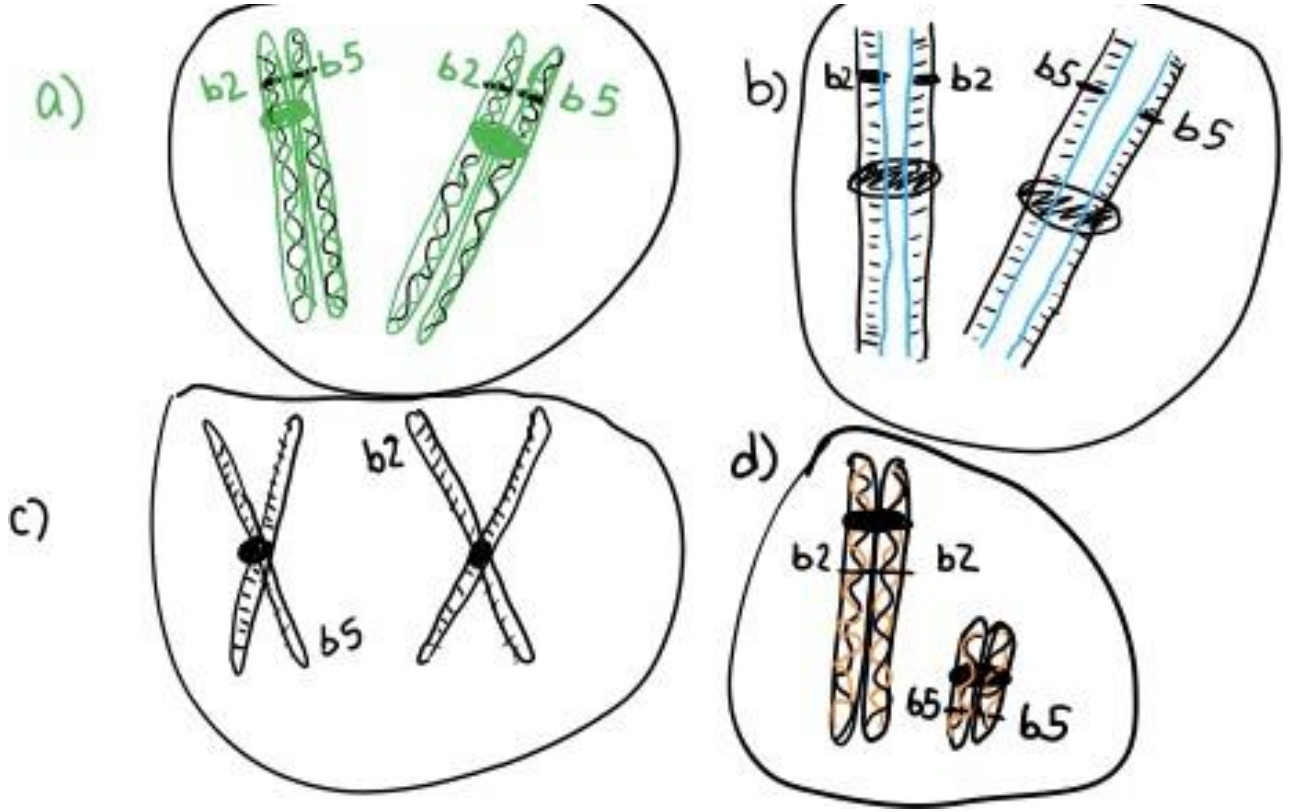
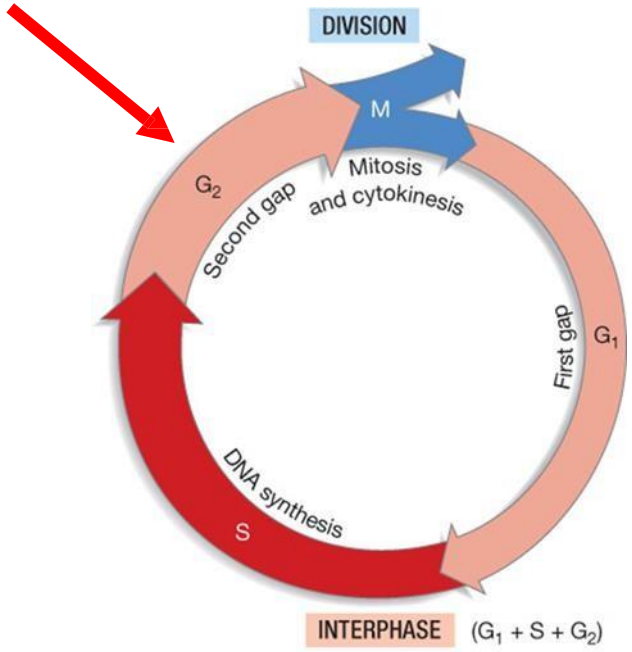
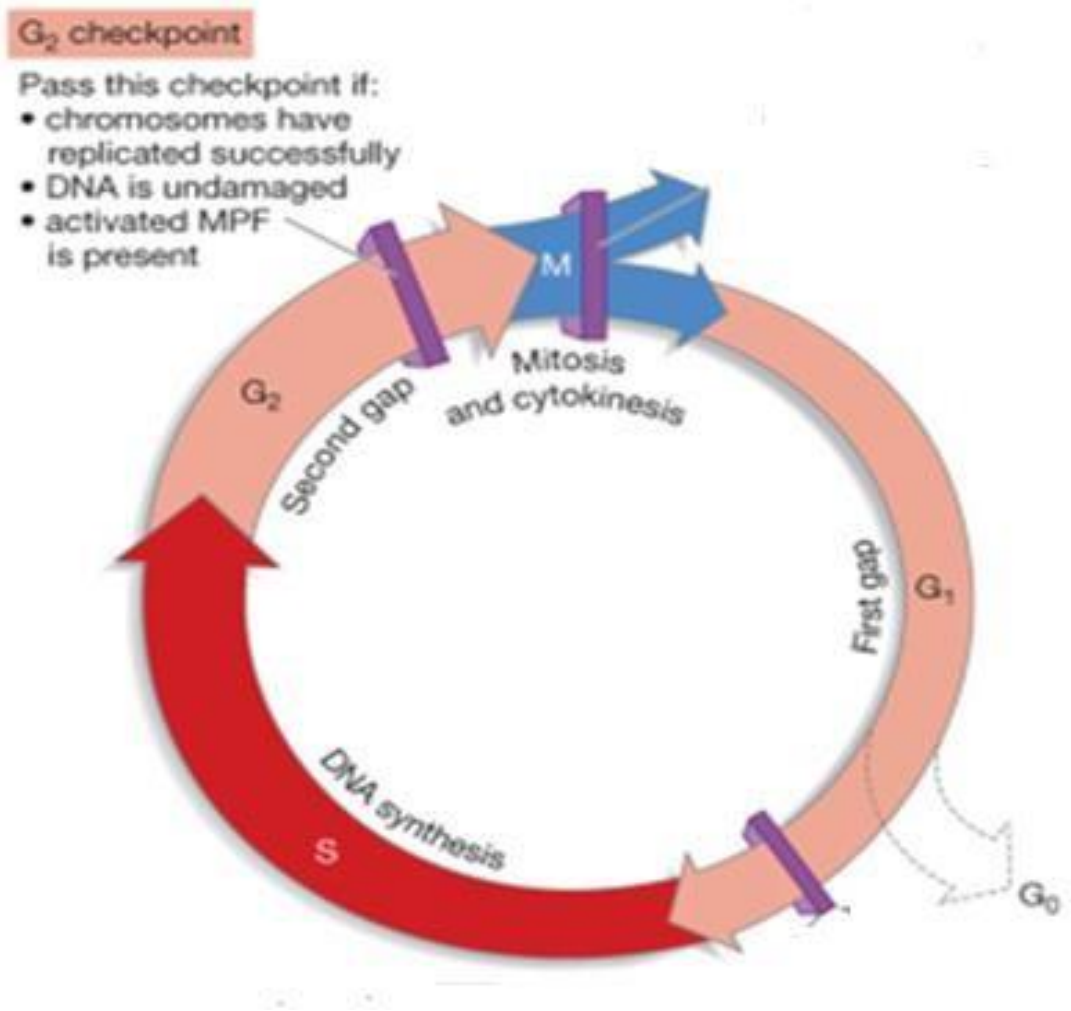


