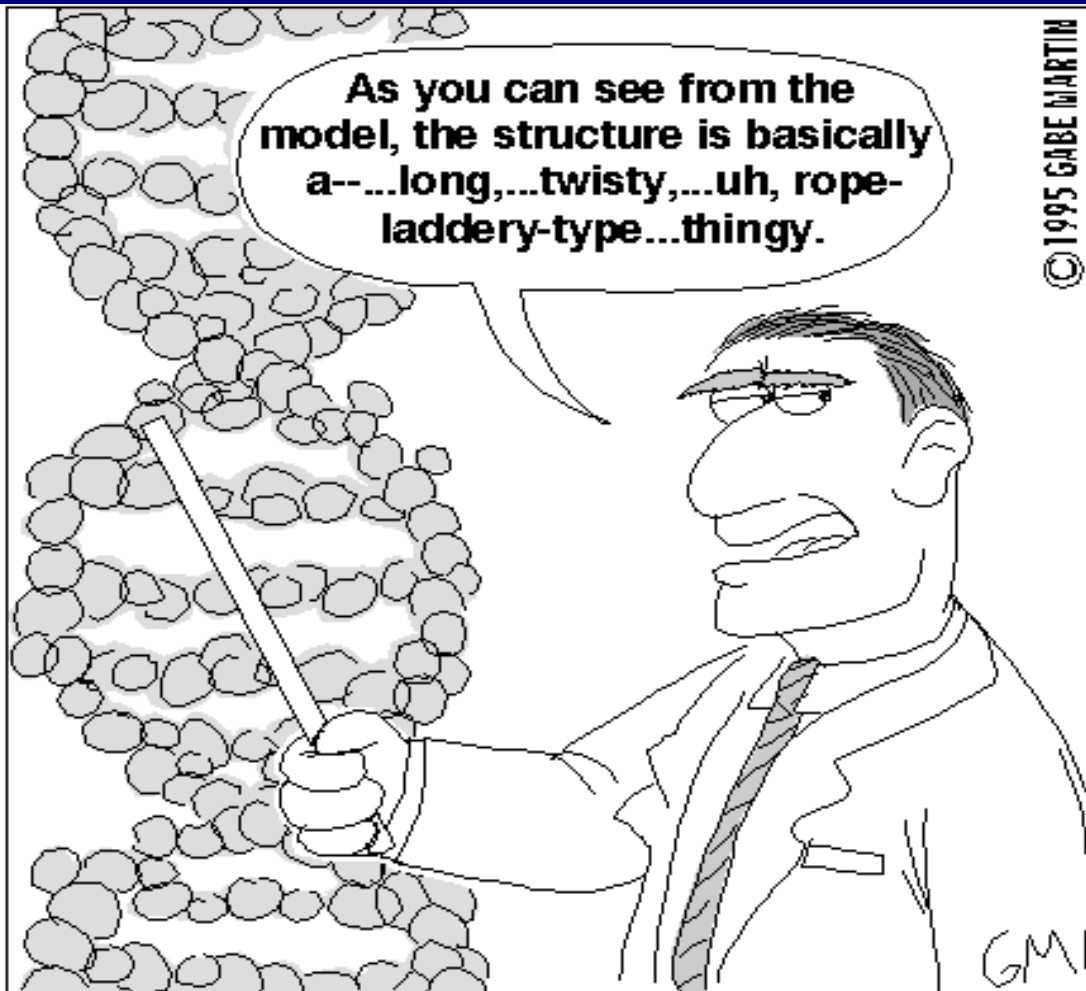


Biology 30 Unit 1

Introduction to Cell Division



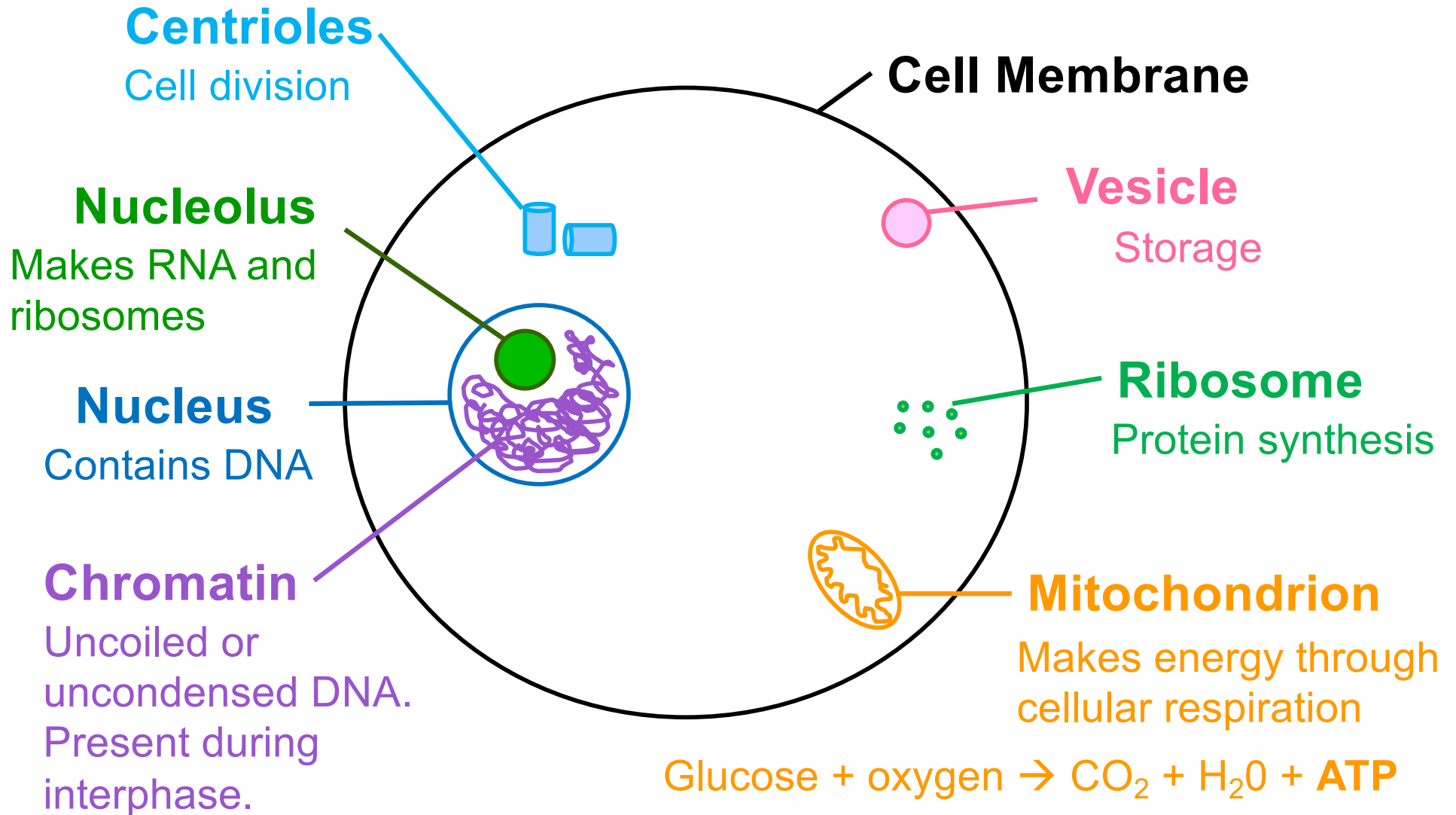
1953: The structure of the DNA molecule is first described.

Learner outcomes...

What you need to know!

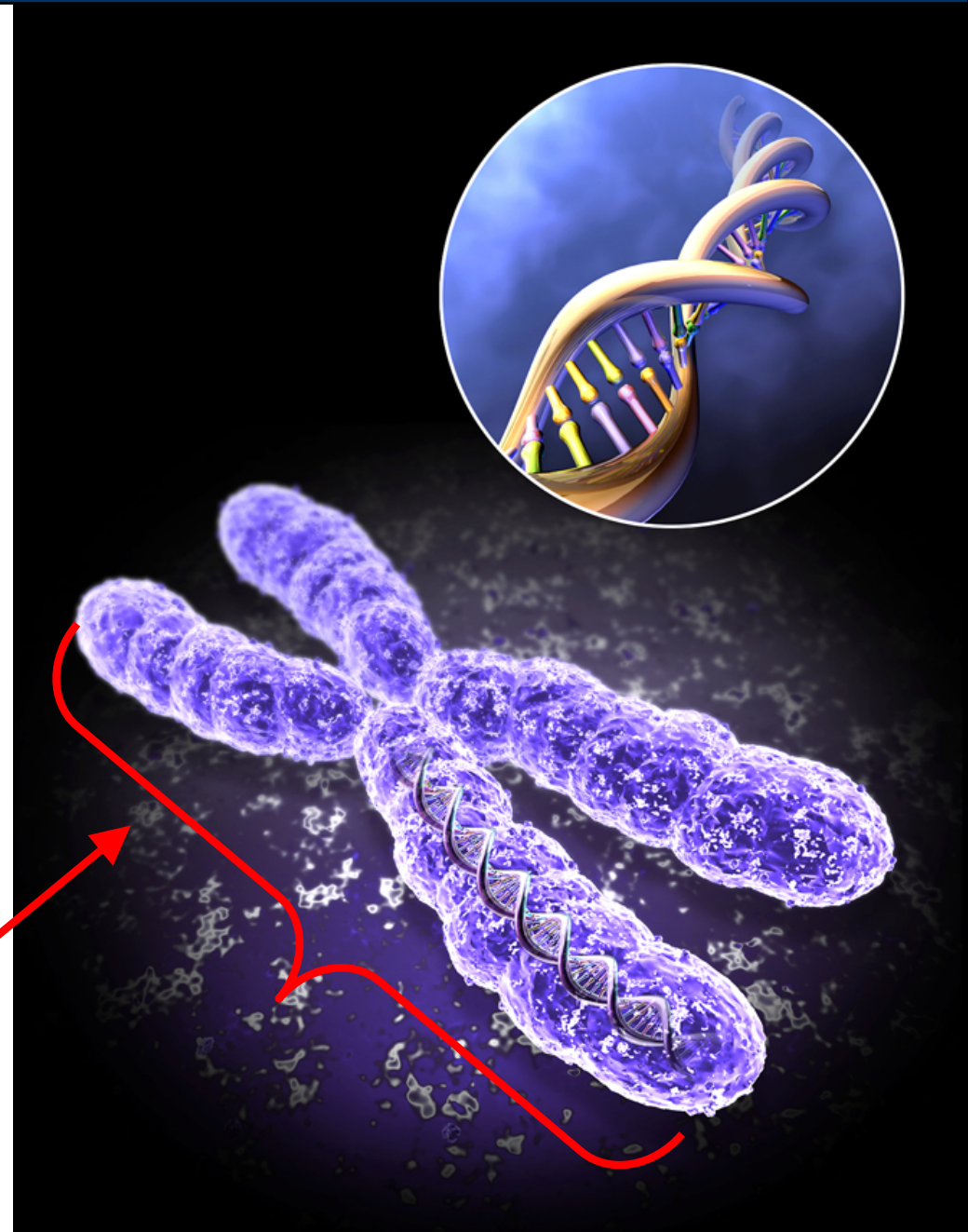
- define and explain the significance of chromosome number in somatic and sex cells; i.e., haploidy, diploidy and polyploidy
- explain, in general terms, the events of the cell cycle; i.e., interphase, mitosis and cytokinesis
- describe the process of meiosis (spermatogenesis and oogenesis) and the necessity for the reduction of chromosome number
- compare the processes of mitosis and meiosis
- describe the processes of crossing over and nondisjunction and evaluate their significance to organism inheritance and development
- compare the formation of fraternal and identical offspring in a single birthing event
- describe the diversity of reproductive strategies by comparing the alternation of generations in a range of organisms; e.g., *Daphnia*, *sea anemone*, *moss*, *pine*.

Animal Cell



Chromosome

- The genetic information of a cell is contained in its DNA in the nucleus
- When a cell is preparing to divide, DNA is coiled around a histone protein and then condensed and packaged to form a chromosome

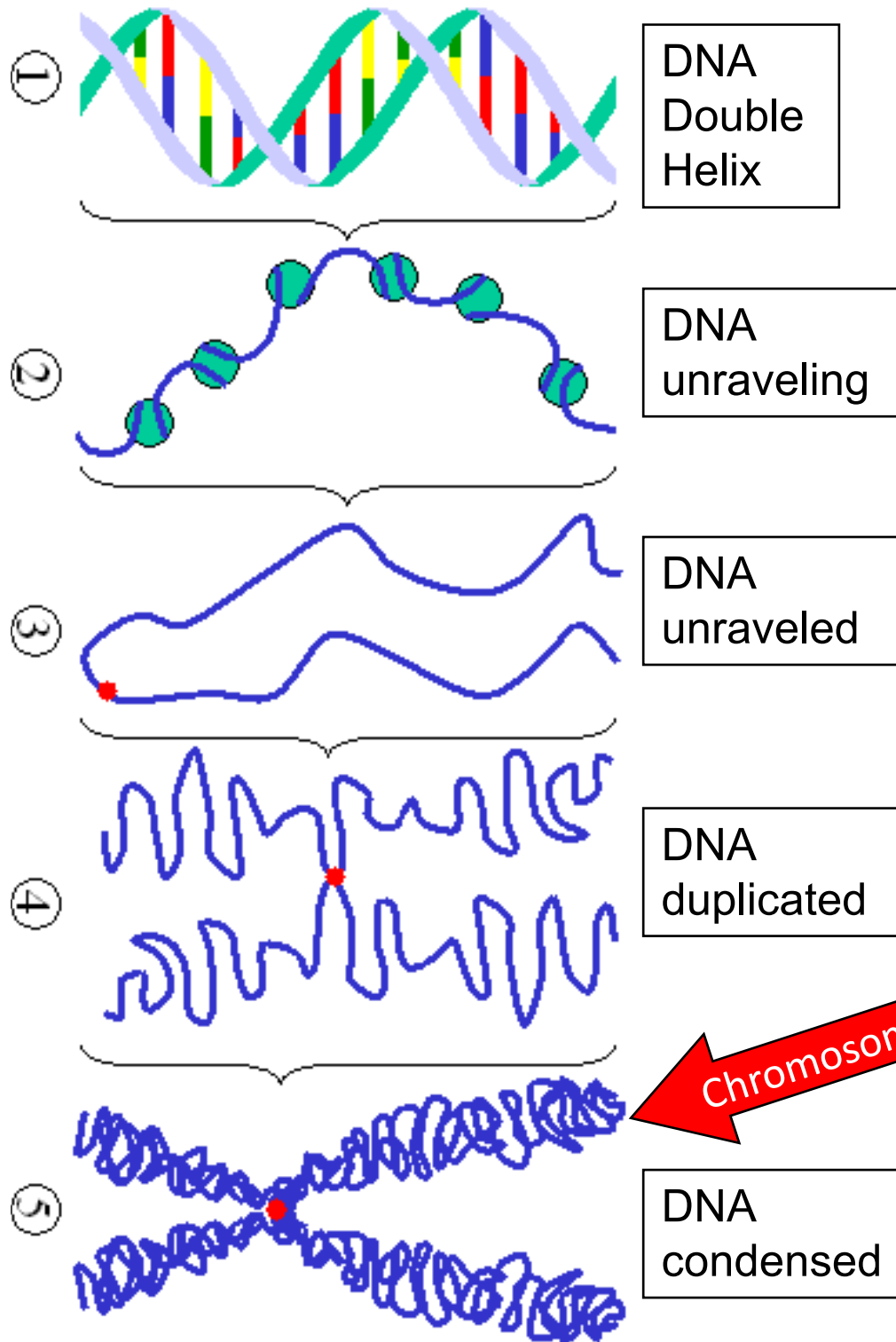


Chromosomes

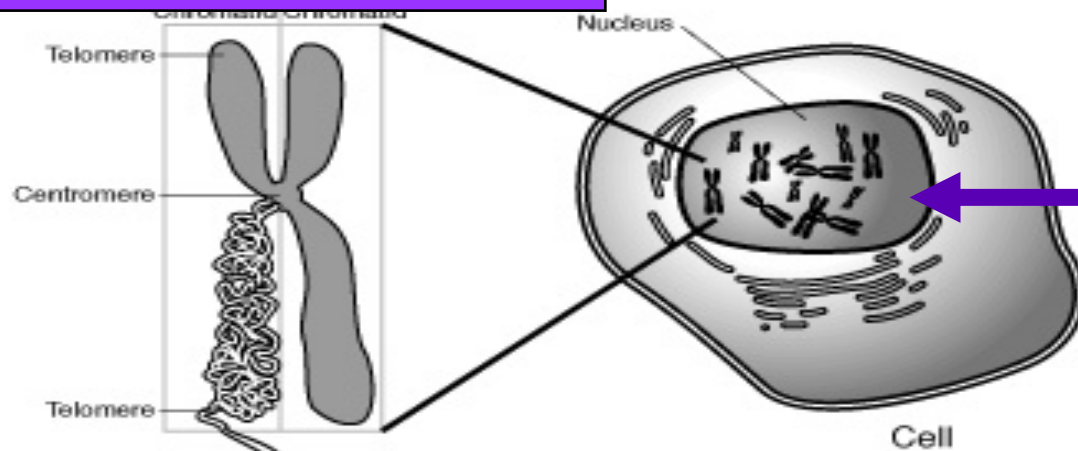
- long threads of **DNA** wrapped around a bead of protein (a **histone**) to form **chromatin** (threadlike)

↓

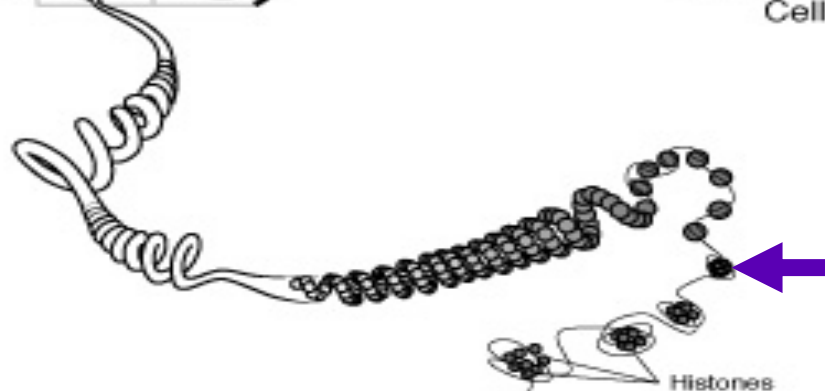
- When a cell is getting ready to divide the **chromatin coils up and forms thicker strands of chromosomes** and later replicate to look like X's.



Chromosome



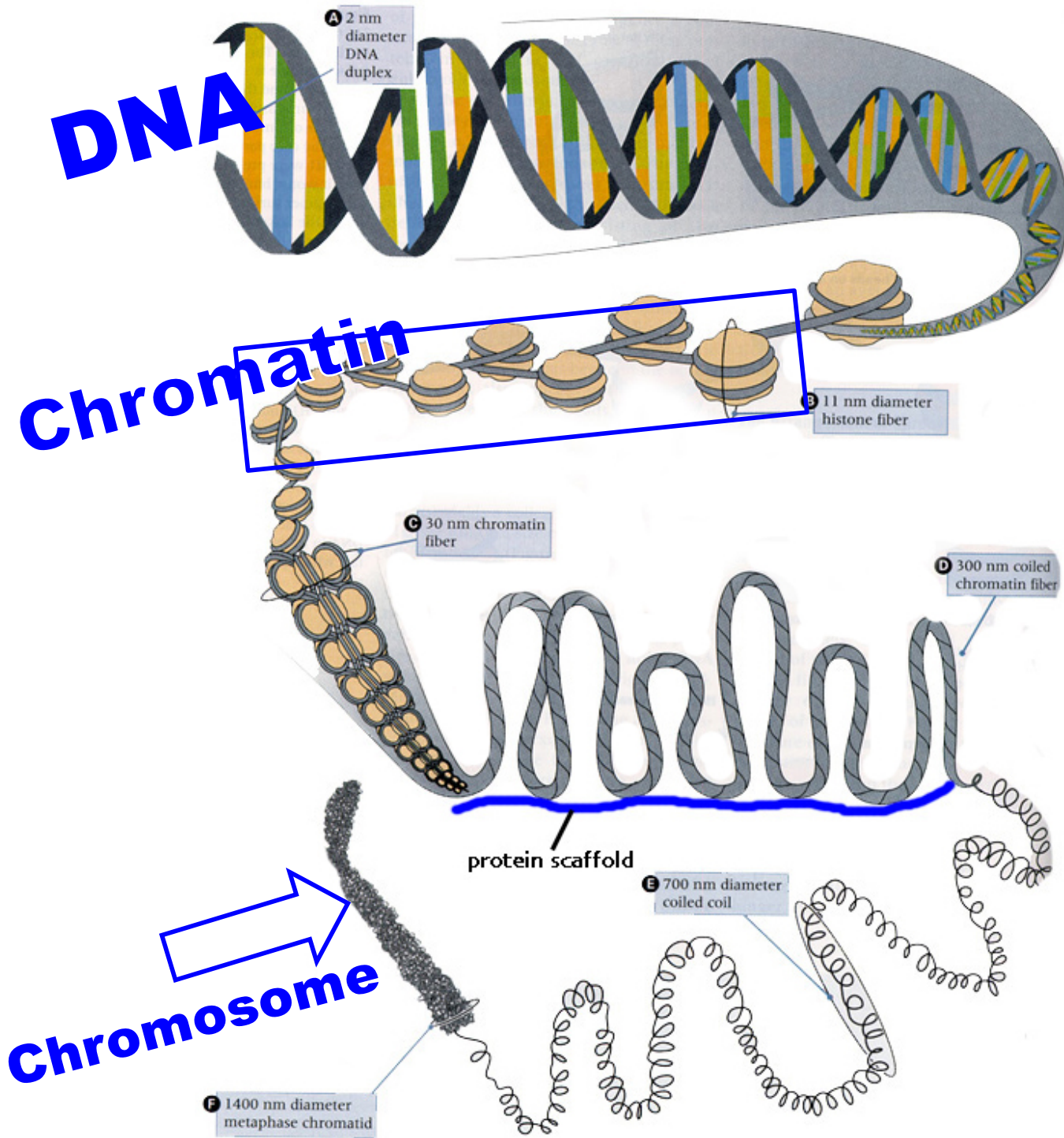
Nucleus



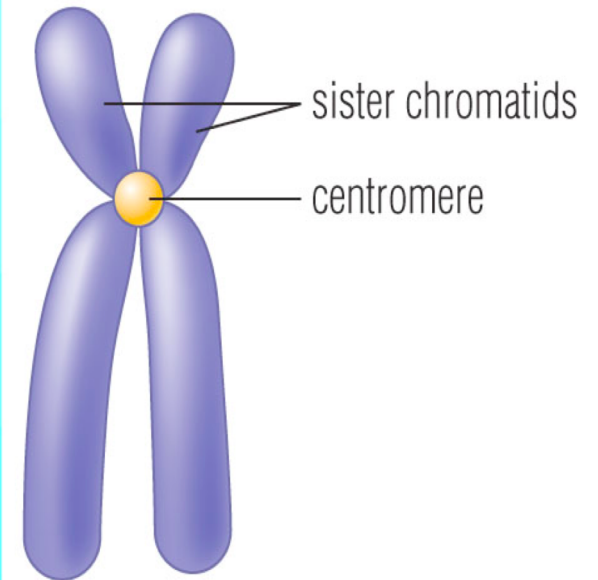
Chromatin
(thin strands)



DNA



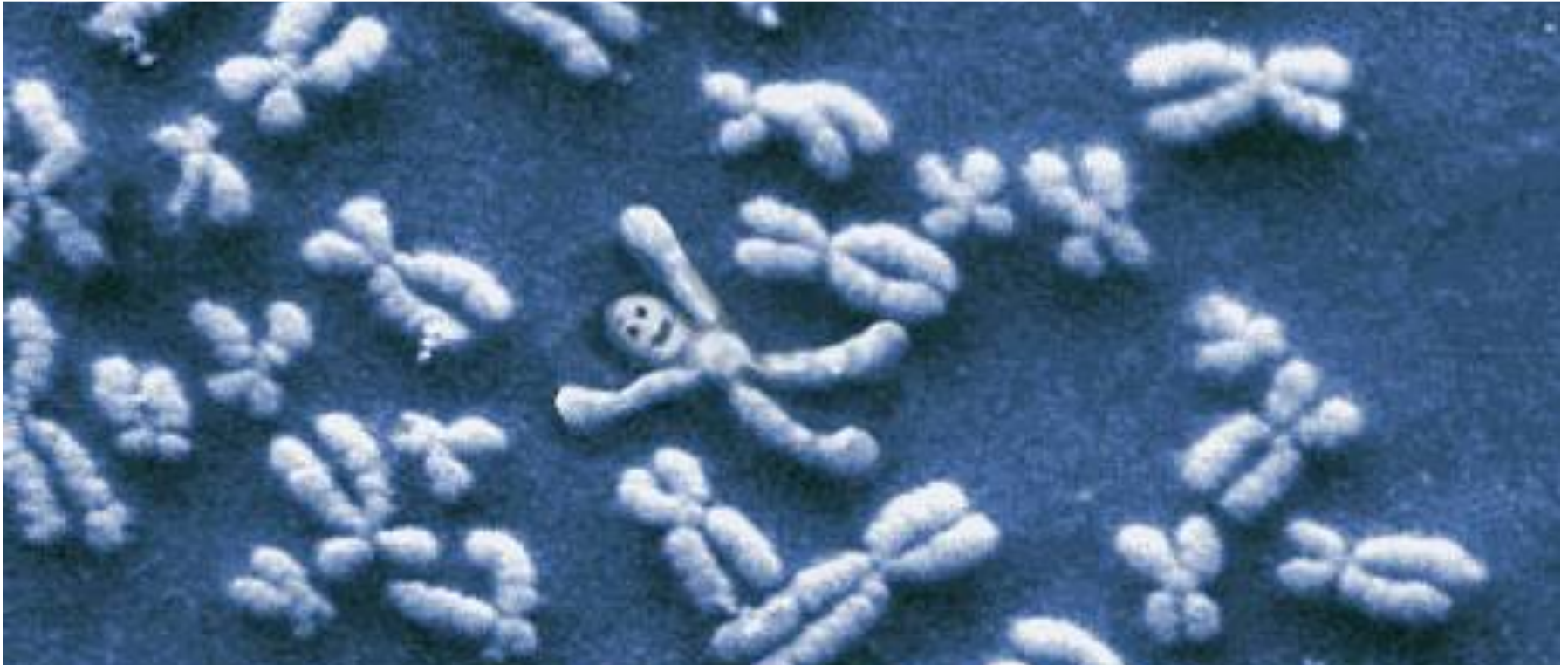
Chromosomes depicted in this X-shaped form



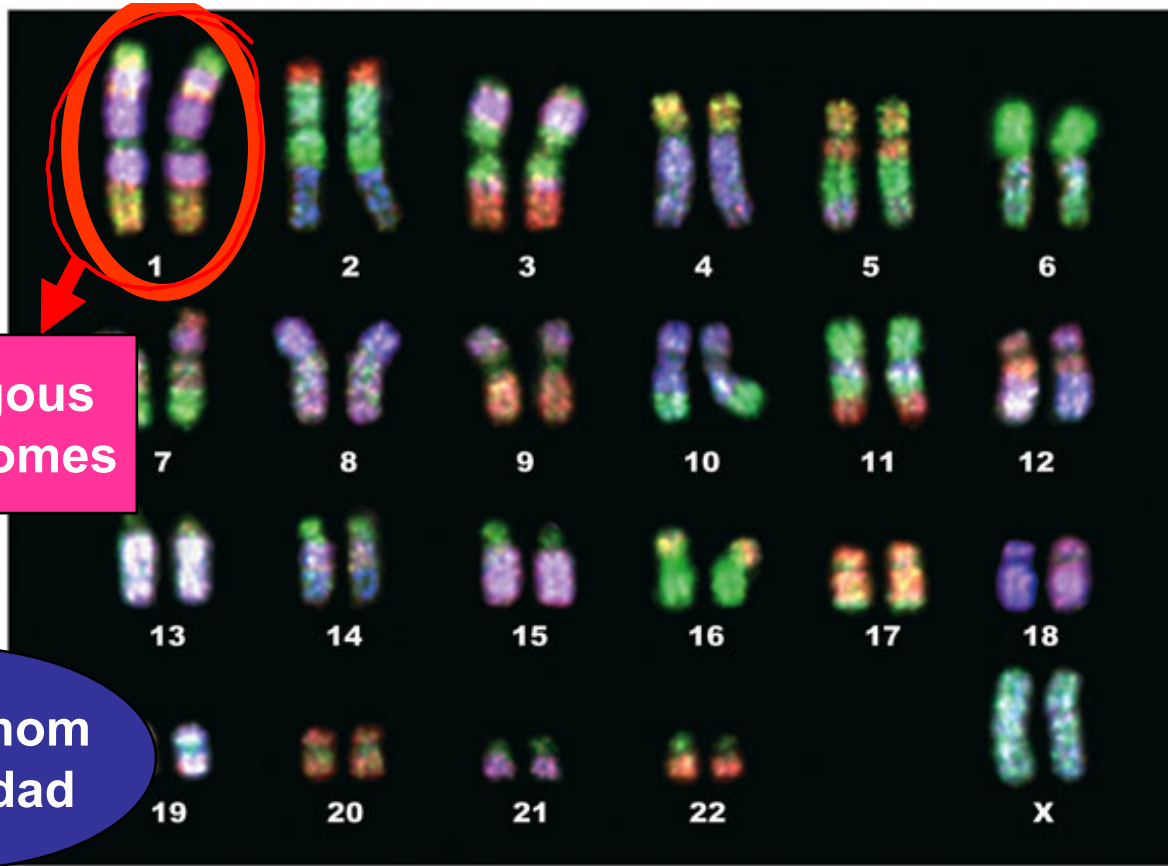
...have already been duplicated in preparation for mitosis (or meiosis).

The two identical copies (sister chromatids) are connected at the centromere.

- DNA is found in chromatin / chromosomes
- Chromosomes = condensed(bundled) chromatin



**Chromosomes look like X's
only when they are replicated!**



Homologous Chromosomes

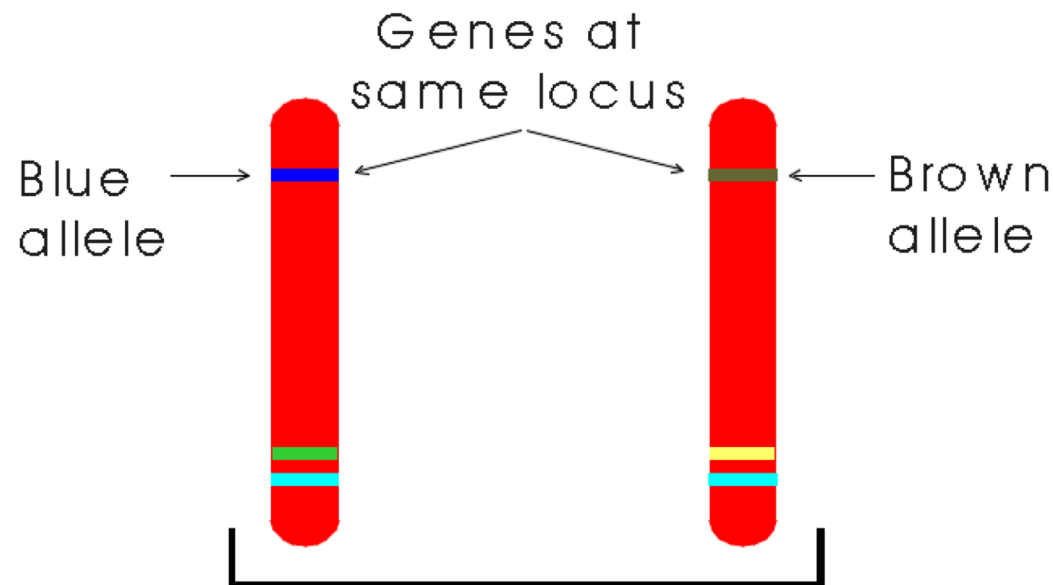
1 from mom
1 from dad

Humans have **46** chromosomes (**23 pairs**).
44 are **autosomes** (not sex controlling).
Autosomes are chromosomes #1-22.
2 are sex chromosomes (# 23 pair)

Females = XX Males = XY

Homologous Chromosomes

Homologous chromosomes carry the same genes at the same location or **locus**. One from mom and one from dad



Even though homologous chromosomes look alike they are **NOT IDENTICAL** because they carry different forms or **alleles** of the same gene.