G2 phase or Gap phase 2

- Shortest part of interphase
- final preparations are made before cell divides.
- may be additional growth
- more organelles may be duplicated



G2 checkpoint (not testable)



Before entering mitosis the cell must pass another checkpoint.

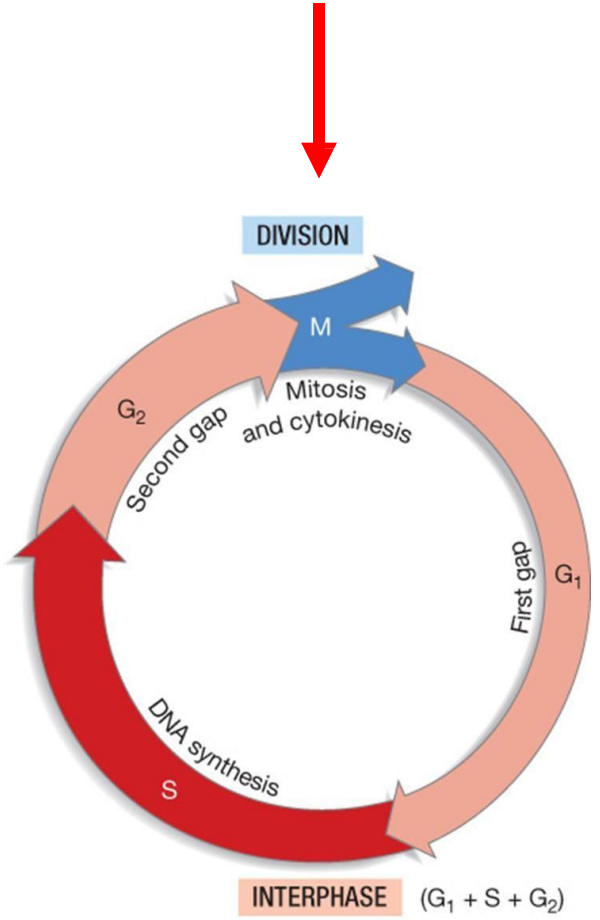
- Have chromosomes replicated successfully?
- Is the DNA undamaged?
- Is MPF present:

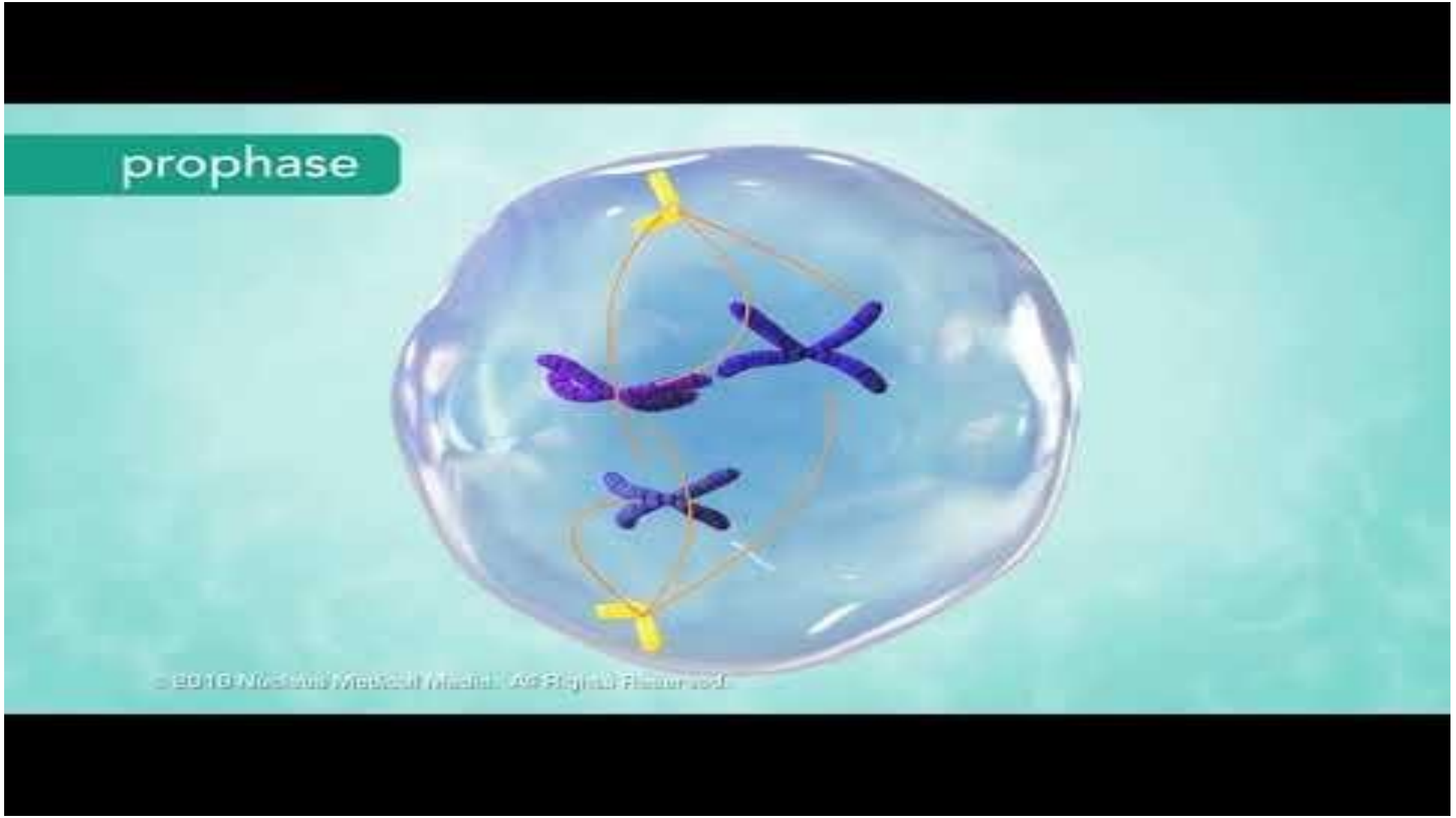
MPF = mitosis promoting factor - an enzyme needed to initiate mitosis