-but essentially they are “talking” about the same thing

Diploid (2n)

**DIPLOID is the number of chromosomes
IN EACH SET of somatic(body) cells**

or in other words

**having two complete sets chromosomes
in each somatic(body) cell**

- Humans obtain $\frac{1}{2}$ their chromosomes from their mom (**n**) and $\frac{1}{2}$ from dad (**n**)

- **$n + n = 2n$**

- In humans,

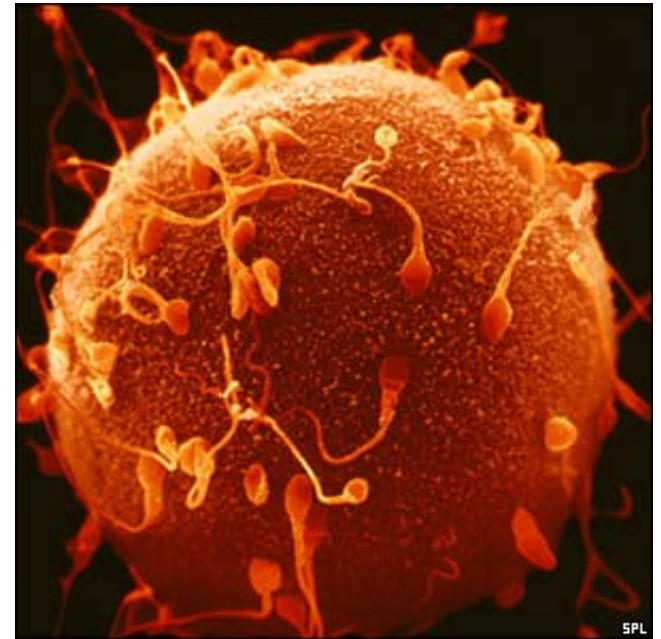
-total diploid number of chromosomes is 46

$$2n=46$$

Haploid (n)

- In humans the total number of chromosomes in the **gametes** (egg or sperm) of an organism
- In humans,
 - sperm have 23 chromosomes
 - eggs have 23 chromosomes
 - Therefore, the **haploid (n) number is 23**

$$n=23$$



“n” means...

NUMBER OF UNIQUE CHROMOSOMES

Haploid (n)

- HAPLOID number is NOT ALWAYS the number of chromosomes in gametes
- In humans,
 - sperm have 23 chromosome & eggs have 23 chromosomes
 - the **haploid (n) number is 23....easy peezy...BUT**
- In strawberries they have 56 chromosomes total BUT have 7 in each set with 8 unique sets
 - so their haploid number would be 8 while it has 28 chromosomes in gametes

**HAPLOID number is THE NUMBER OF
UNIQUE SETS OF CHROMOSOMES**

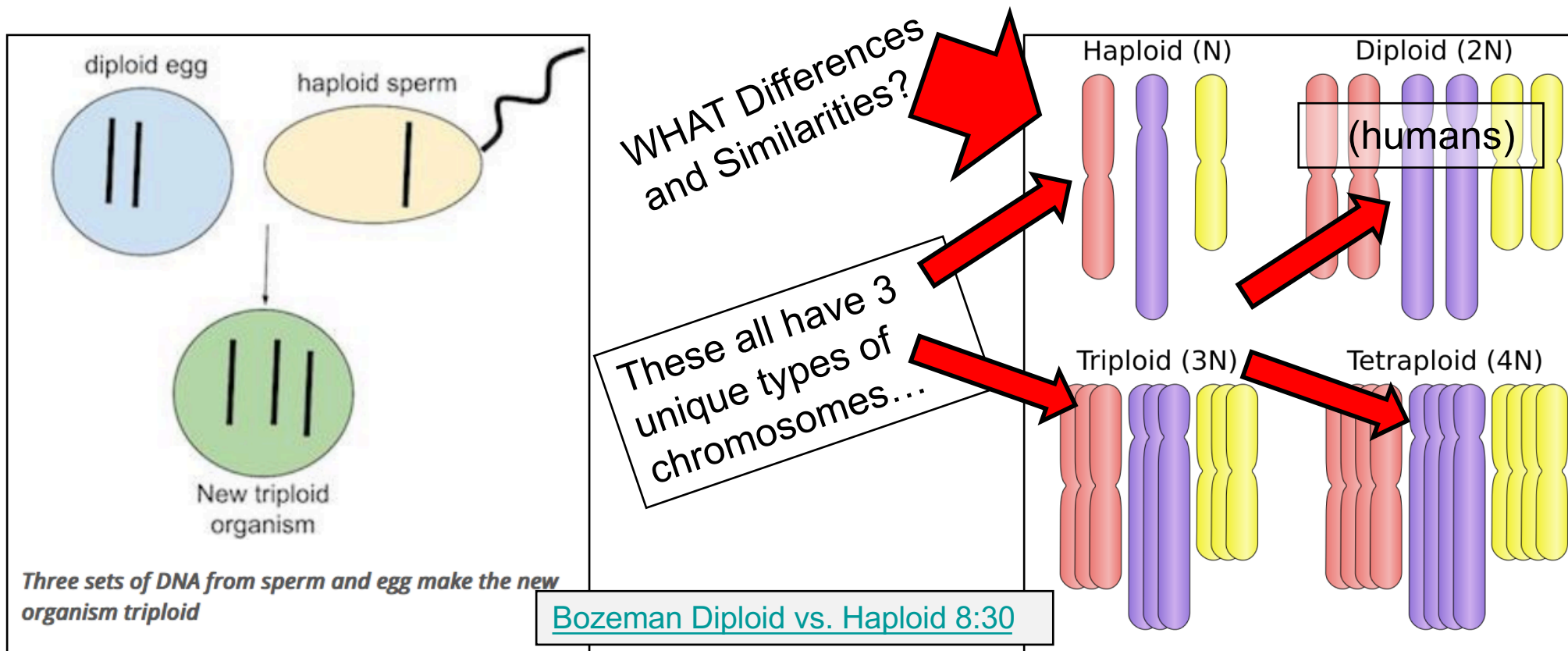
Diploid Numbers Are Unique

- Just because two organisms may have the same diploid number DOES NOT mean that they are related
- Diploid numbers DO NOT indicate the complexity of an organism!!

Organism	Diploid Number (2N)	Haploid Number (N)
Dog	78	39
Cat	38	19
Shrimp	4	2
Scorpion	256	128
Green Ash Tree	46	23
Human	46	23

Polyploidy

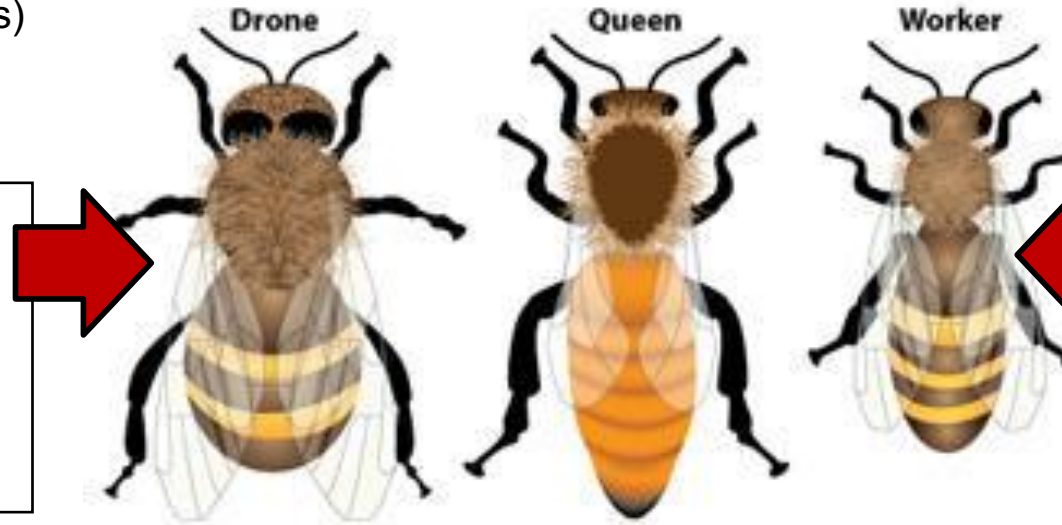
- Some organisms are polyploid, meaning that **they have more than 2 chromosomes of a certain “type” of chromosome**
 - Tetraploid = **4n** (4 homologous chromosomes)...4 that are “talking” about the same thing
 - Triploid = **3n** (3 homologous chromosomes)...3 that are “talking” about the same thing
 - Octaploid = **8n** (8 homologous chromosomes)...8 that are “talking” about the same thing



FYI: Some interesting numbers:

Haplodiploidy: Having half the chromosomes of the females

(don't need to know this)



Grown from an **unfertilized** egg...

Technically only has a mother!

Grown from a **fertilized** egg...

She can lay eggs but has no sperm to fertilize them with so they would all turn out to be drones.

Ophioglossum reticulatum

Adders Tongue



Highest known chromosome count at

1024

Watch this video on polyploidy...the SCI show

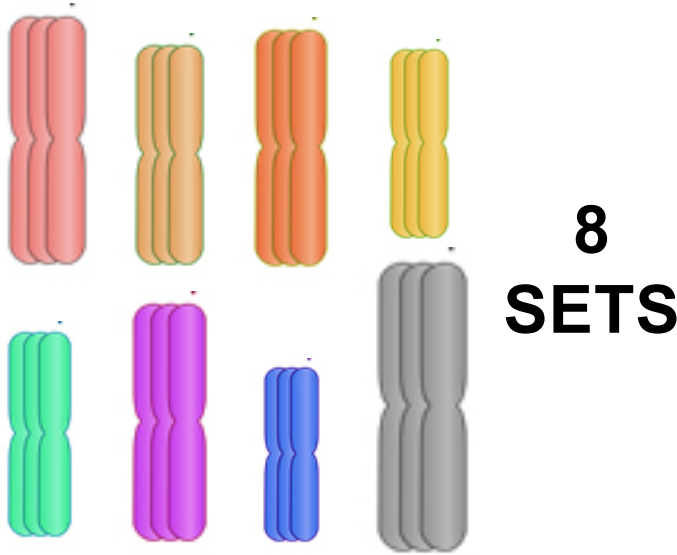
- <https://www.youtube.com/watch?v=exA6-wrqOGQ>

- Why are mules sterile?

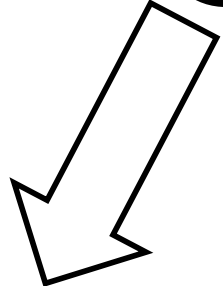
https://www.youtube.com/watch?v=y_zdKJnDXkk

Polyploidy Example

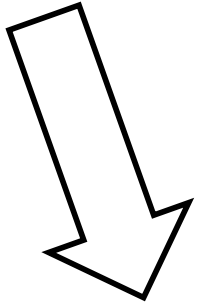
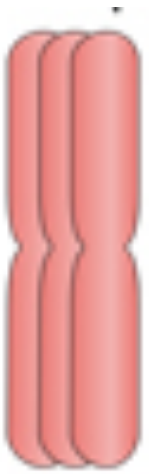
Number of Unique
Chromosome Sets
(number of sets)
(haploid number)



$$3n = 24$$



Number of homologous
chromosomes in each set
(# of similar chromosomes)



Total number of
chromosomes per
somatic cell

Polyploidy Calculations

- Example 1...

An organism has a ploidy number of $5n$, and a haploid number of 3. How many chromosomes does the organism have? *we know that $n = 3$*

$$5 \text{ (chromosomes in each set)} \times 3 \text{ (number of sets)} = 15 \text{ total}$$

$5n = 15$

Example 2...

An organism has a haploid number of 6 and 30 chromosomes total. What is the ploidy number?

we know that $n = 6$

we know that total # = 30

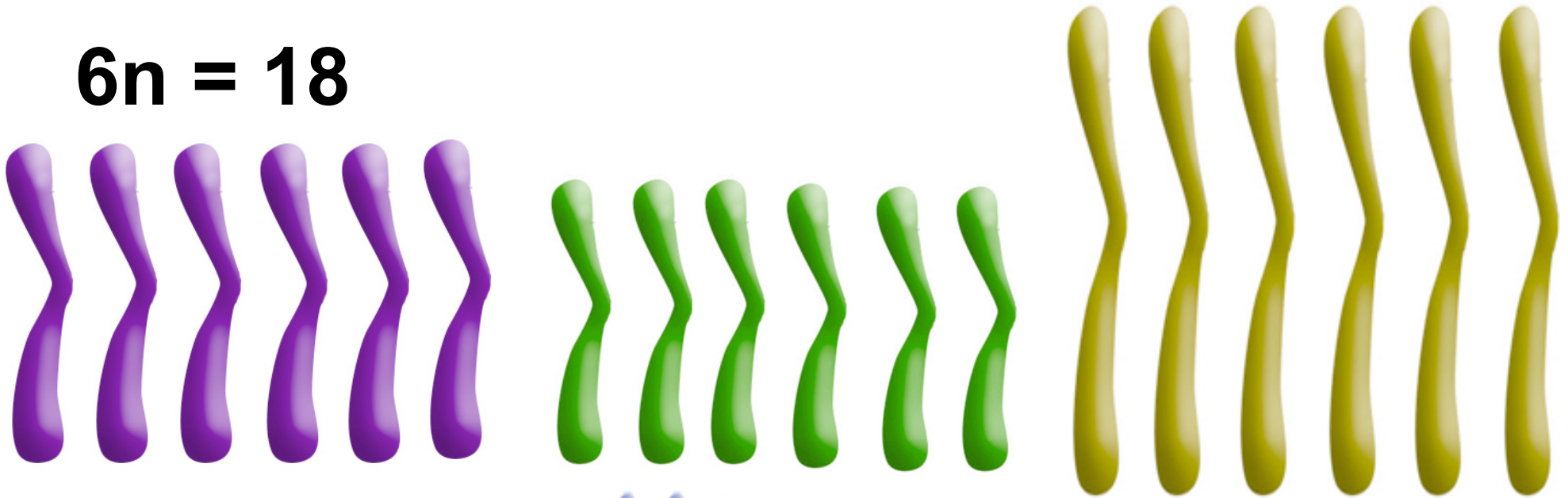
$$30 \text{ (total chromosomes)} / 6 \text{ (number of sets)} = 5n \text{ ploidy number}$$

$5n = 30$

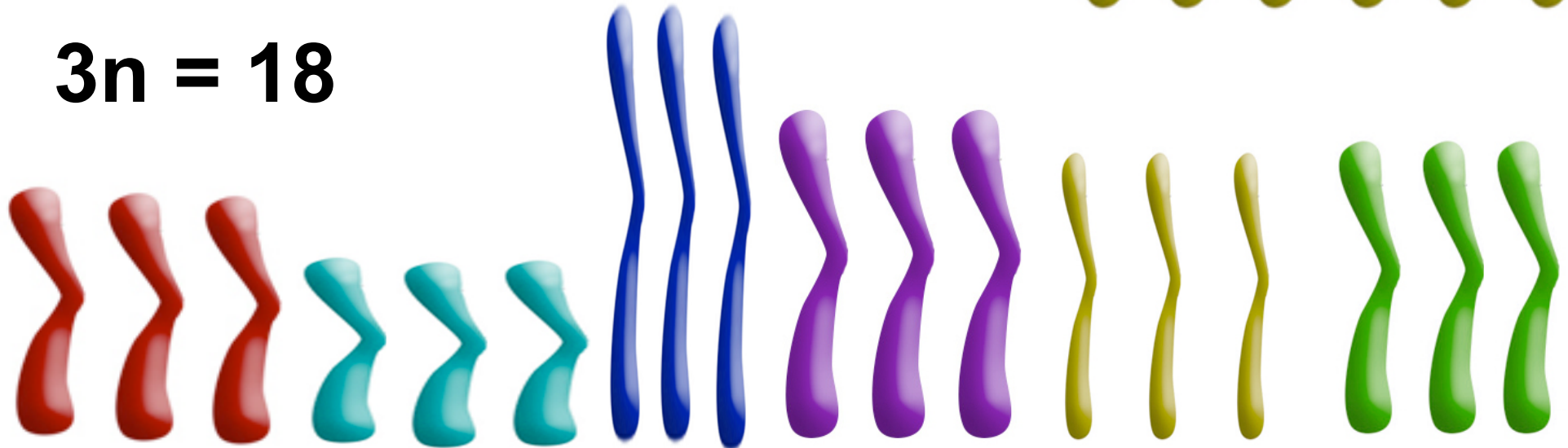
Polyploidy examples

Draw unique chromosomes to represent the following..

$$6n = 18$$



$$3n = 18$$



Polyploidy examples

PLOIDY = number of a chromosomes in a “set”
(eg) 4n means... 4 similar chromosomes that are “talking”
about the same things like hair colour, skin color, etc

Organism	Haploid (n)	Chromosome total number	Ploidy
Human	23	46	2n
Oats	7	42	6n
Peanut	10	40	4n
Sugar Cane	10	80	8n
Potato	12	48	4n
Cotton	13	52	4n
Apple	17	51	3n

Extra Polyploid Example

- **We are $2n=46$**

- We send "n" (haploid number) in our gametes
- **Meaning:** because "n" is 23 in humans, we send 23 chromosomes in our gametes (23 unique sets with 1 in each set)

An alien that is $6n=48$

- it sends " $3n$ " in its male or female gametes
- **Meaning:** because "n" is 8(unique sets) in aliens, it sends 24 chromosomes in their gametes (8 unique sets with 3 in each set)

The Case of the Banana

- Tetraploid + Diploid = triploid

Organisms with odd number of chromosomes cannot reproduce sexually
-so you get good bananas without seeds



+



=

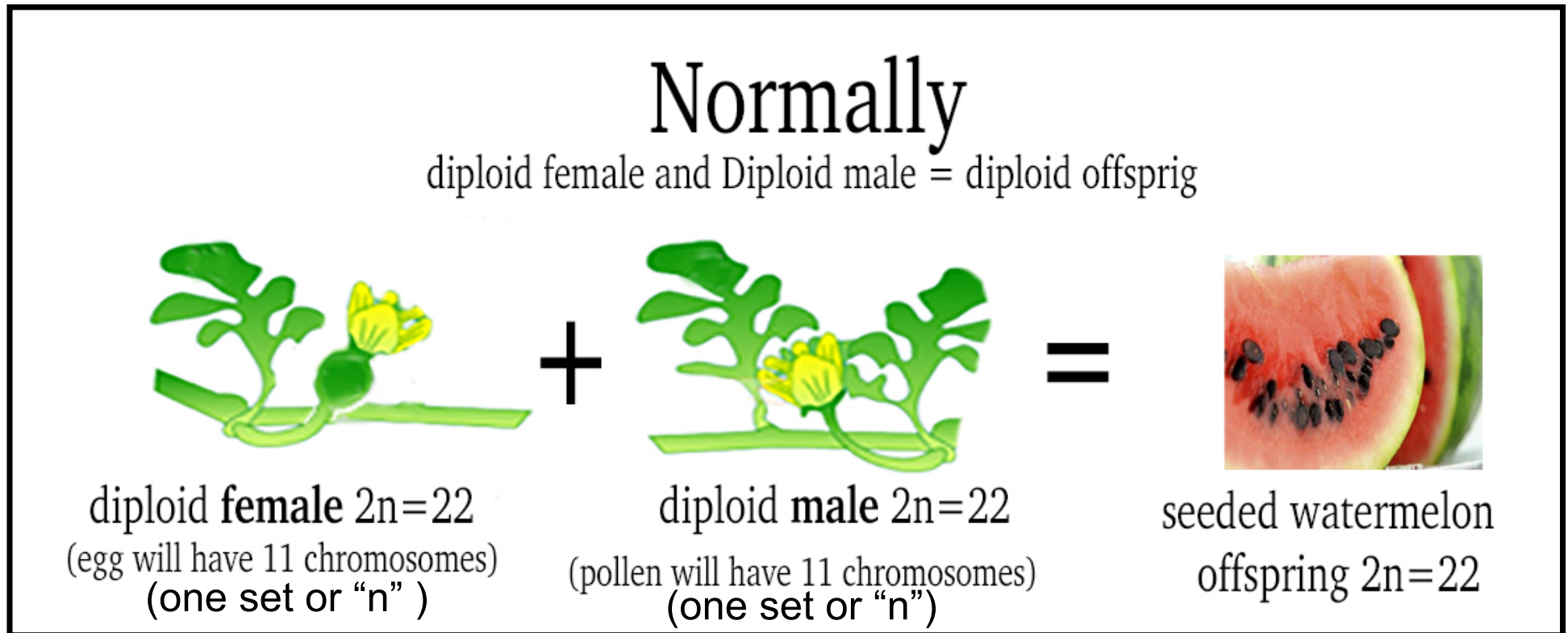


Wild banana
(big seeds but edible)

Wild banana
(smaller seeds but not good eating)

Polyploidy is all around us

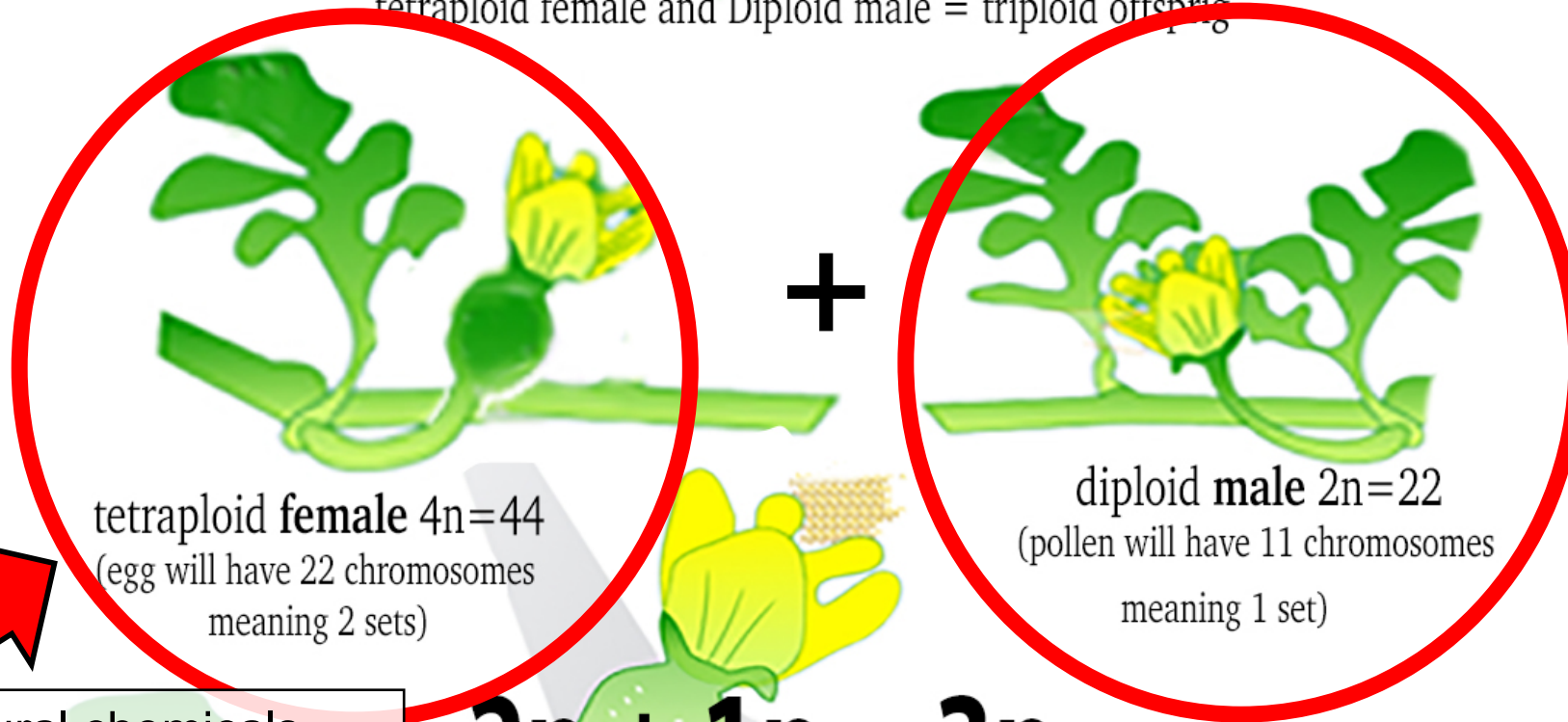
Have you ever wondered why there is such a thing as “seedless watermelons”? <https://www.youtube.com/watch?v=yvy1xA2RwxM>



$$\begin{array}{ccccccc} n & + & n & = & 2n \\ \text{(egg gamete)} & & \text{(sperm gamete)} & & \text{(full \# of chromosomes)} \end{array}$$

Polyploid example created by humans

tetraploid female and Diploid male = triploid offspring



tetraploid **female** $4n=44$
(egg will have 22 chromosomes
meaning 2 sets)

diploid **male** $2n=22$
(pollen will have 11 chromosomes
meaning 1 set)

$$2n + 1n = 3n$$

$$3n=33$$

These seeds are then planted to
create seedless watermelons.

- . By using natural chemicals, plant breeders can double the number of chromosomes in a plant. Then, the **tetraploid** (four sets of chromosomes) watermelons are crossed with a standard diploid watermelon to make **triploid** watermelon seeds. When planted these watermelon are **SEEDLESS**

Do with kids on sheet

Human Normal

$2n = 46$ $2n = 46$

↓ ↓

(23) (23)

$2n = 46$ offspring

$\frac{4n = 8}{(2)}$ $\frac{2n = 4}{(2)}$

○○○○ ○○

* 2 sets * * 2 sets * What is similarity

↓ ↓

○○ ○○

= ○○○ ⇒ $3n_{(2)} = 6$

Basic (2n) Human Example

Male
 $2n=46$

Female
 $2n=46$

Gamete

Polyploid Example

Male
 $4n=8$

Female
 $2n=4$

draw parent
Chromosomes
(2 sets of 4 for male)
(2 sets of 2 for female)

draw parent
gamete
chromosomes

draw added up
Chromosomes
in zygote

$$3n = 6$$

Polyploid Example 2

- a) Lets say an organism after modification is $7n=84$.
b) If one of its parents is tetraploid, how many chromosomes does the parent have?

FIRST: find "n" in the $7n=84$

$$n = 12$$



=meaning the organism has
12 unique sets of chromosomes

SECOND: apply that to the tetraploid...

$$4n = ?$$

$$4(12) = ?$$

$$4(12) = 48$$

So the tetraploid parent has 48
chromosomes

Ploidy REVIEW

Haploid = “n” or number of distinct sets of chromosomes
(eg) as humans we have 23 distinct chromosomes

Diploid = “2n” or we have 2 in every distinct set of chromosomes
(eg) we have 23 sets(distinct sets) of chromosomes. 2 in each set

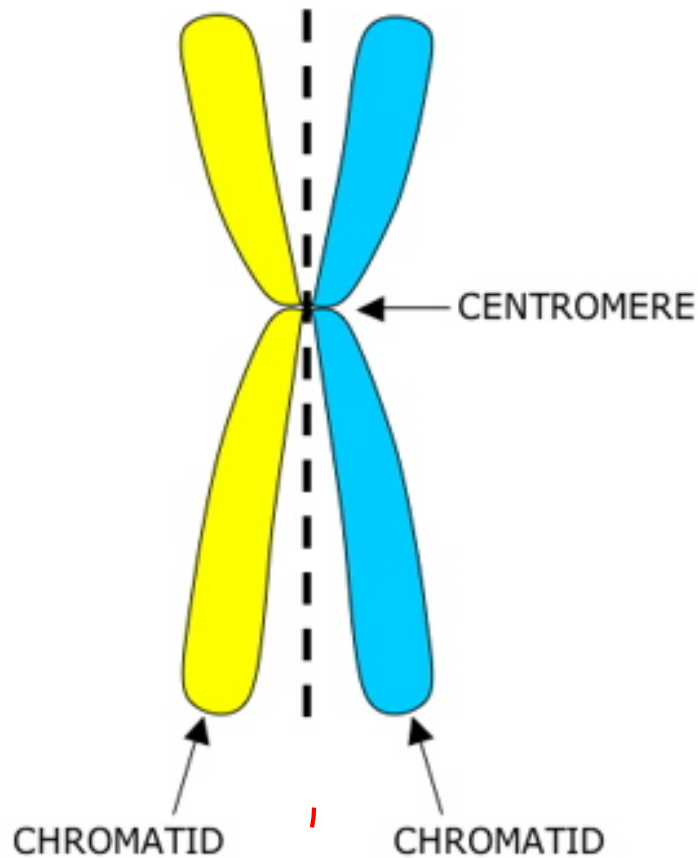
Polyploid = “3n, 4n, 5n, etc.” or **3 chromosomes** in each distinct set,
4 chromosomes in each distinct set,
5 chromosomes in each distinct set,

QUESTION!! What if you had a octaploid mama and the child turned out be a hexaploid. What is the ploidy of the dad?
 $8n + ? = 6n \dots\dots\dots 4n + 2n = 6n$
...therefore **Dad is 4n**

QUESTION!! What if you had a hexaploidy mom and a tetraploidy dad, what would your ploidy be?
 $6n + 4n = ?? \dots\dots\dots 3n + 2n = 5n$

Chromosomes

Replicated chromosome

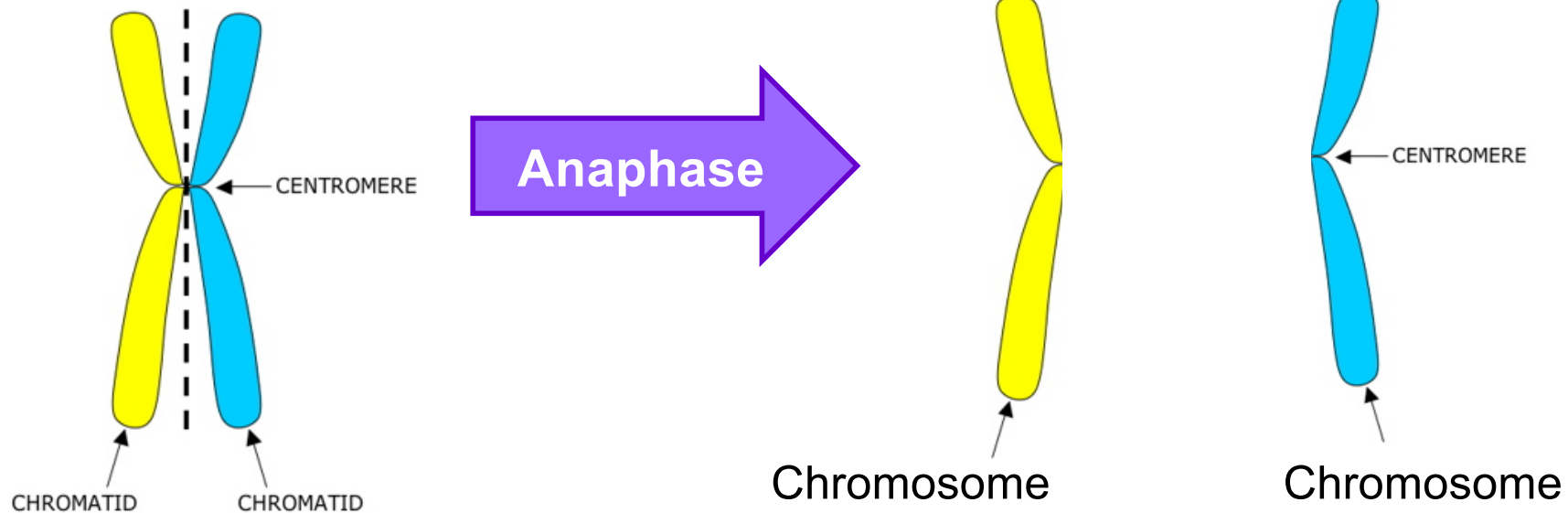


Chromosomes **MUST** replicate themselves prior to cell division. The two sister chromatids shown are identical to each other and were created during DNA synthesis!