M phase: Mitosis & Cytokinesis

Goal of Mitosis: To produce daughter/progeny cells, genetically identical to each other and to the original parent cell.

This requires that the content of the nucleus and the cytoplasm must be divided equally.

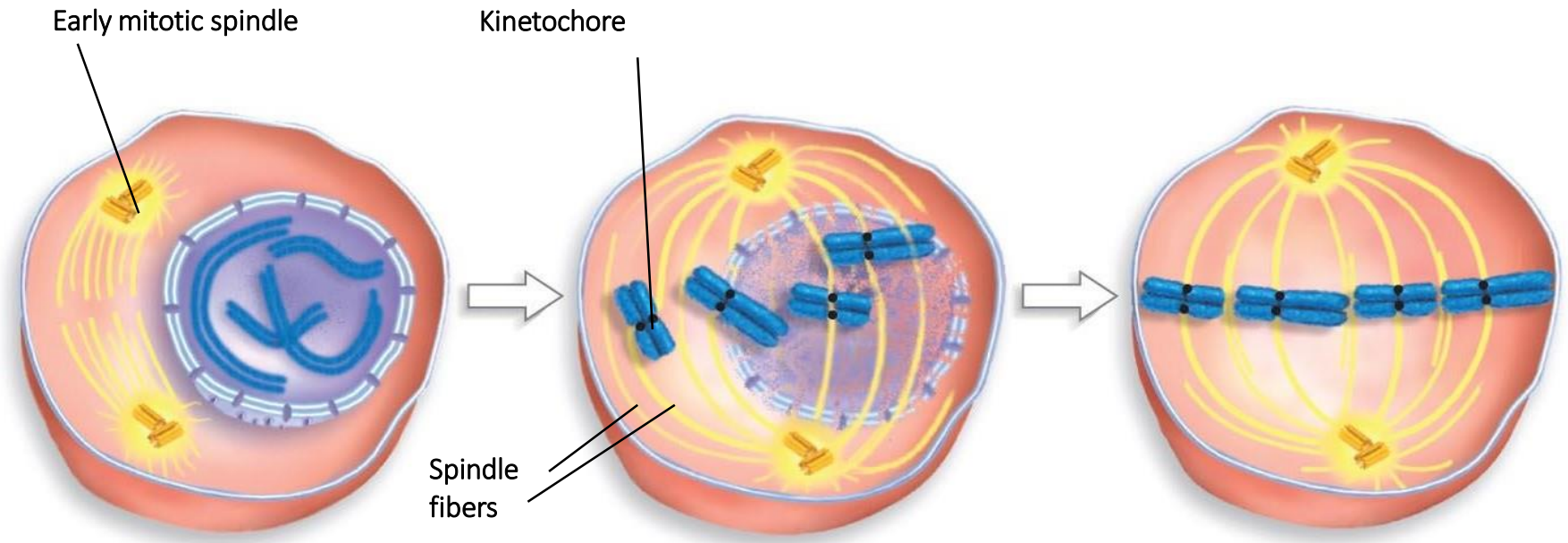




https://www.youtube.com/watch?v=5bq1To_RKEo

Mitosis – one round of nuclear division (4 or 5 phases)

Prophase > Prometaphase > Metaphase > Anaphase > Telophase



Prophase: Chromosomes condense, and mitotic spindle begins to form.

Prometaphase: Nuclear envelope breaks down. Spindle fibers contact chromosomes at kinetochore.

Metaphase (M=middle): Chromosomes complete migration to middle of cell.

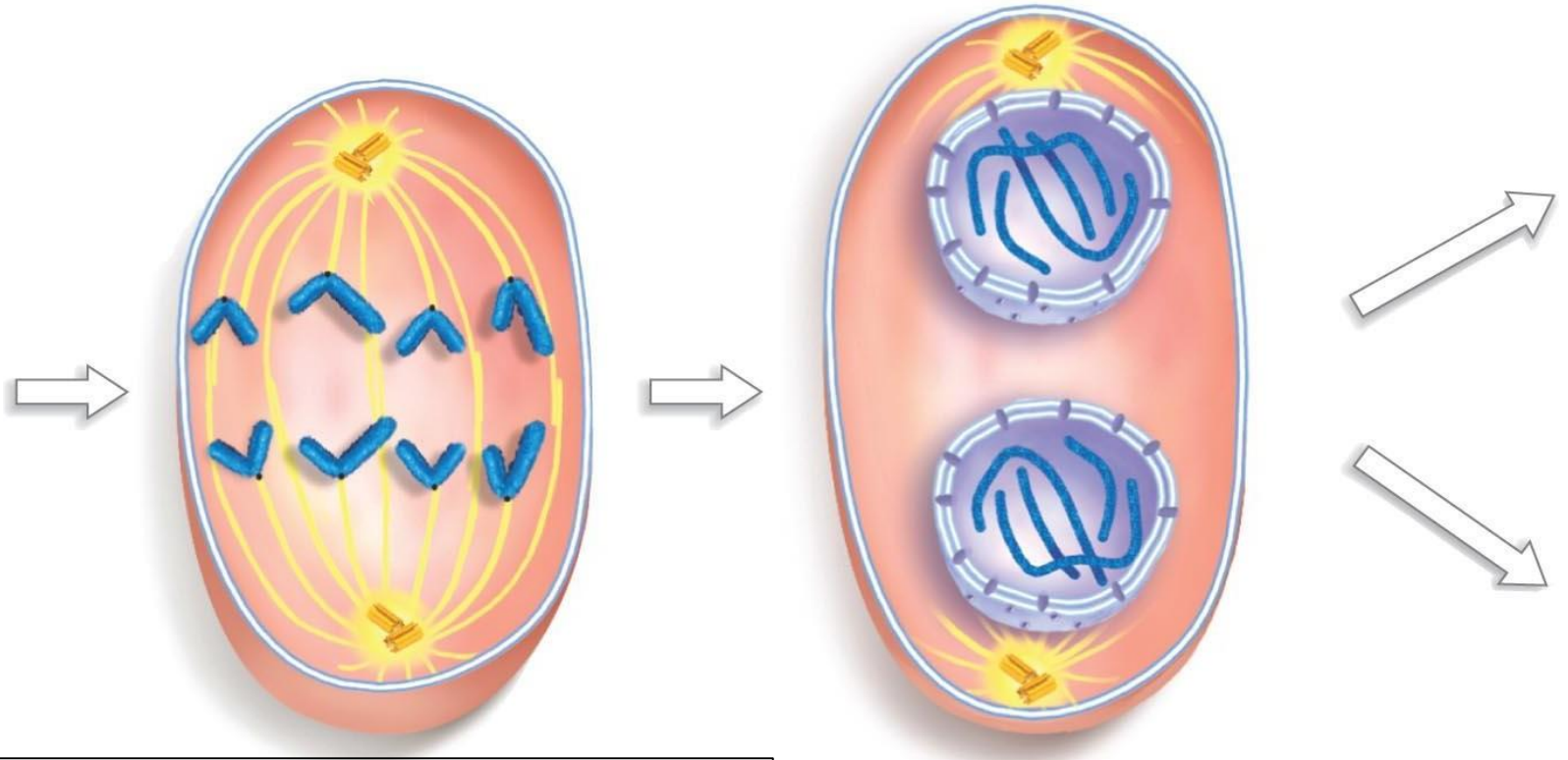
M checkpoint (not testable)