A chromatid is $\frac{1}{2}$ of a replicated chromosome. It's only called a chromatid while it is attached by the centromere to its sister chromatid.

Chromatids → Chromosomes

Replicated chromosome



When replicated chromosomes or sister chromatids split apart in anaphase they are called chromosomes.

Cell Division

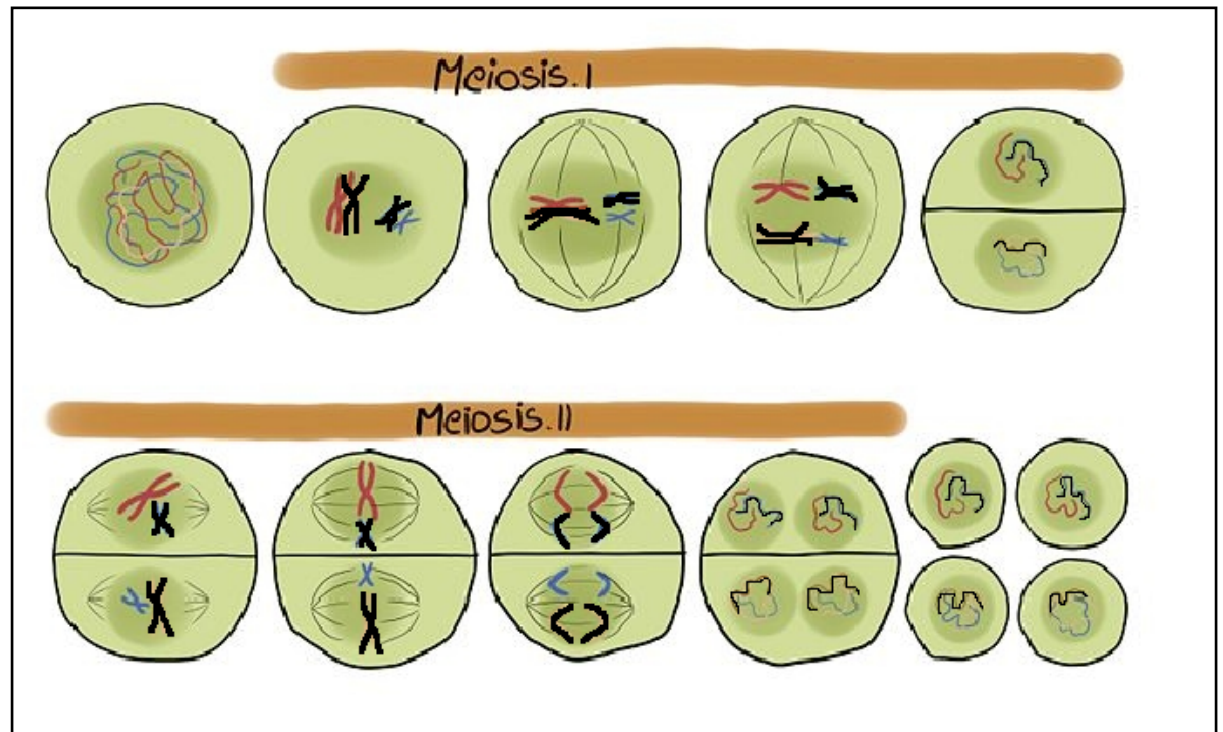
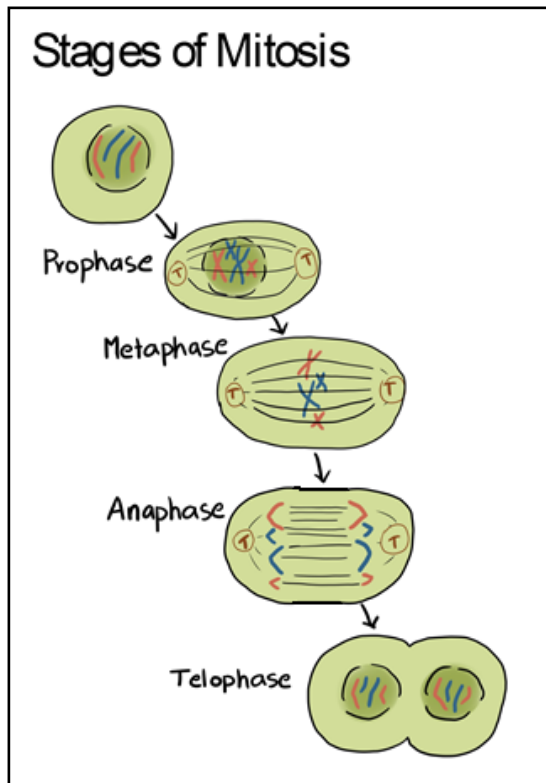
- Cells divide for two reasons:
 1. Growth, maintenance & repair (MITOSIS)
 2. Gamete formation (MEIOSIS)
- During mitosis, a diploid cell splits into two diploid cells
- During meiosis, a diploid cell splits into four haploid cells



- WORKBOOK
- Pages 2 and 3

Mitosis and Meiosis

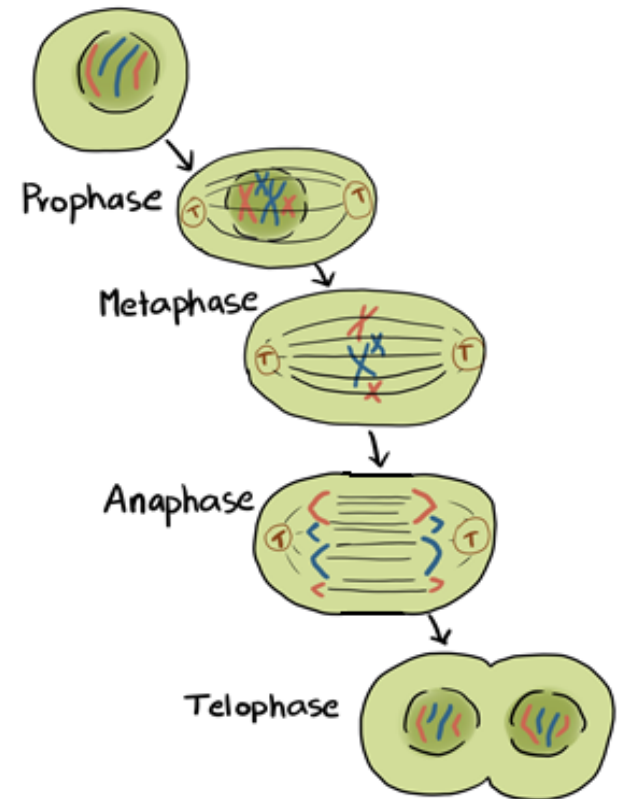
- There are two types of cell division: **mitosis** and **meiosis**. Most of the time when people refer to “cell division,” they mean mitosis, the process of making new body cells. Meiosis is the type of cell division that creates egg and sperm cells.



Mitosis Versus Meiosis

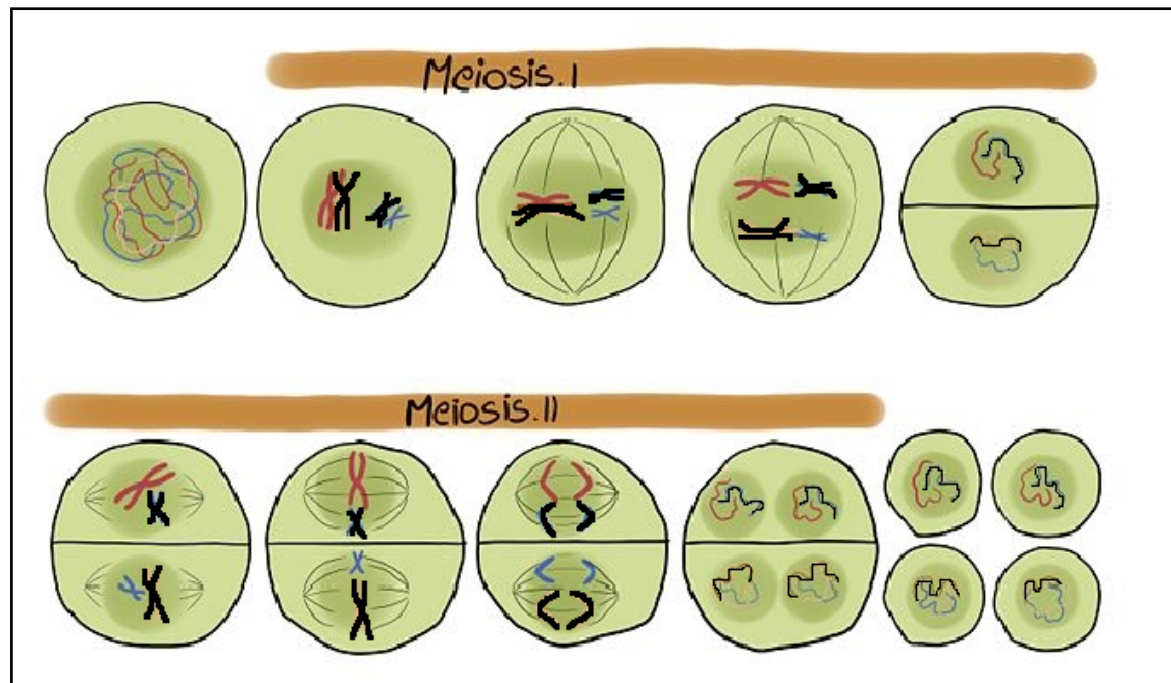
- Mitosis is a fundamental process for life. During Interphase, a cell duplicates all of its contents, including its chromosomes, then through mitosis splits to form two identical daughter cells. Because this process is so critical, the steps of mitosis are carefully controlled by a number of genes. When mitosis is not regulated correctly, health problems such as cancer can result.

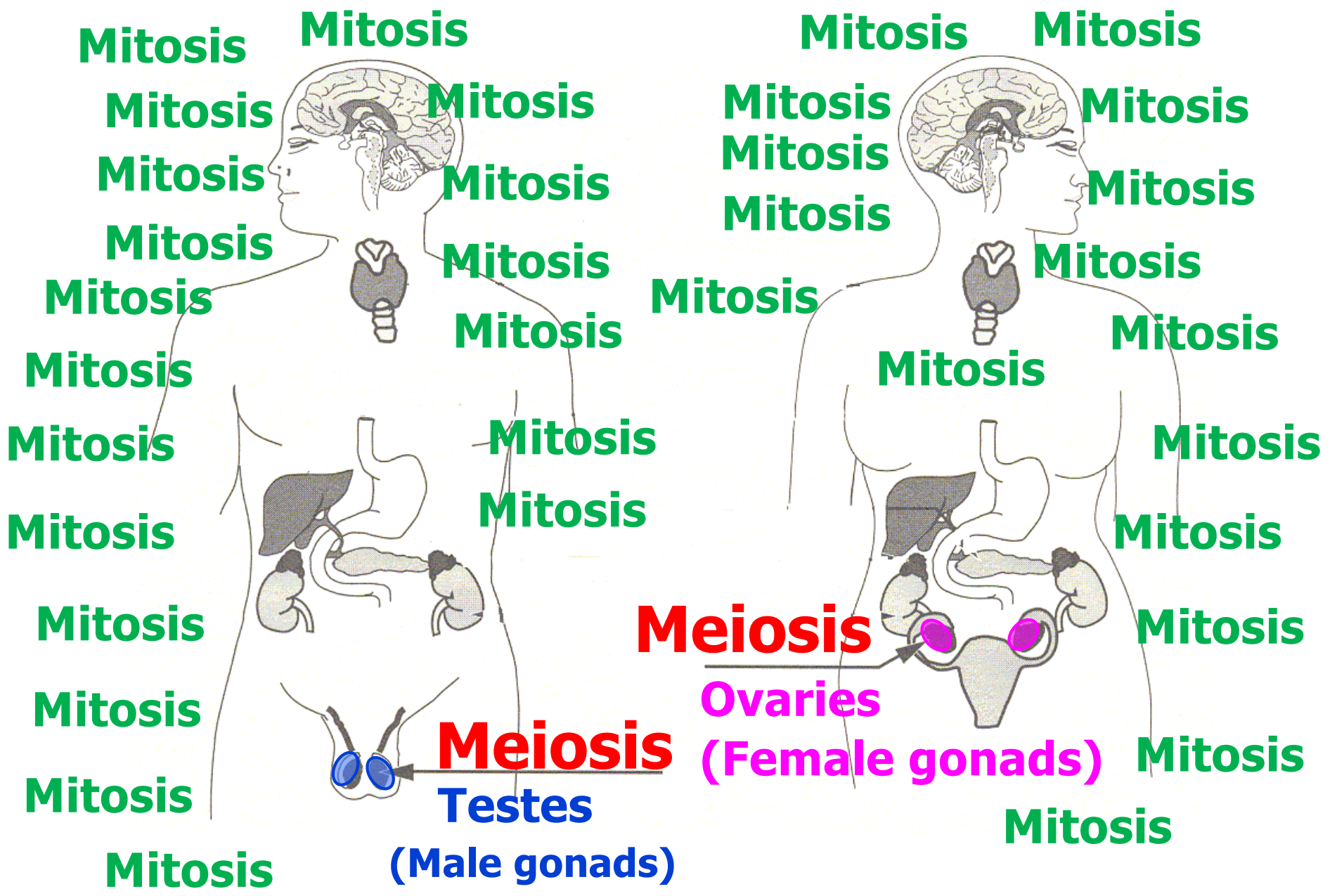
Stages of Mitosis



Mitosis Versus Meiosis

The other type of cell division, meiosis, ensures that humans have the same number of chromosomes in each generation. It is a two-step process that reduces the chromosome number by half – from 46 to 23 – to form sperm and egg cells. When the sperm and egg cells unite at conception, each contributes 23 chromosomes so the resulting embryo will have the usual 46. Meiosis also allows genetic variation through a process of DNA shuffling while the cells are dividing.





Mitosis

Mitosis

Mitosis

Mitosis

Mitosis

Mitosis

Mitosis

Mitosis

Mitosis

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Mitosis

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Mitosis

Mitosis

Mitosis

Meiosis

Mitosis

Mitosis

Ovaries

(Female gonads)

Mitosis

Mitosis

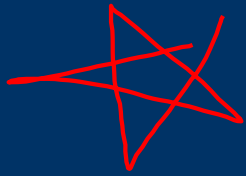
Meiosis

Testes

Mitosis

Mitosis

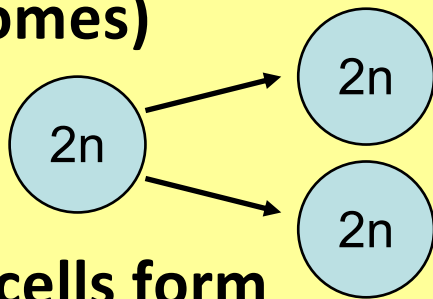
(Male gonads)



Two Types of Cell Division

MITOSIS (IPMAT)

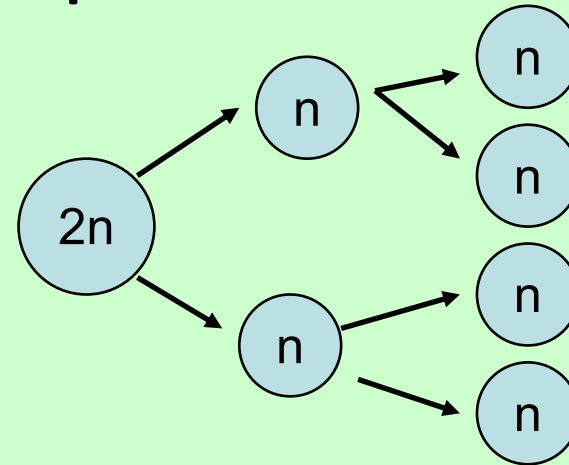
- mitosis is used in the process of organism growth, maintenance & repair of old cells **BUT KEEP IN MIND** mitosis specifically is the **SEPARATING OF GENETIC MATERIAL**
- $2n$ cell \rightarrow $2n$ cells *Diploid*
(46 chromosomes \rightarrow 46 chromosomes)



- 2 diploid cells form
- Occurs in somatic cells in the human body!

MEIOSIS (IPMATPMAT)

- For gamete formation
 - sperm & egg
- $2n$ cell \rightarrow n cells *haploid.*
(46 chromosomes \rightarrow 23 chromosomes)
- 4 haploid cells form



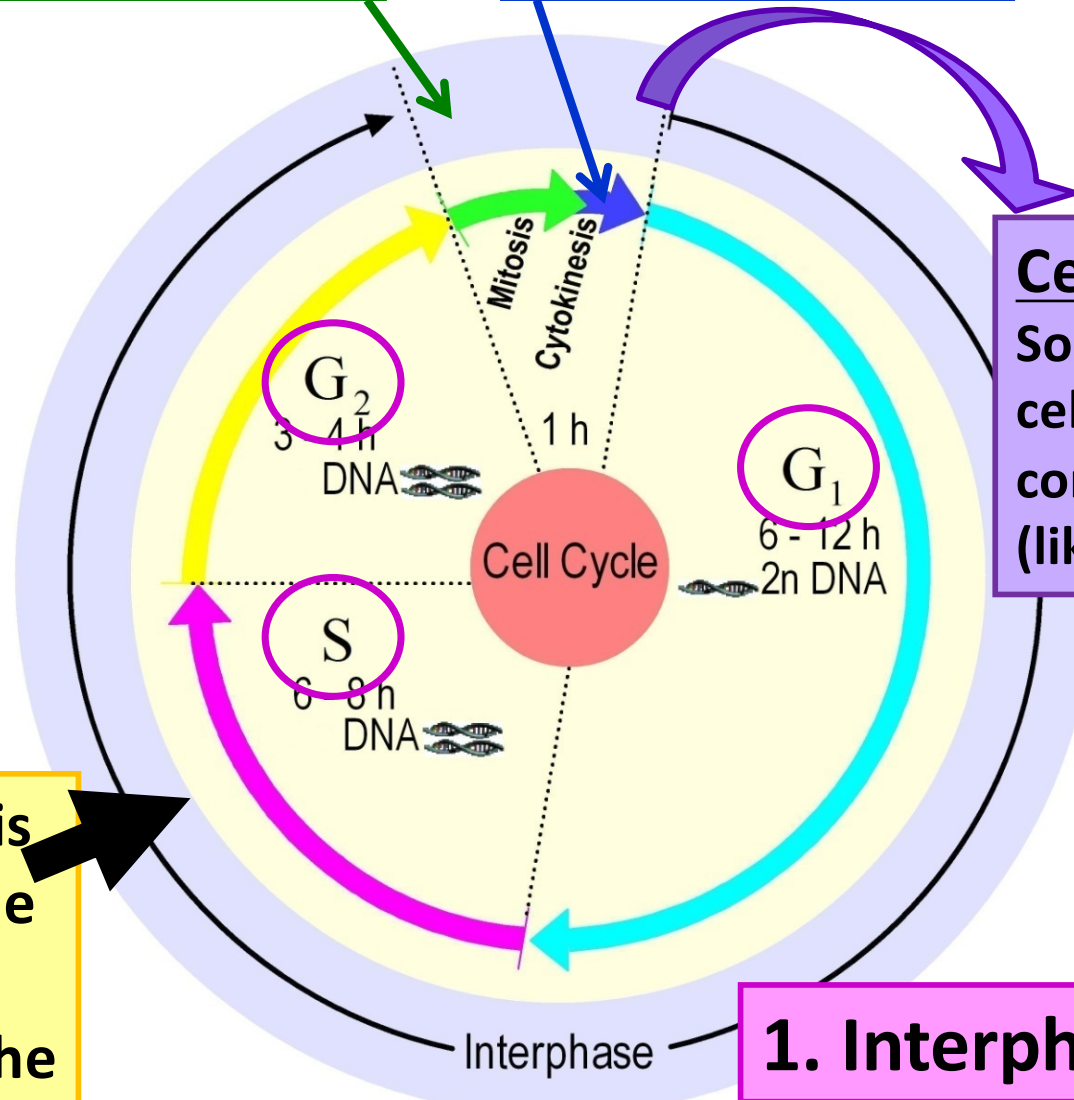
- Occurs only in gonads (ovaries and testes)
- Cause of most existing genetic variation

The Cell Cycle – 3 Phases

INTERPHASE – MITOSIS - CYTOKINESIS

2. Mitosis

3. Cytokinesis



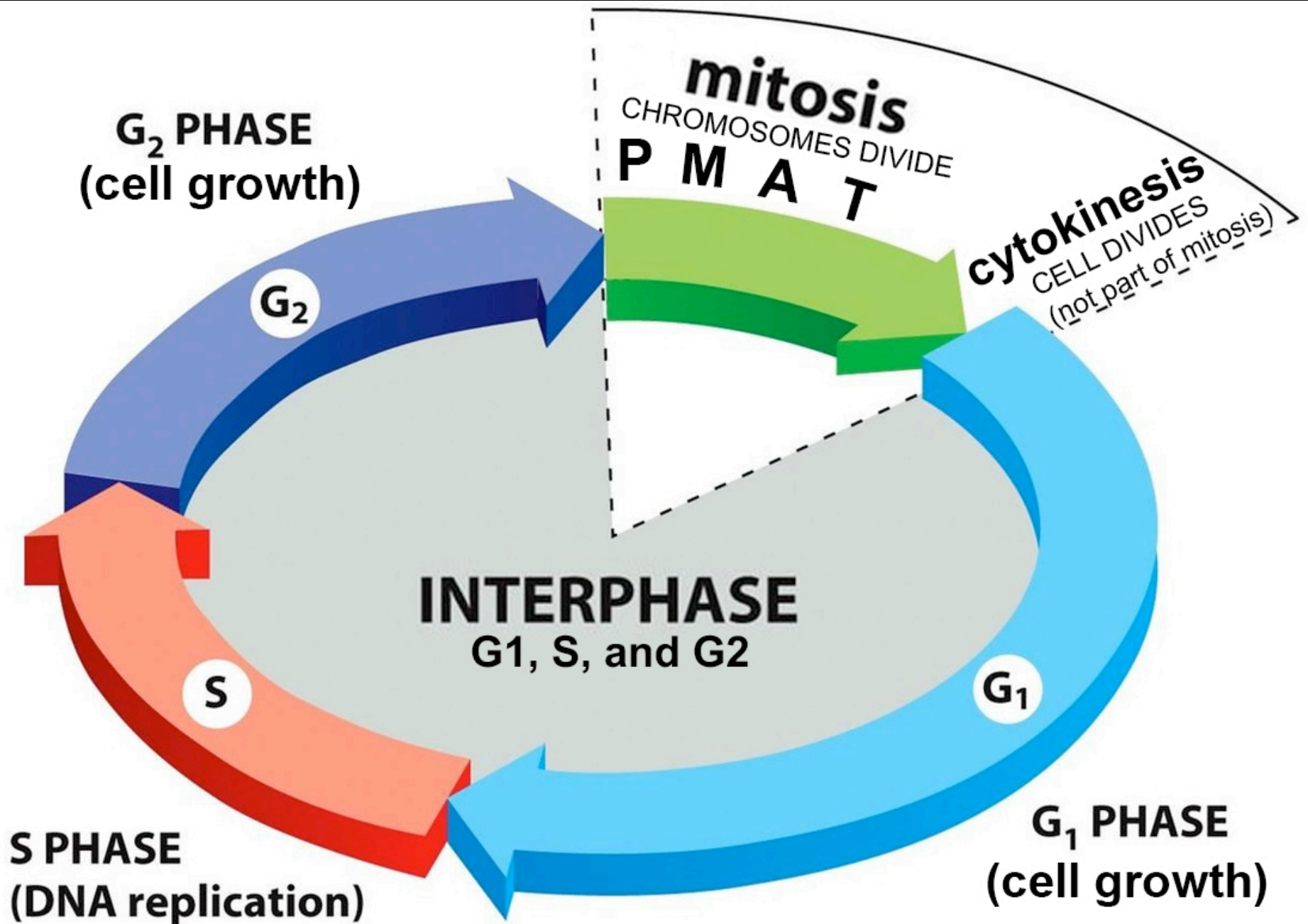
Cell Specialization

Some cells leave the cell cycle – do not continue to divide. (like red blood cells)

DNA synthesis is necessary so the chromosome numbers stay the

1. Interphase

The Cell Cycle



The Cell Cycle

IMPORTANT NOTES ON THE CELL CYCLE:

3 PHASES:

Interphase – the longest phase including growth and DNA duplication

Mitosis - division of the duplicated DNA

Cytokinesis – separation into TWO identical cells

After cytokinesis some cells do not go back into the cell cycle. A cell can...

- a. go back into the cell cycle
- b. Specialize...perform a specific function like BLOOD CELLS

PLAY ME

INTERPHASE: Stage prior to Mitosis

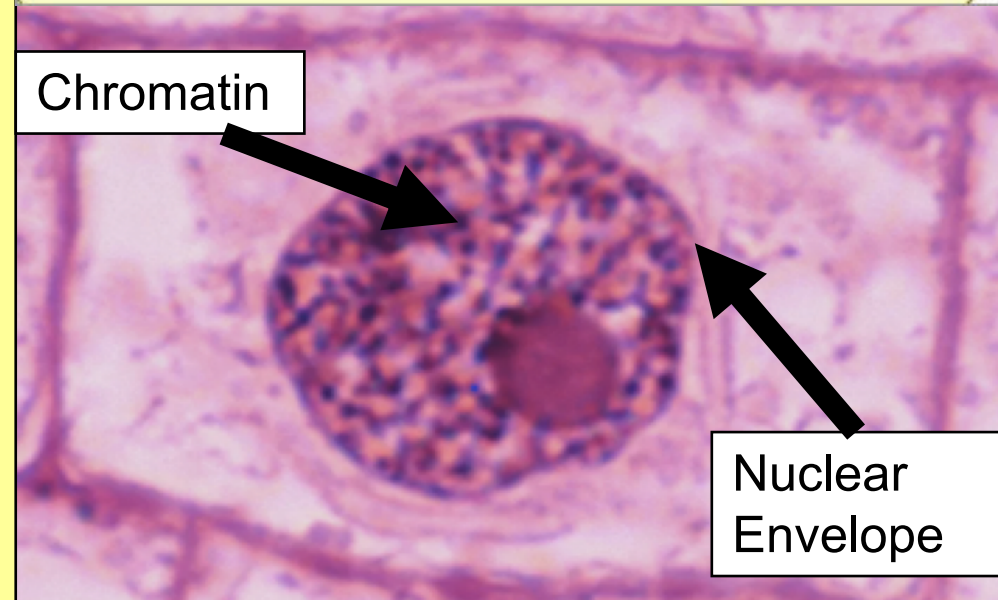
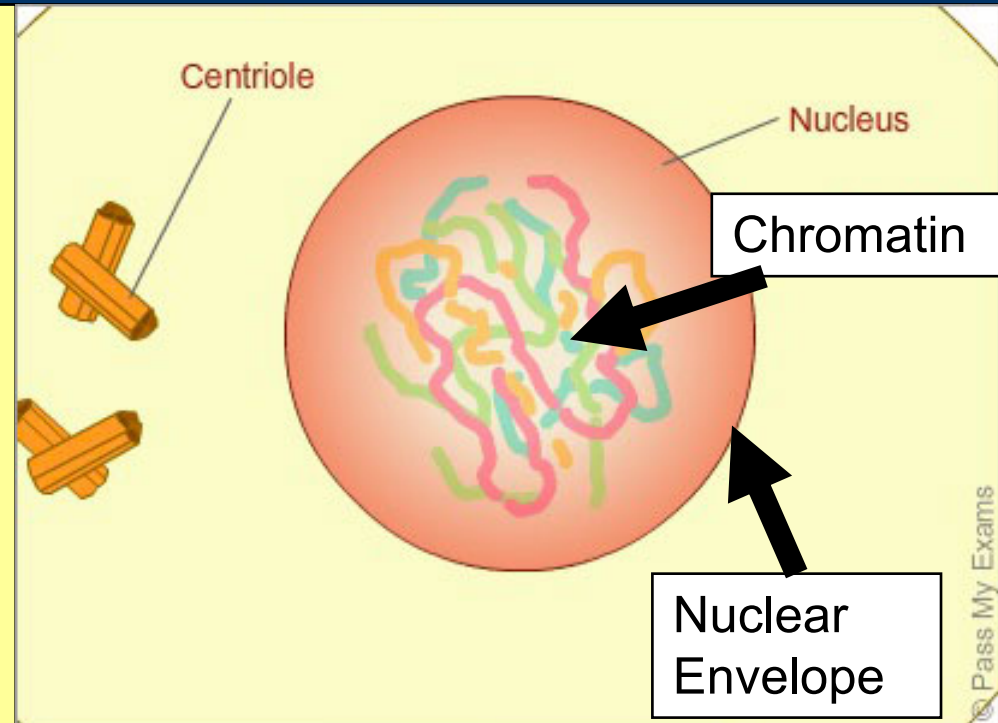
-Chromosomes not visible.

-DNA is in form of chromatin.

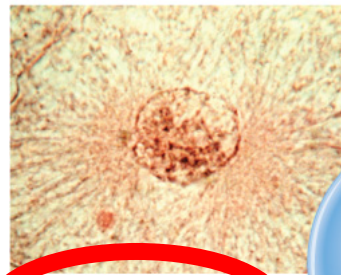
Main Events:

1. **G1 (growth / protein synthesis),**
2. **S- DNA Replication (sister chromatids form) and**
3. **G2 (growth / protein synthesis)**

http://www.youtube.com/watch?v=-G-3BDlnK58&safe=active&safety_mode=true

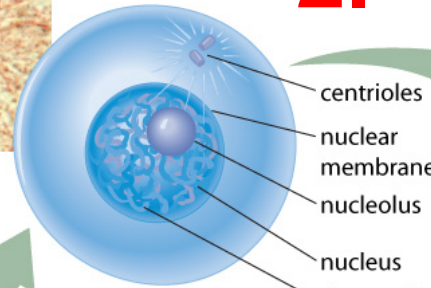


Preview of Mitosis



A Interphase
Precedes mitosis.

1.



2.