Near the end of metaphase the M checkpoint occurs (also called the spindle fiber checkpoint).

Are the spindle fibers correctly attached to the kinetochore of each sister chromatids or not? If not, cell division does not proceed.

Why is this checkpoint is important - the next step is Anaphase, when the sister chromatids separate from each other; so, very important that the spindle fibers are correctly attached.

Sister chromatids separate in mitosis

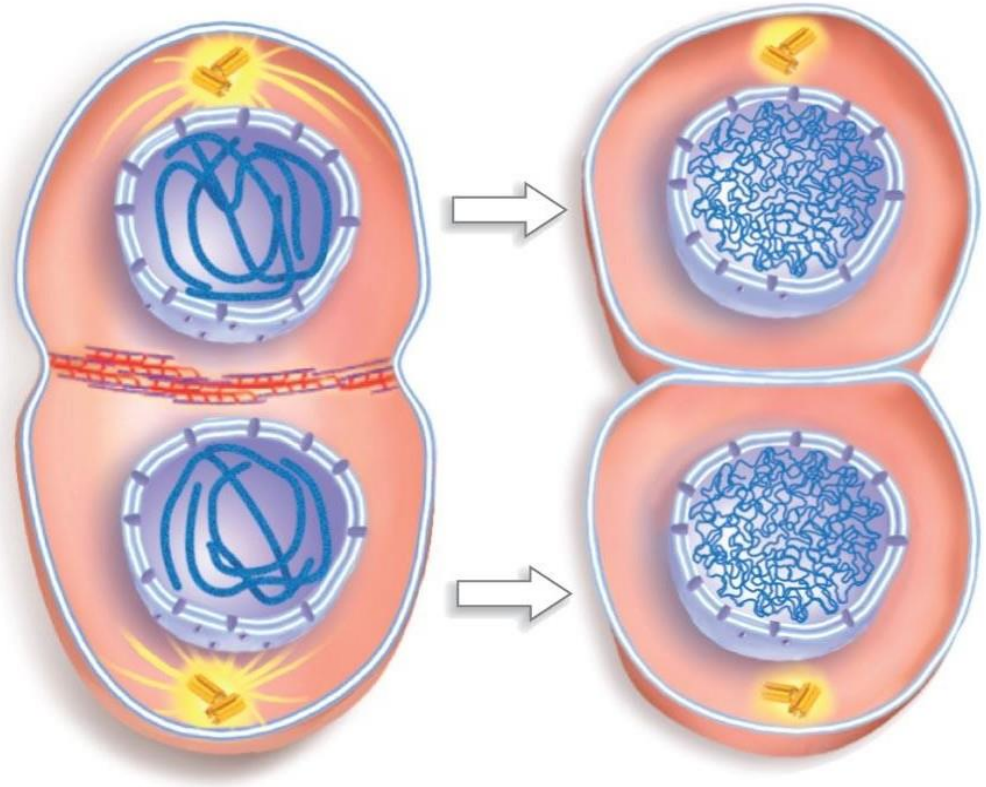


Anaphase (A=Apart): Sister chromatids separate. Upgraded to chromosomes. Chromosomes are pulled to opposite poles of the cell.

Telophase: The nuclear envelope re-forms, and the spindle apparatus disintegrates. DNA starts to decondense.

Last stage of mitosis.

Cytokinesis



Cytoplasm is divided

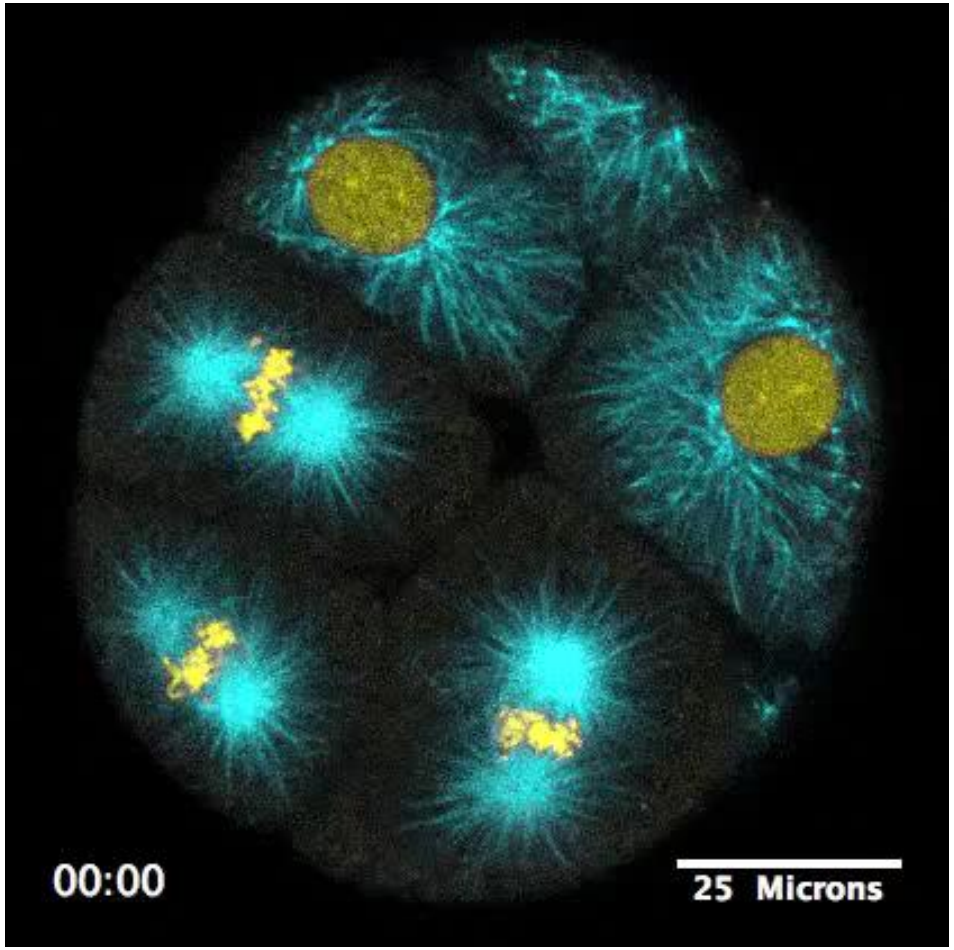
Cell division is complete: Two daughter cells form.

Mitosis fingers – sister chromatids

Mitosis happens very quickly (sea urchin cells)

- Watch the two cells near the top first.

- What structures are gold in colour?

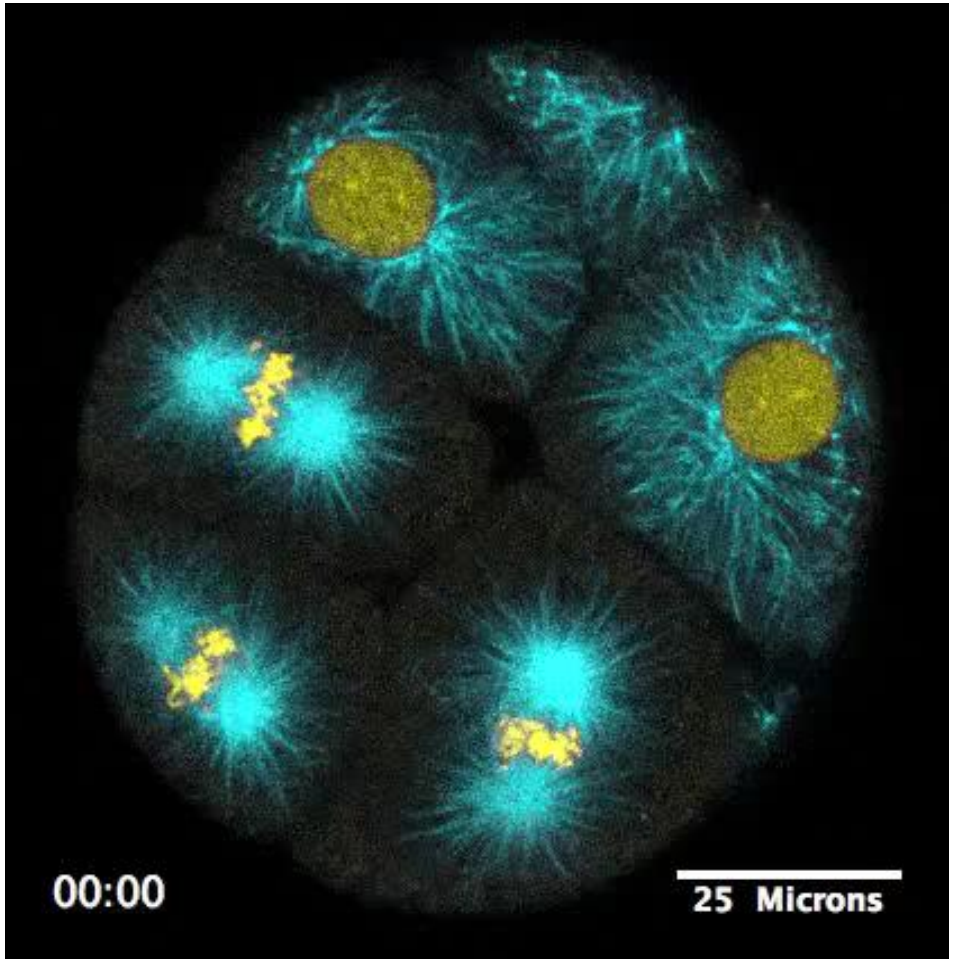


http://cellimagelibrary.org/images/15792?fbclid=IwAR07DWz9LDLIT5MnVzkeEo5_Rzom5U67LFVMrRkKmyxQxLiV0aoGCeEy508

Mitosis

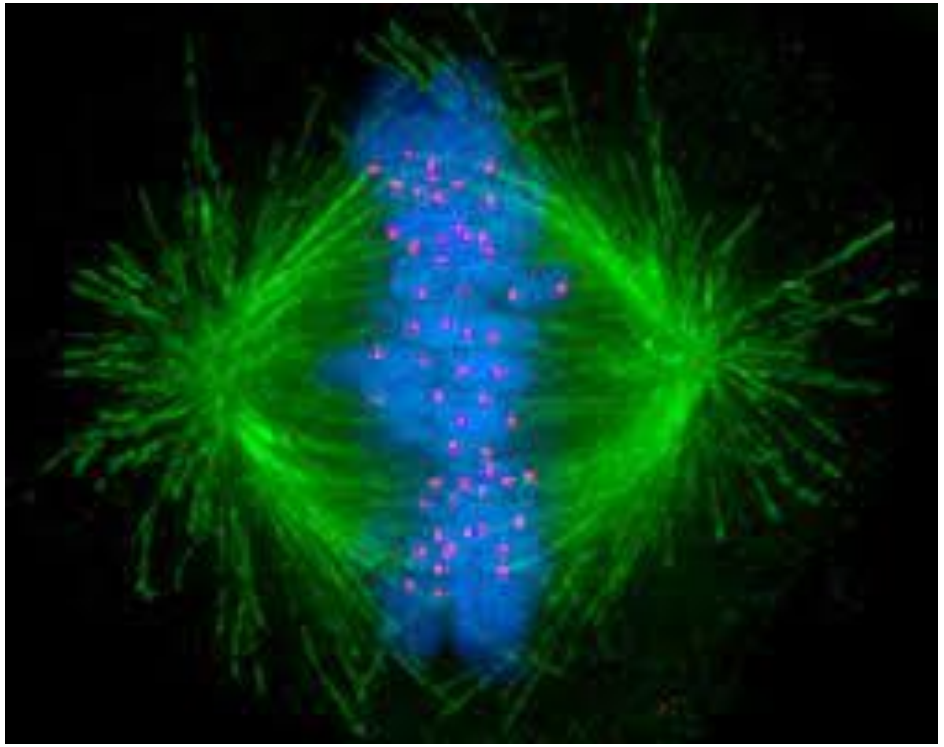
- Watch the three cells near the bottom of the video