B Prophase
The chromatin coils to form visible chromosomes.

growing spindle fibres

centrioles

nuclear membrane

nucleolus

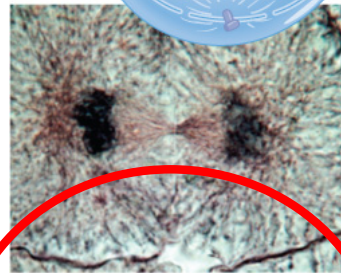
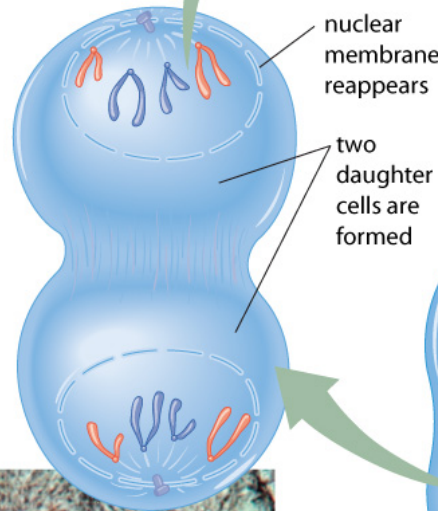
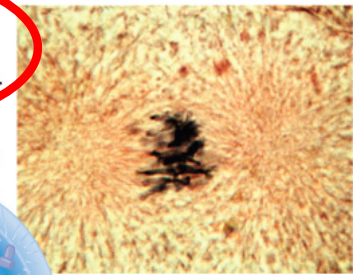
nucleus

chromatin

centrioles migrate toward poles

replicated chromosome

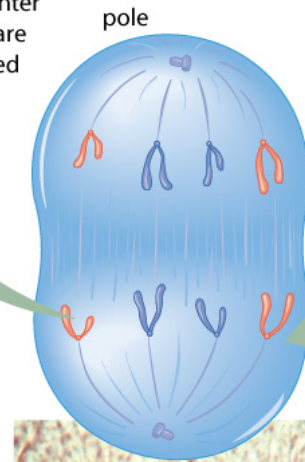
disappearing nuclear membrane



E Telophase

Two daughter cells are formed. The cells divide as the cell cycle proceeds into cytokinesis. Both daughter cells then proceed into the next interphase.

5.



D Anaphase

The centromeres split and the sister chromatids are pulled apart to opposite poles of the cell.

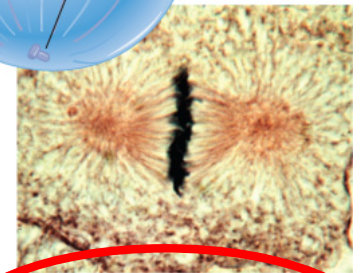
4.

centrioles now at poles

centromere

sister chromatids

centrioles now at poles



C Metaphase
The chromosomes move to the equator of the cell.

3.

Mitosis Animation (McGraw-Hill)

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation_mitosis_and_cytokinesis.html

Figure 16.8 These illustrations and micrographs show what happens inside a cell during interphase (A) and mitotic cell division (B to E).

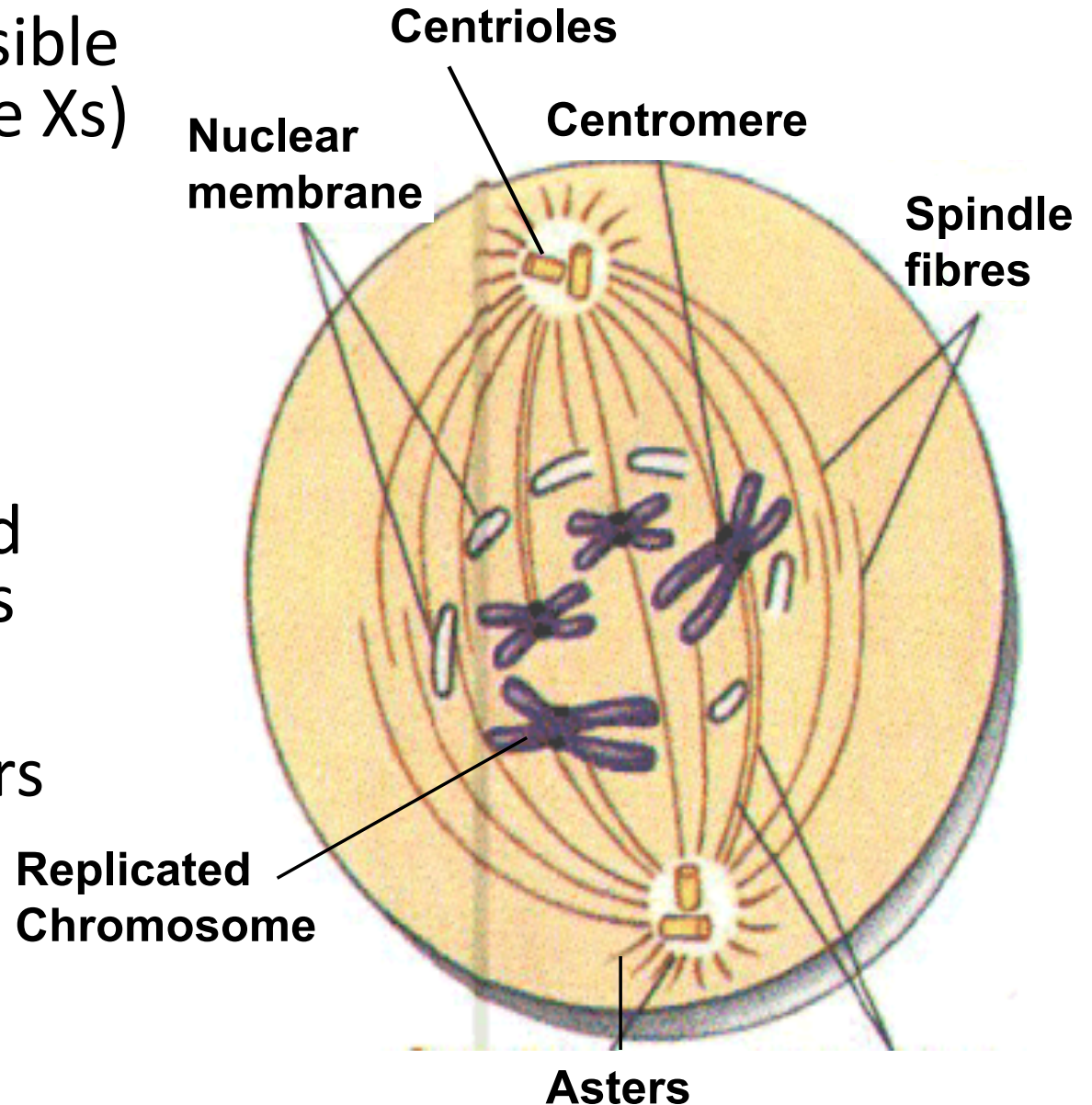
WHAT IS MITOSIS?

Mitosis is simply the division of DNA

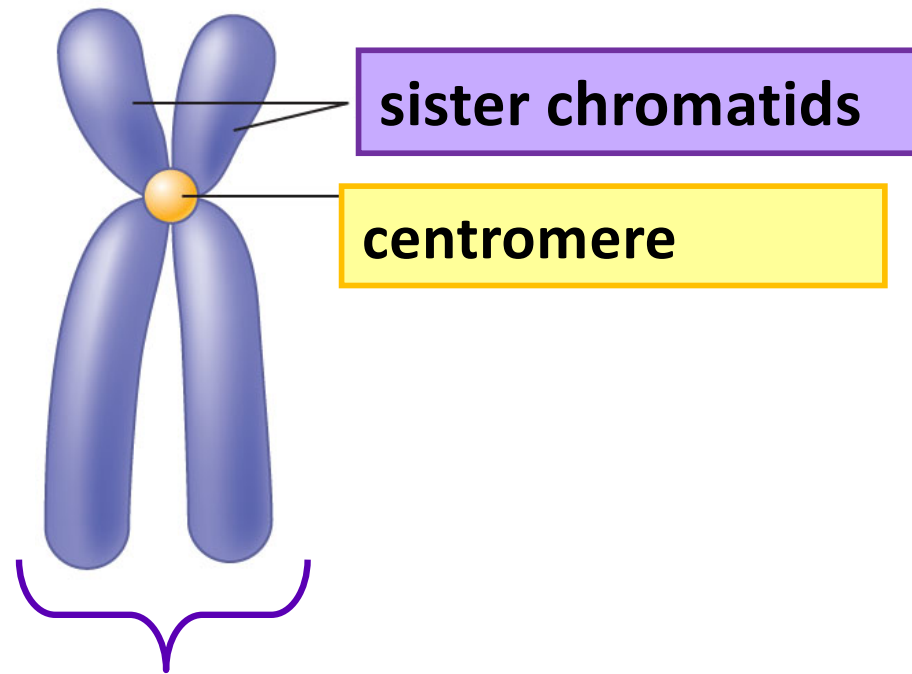
[PLAY ME: Stages of Mitosis](#)

Prophase (PREPARE)

- Chromatin becomes visible chromosomes (look like Xs)
- nuclear membrane disappears
- Centrioles separate and move to opposite poles
- Spindle fibers and asters form



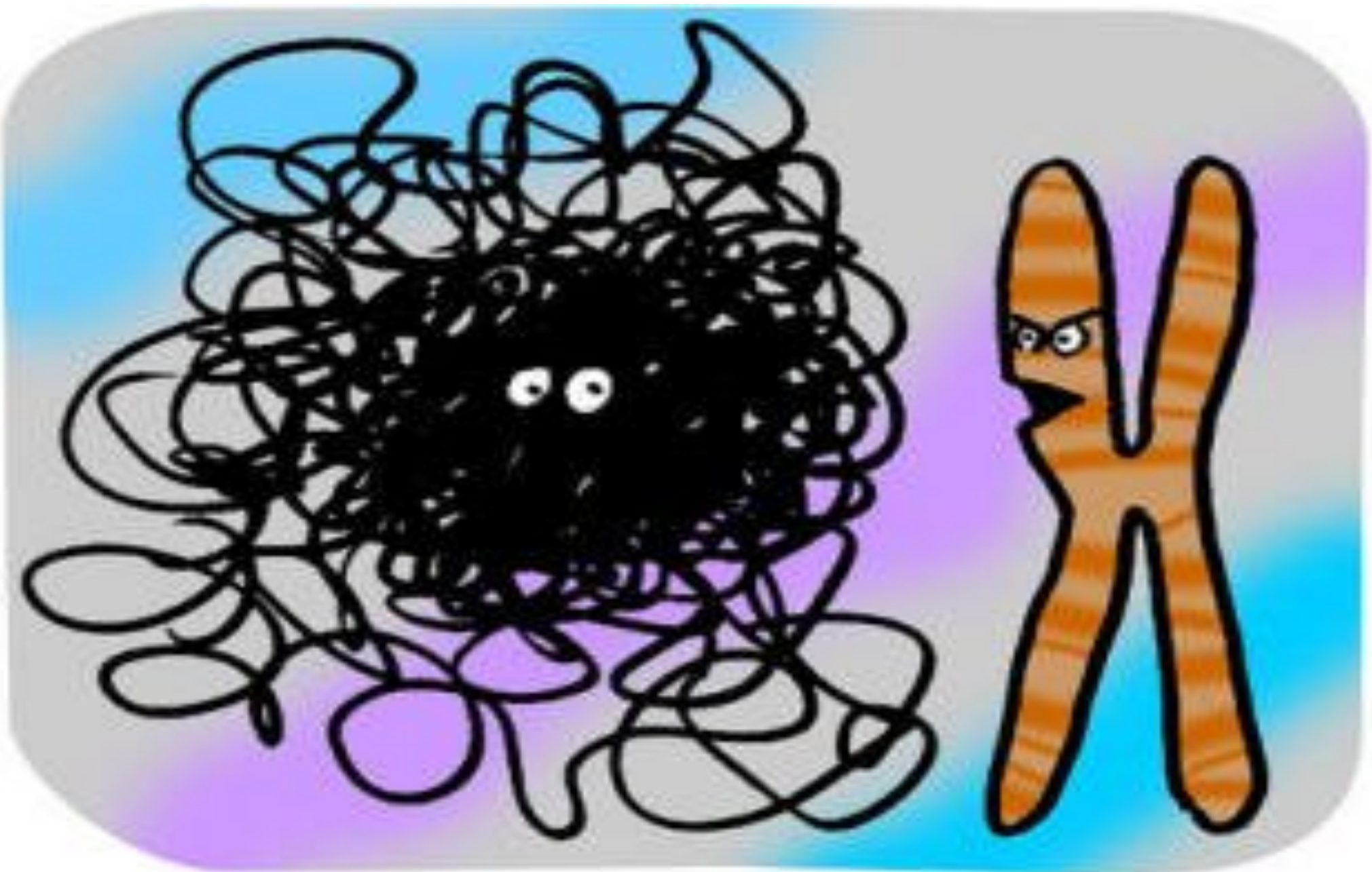
Chromosomes during Prophase and Metaphase



sister chromatids

centromere

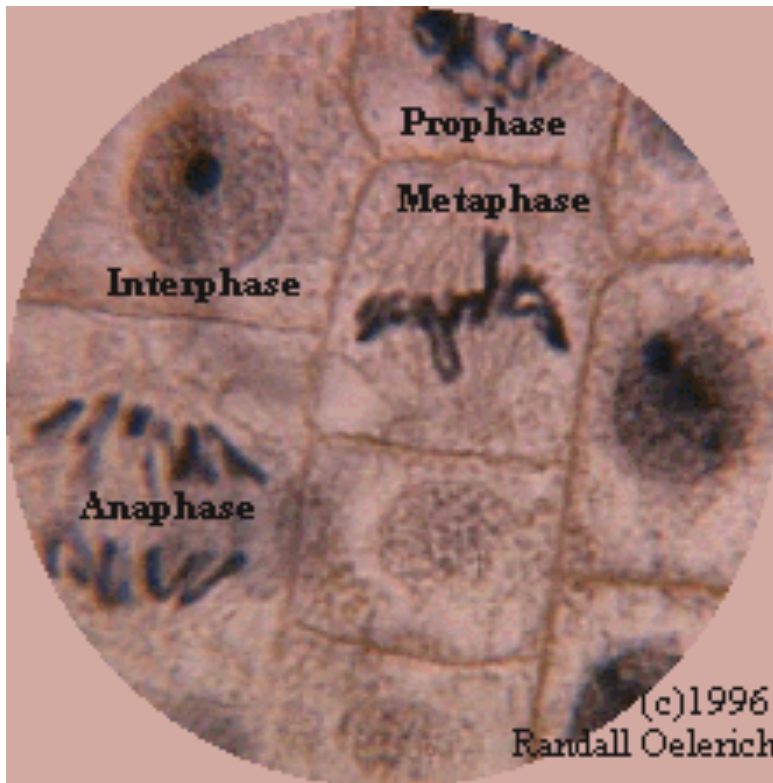
Replicated chromosome



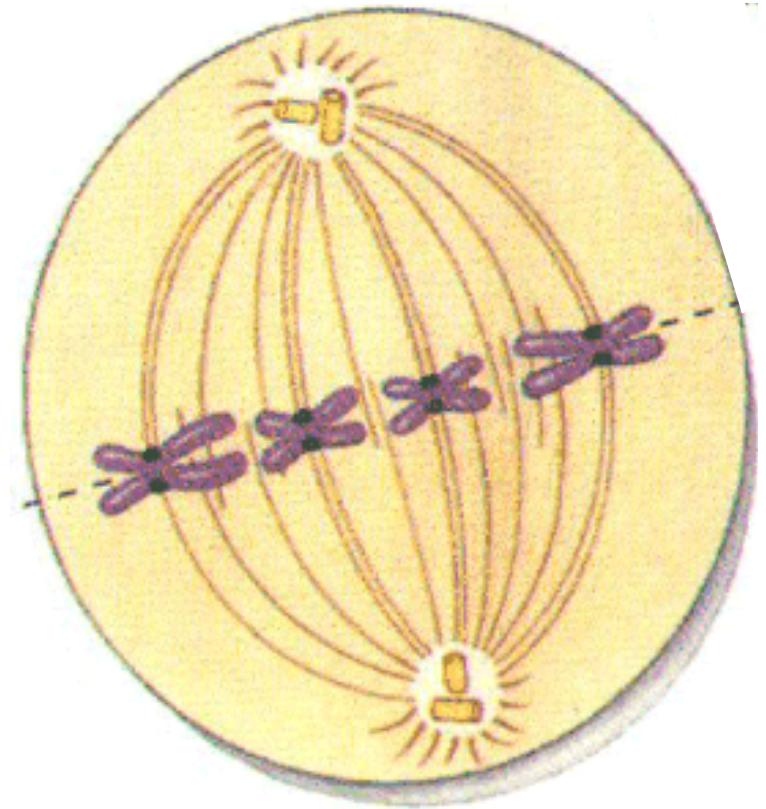
Dude, mitosis starts in five minutes...
I can't believe you're not condensed yet.