- What stage of mitosis are those cells in at the start of the video?



http://cellimagelibrary.org/images/15792?fbclid=IwAR07DWz9LDLIT5MnVzkeEo5_Rzom5U67LFVMrRkKmyxQxLiV0aoGCeEy508

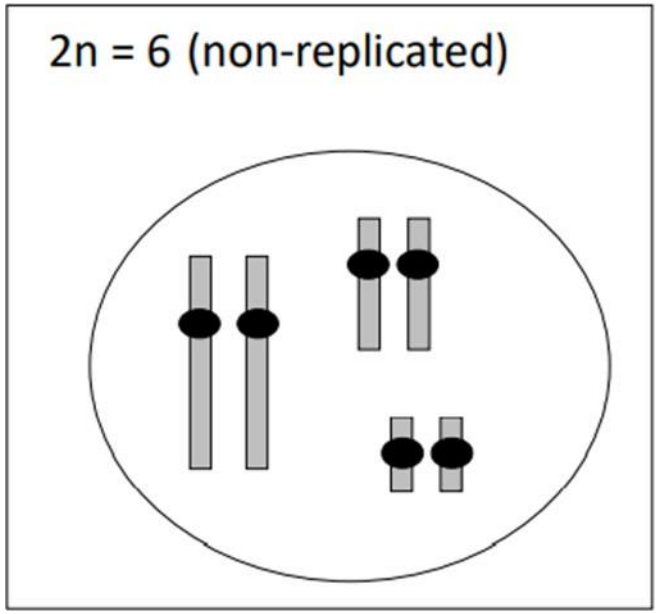
Questions?



https://en.wikipedia.org/wiki/Spindle_apparatus

iClicker Question

The cell is in which stage of the cell cycle?



A. G1

B. S

C. G2

D. Mitosis

E. Not sure

iClicker Question

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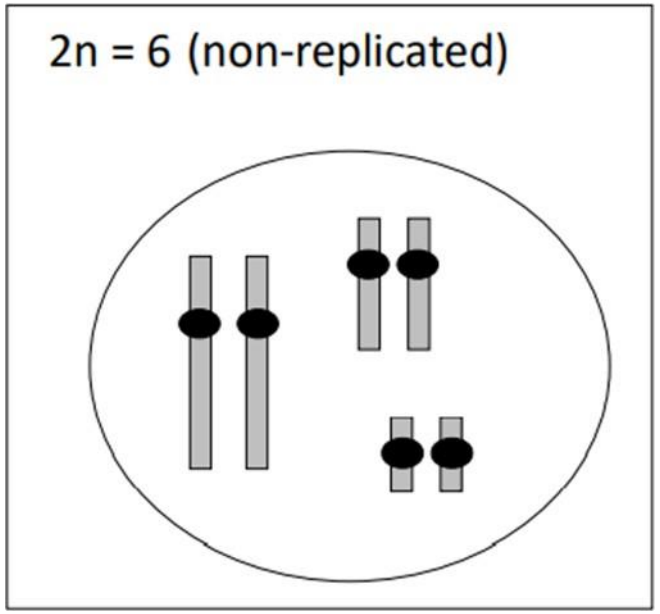

A. G1

B. S

C. G2

D. Mitosis

E. Not sure

iClicker Question

From a population of dividing human cells, biologists isolate cells at various phases of the cell cycle. They find some normal cells that have 1.5 times the DNA compared to normal non-dividing human cells. These cells are in which cell-cycle phase?

A. G1 phase
B. S phase
C. G2 phase
D. M phase
E. E phase

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iClicker Question

A diploid species of animal has three pairs of chromosomes in the nucleus of their adult cells. How many total molecules of DNA do the nuclei of these cells have during G2 phase?

A. 3
B. 6
C. 12
D. 24
E. a bazillion

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Cell Cycle & Mitosis – Learning Objectives

Understand/know:

- The stages of the cell cycle (interphase and mitosis)
  - How ploidy, number of chromatids and number of DNA molecules changes through mitosis
  - Identify homologous chromosomes, genes, alleles, sister and non-sister chromatids

Be able to:

- Interpret diagrams of chromosomes at different stages of the cell cycle and stages of cell division (mitosis).
- Identify and diagram the stages of the cell cycle and mitosis.

Questions?

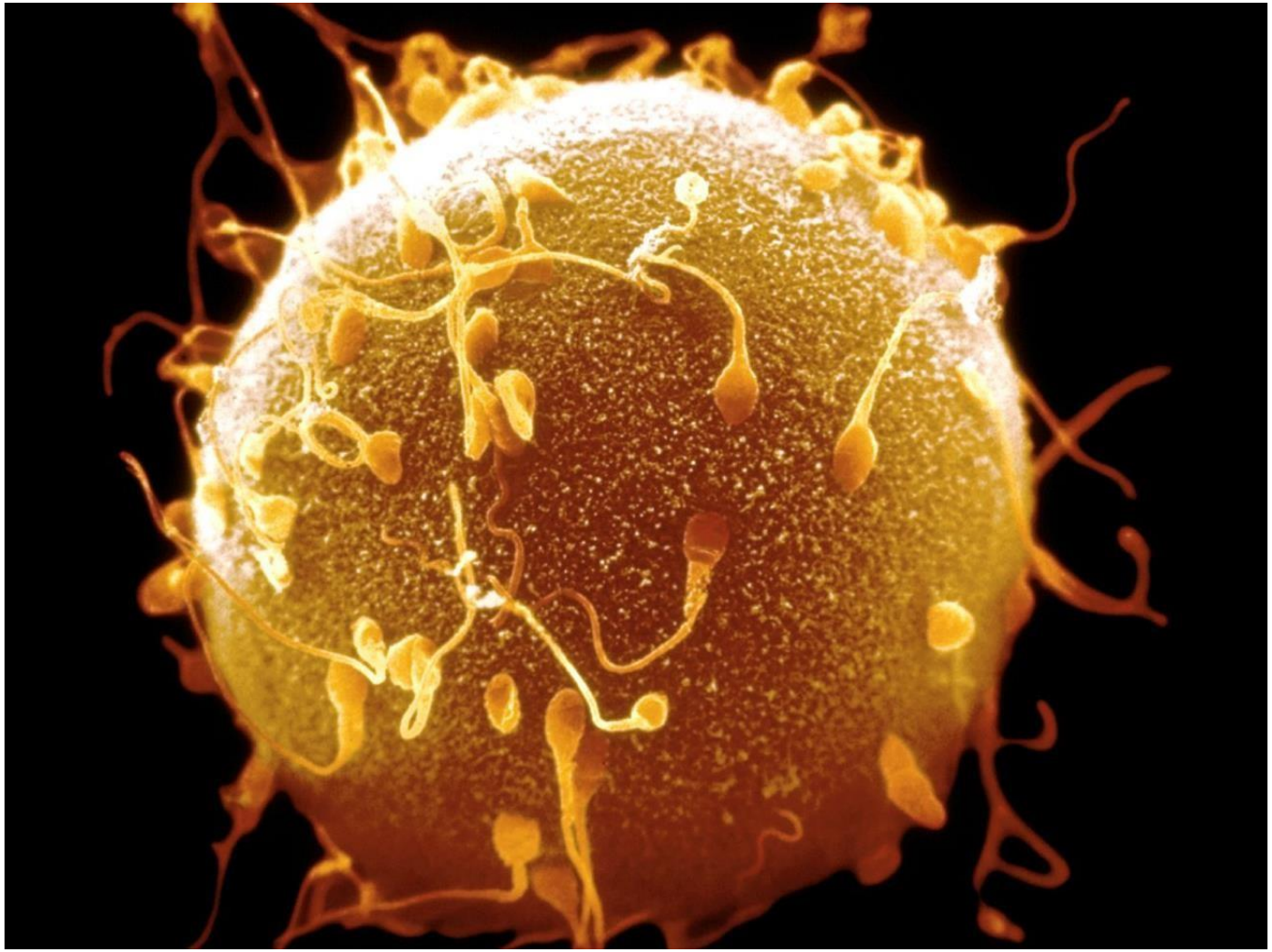
Source:
www.cbc.ca

You should now be able to complete:

- Quiz #1
- Worksheet #1

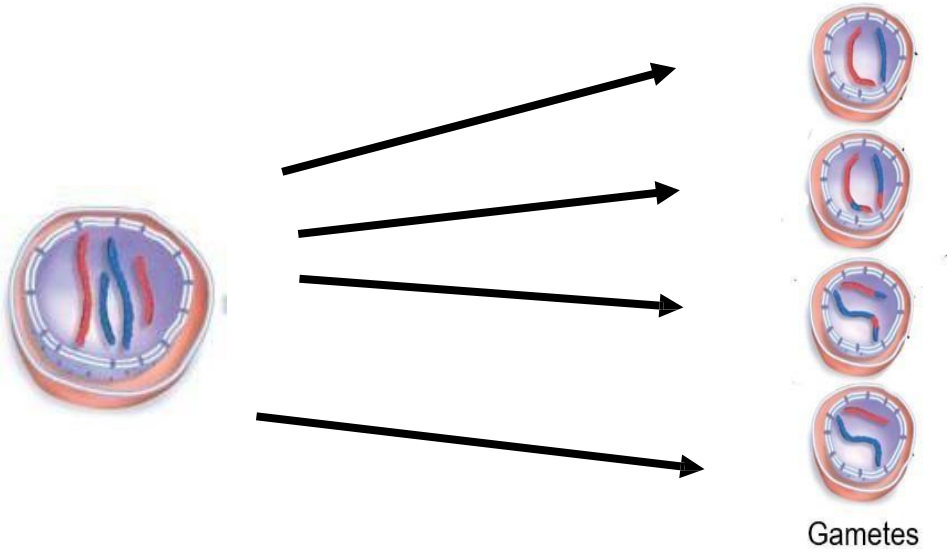
Both are due this Sunday at 11:59 pm

Meiosis

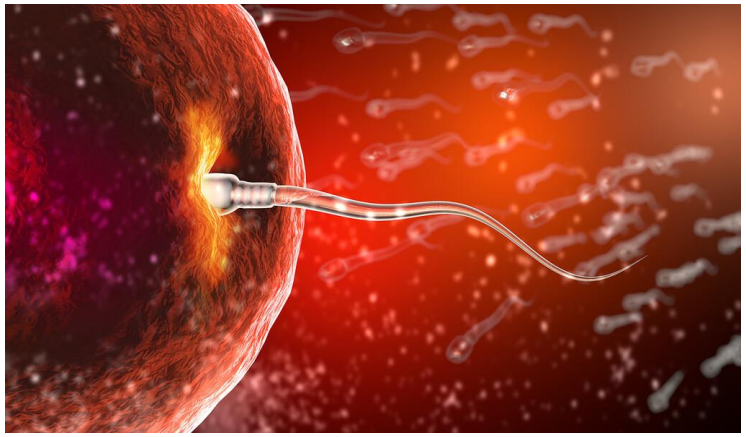


Meiosis

- The goals of meiosis are:
  - to produce 4 daughter cells (gametes – eggs and sperm)
  - with exactly half the number of chromosomes as the parent cells (diploid to haploid) – why?
  - and with novel genotypes, i.e., gametes are genetically different from the parent cell and from each other
- Happens in the gonads – germline cells (not somatic cells)



MEIOSIS (+ cytokinesis) is a type of cell division that produces genetically unique cells – gametes (eggs or sperm).



https://news.yale.edu/2021/04/30/breaking-egg-barrier-sperm-story

Without meiosis
- sexual reproduction, and the genetic variation it produces, would not be possible.

The bananas that we eat are clones.
Susceptible to the Panama fungus.
Cavendish bananas may soon be extinct

Sometimes, even with meiosis, genetic diversity can be low.
Tasmanian Devils have low genetic diversity for a few reasons

- Currently at risk of extinction due to Devil Facial Tumour Disease
- DFTD has resulted in population declines of more than 85%.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5614444/#:~:text=Tasmanian%20devils%20(Sarcophilus%20harrisii)%2C,historical%20factors%20(Jones%20et%20al.

- DFTD is a transmissible cancer
- Cells transmitted when they bite each other during fights.
- Very low genetic diversity; so cells from other “Devils” not recognized as other by immune system.

Meiosis

- Meiosis involves **two** rounds of cell division:

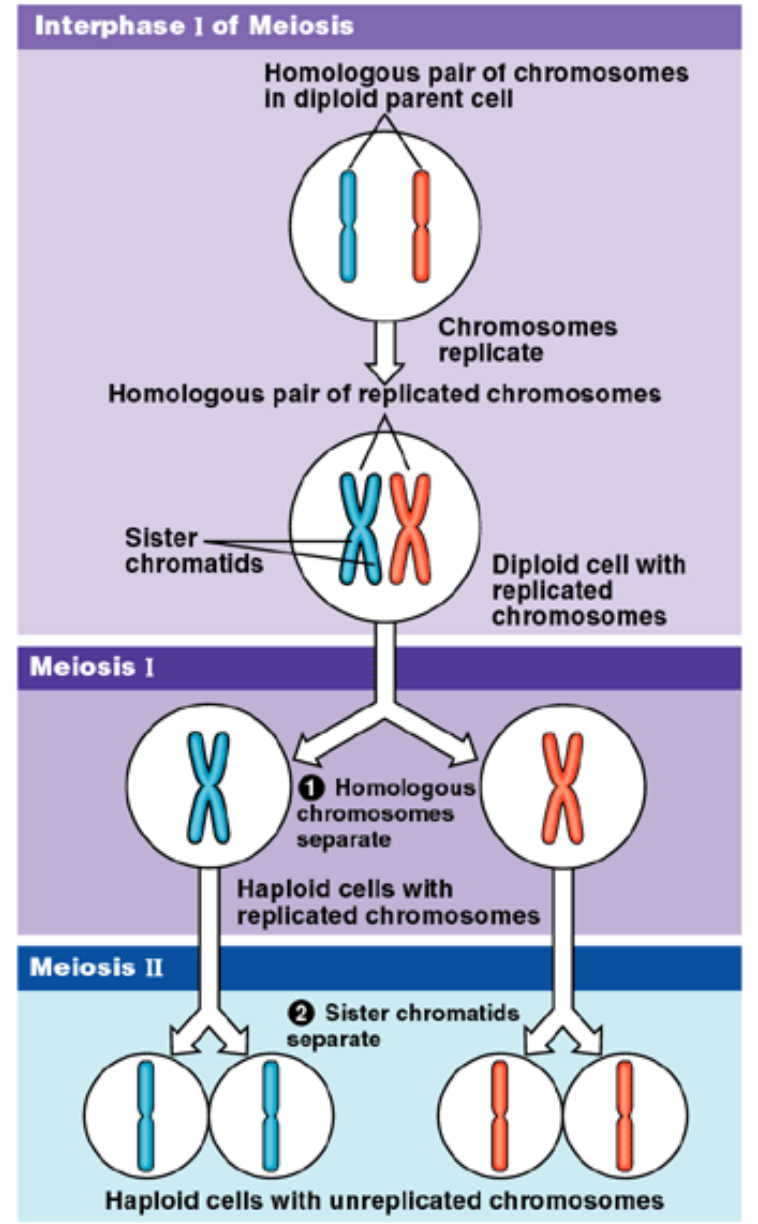
  - Meiosis I and Meiosis II

    M1 = separation of homologous chromosomes

    M2 = separation of sister chromatids

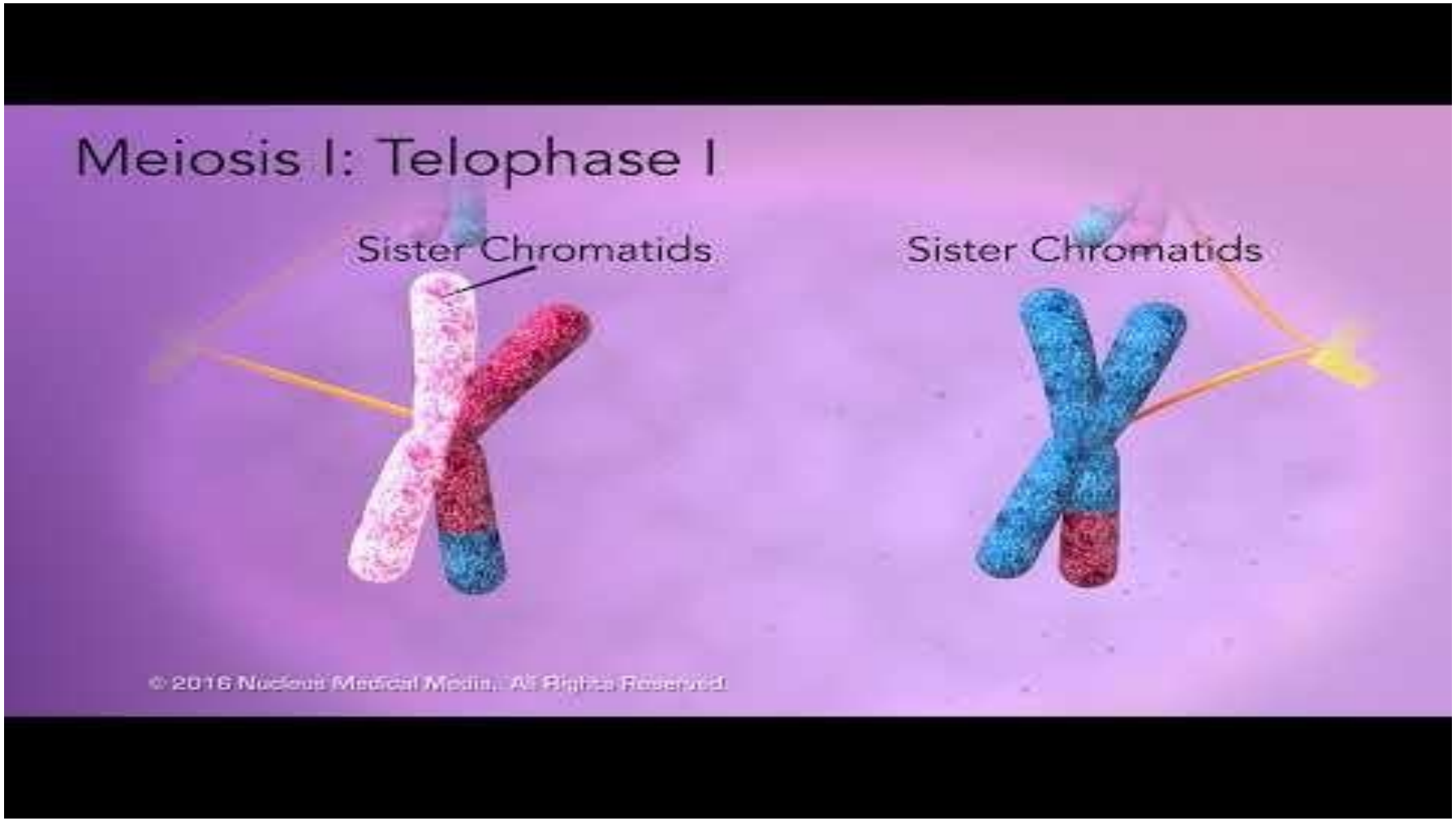
- 4 phases as Meiosis (PMAT x 2)

  - phases labelled I or II
  - e.g. Prophase I or Prophase II



Video on meiosis (nucleus biology)

A few errors/omissions – I will explain



https://www.youtube.com/watch?v=kQu6Yfrr6j0

We reached this point in Tuesday's class.

Thursday's class – continue with Meiosis:

- Phases of Meiosis (Meiosis I and Meiosis II)
- Mechanisms that generate genetic variation in meiosis (crossing-over and recombination in Prophase I; and independent assortment of homologous chromosomes in Metaphase I)
- What gamete genotypes that can be produced (and their frequencies) if:
    - genes are on separate chromosomes.
    - genes are physically linked on a chromosome and crossing-over does not result in recombination of alleles
    - genes are physically linked on a chromosome and crossing-over does result in recombinant genotypes.