Metaphase (MIDDLE)

- Replicated chromosomes line up along the metaphase plate (equator)
- Individual chromosomes can be seen since they are lined up

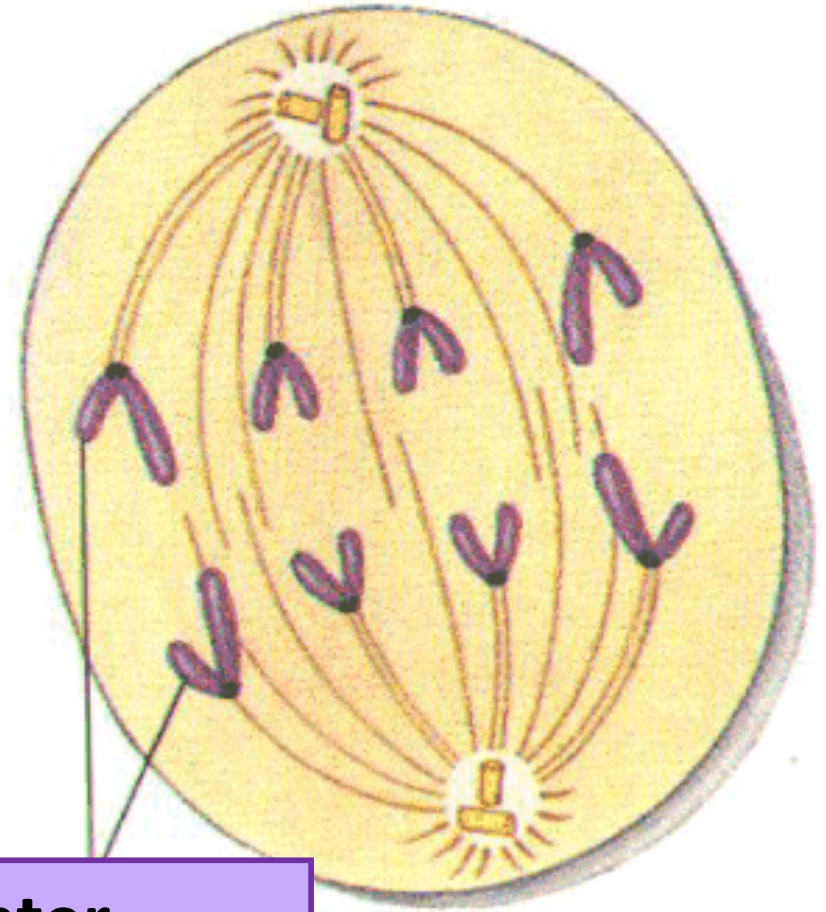
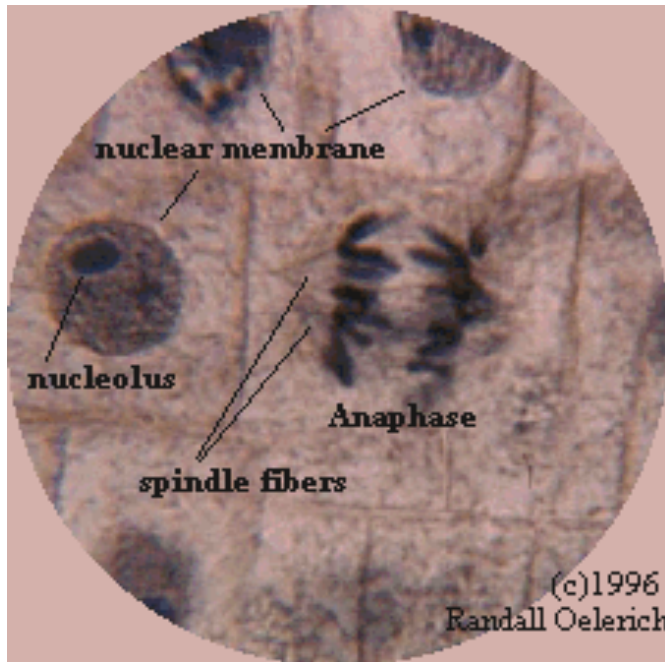


Metaphase
plate



Anaphase (APART)

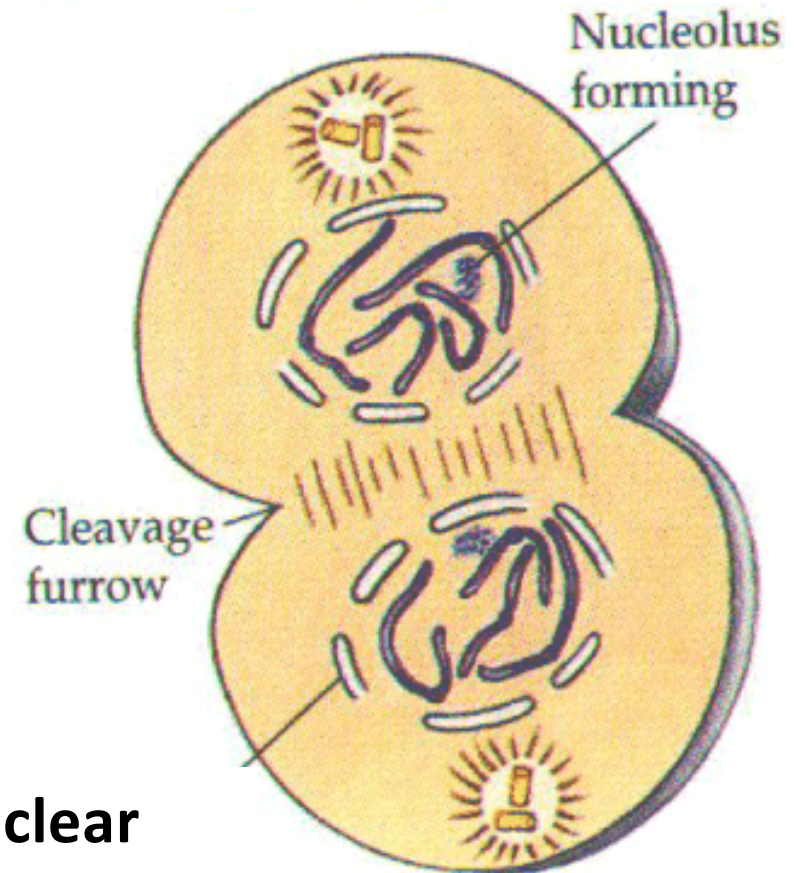
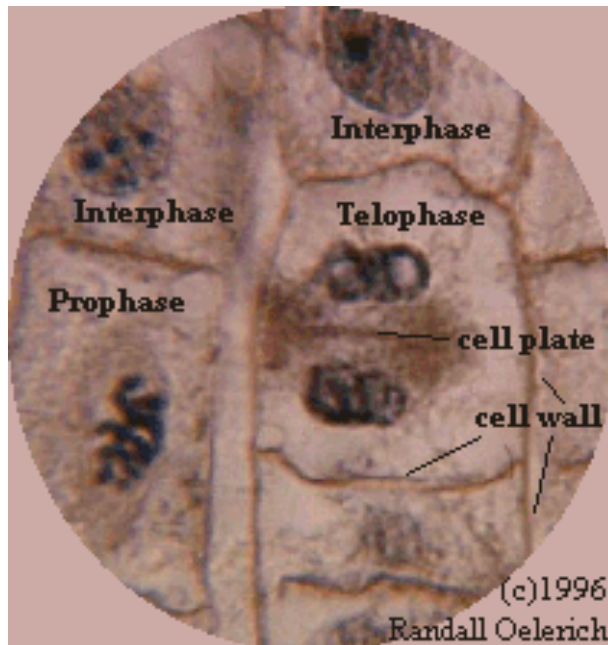
- Action!
- Centromeres divide
- **chromosomes** move to opposite poles



Daughter
chromosomes

Telophase (TEAR into two)

- Chromosomes reach opposite poles
- Chromosomes begin to lengthen out again becoming chromatin
- Spindle fibers dissolve
- Nuclear membrane reappears



**Nuclear
membrane
forming**

I Propose Men Are Toads

I Prepare

n
t
e
r
p
h
a
s
e

Middle

e
t
a
p
h
a
s
e

Apart

n
a
p
h
a
s
e

Tear in two

e
l
o
p
h
a
s
e

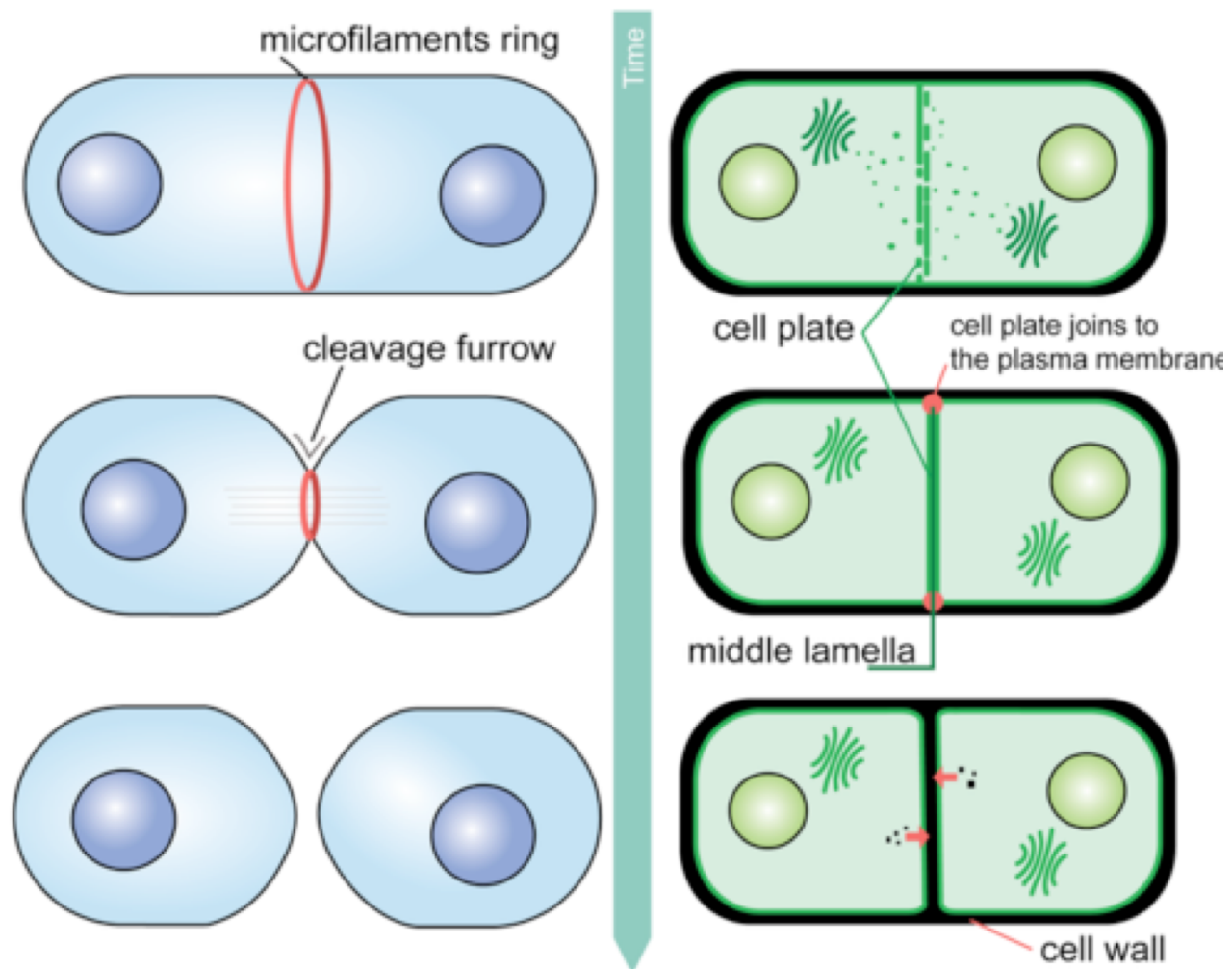
Cytokinesis (cytoplasm divides)

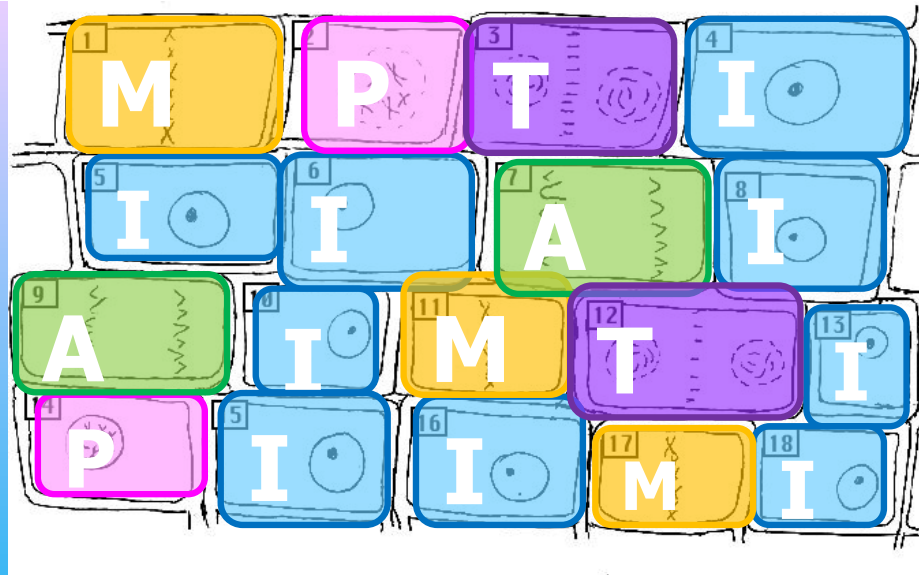
- **ANIMAL CELLS:** Cytoplasm pinches in or **invaginates**
- **PLANT CELLS:** Cell plate is formed in plant cells
 - Cell plate eventually becomes cell wall (**made of cellulose**)

Mitosis animations

http://www.youtube.com/watch?v=cvlpmmvB_m4&safety_mode=true&safe=active&persist_safety_mode=1

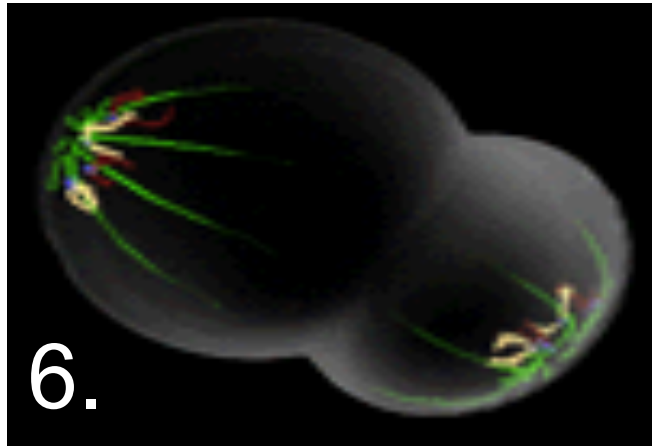
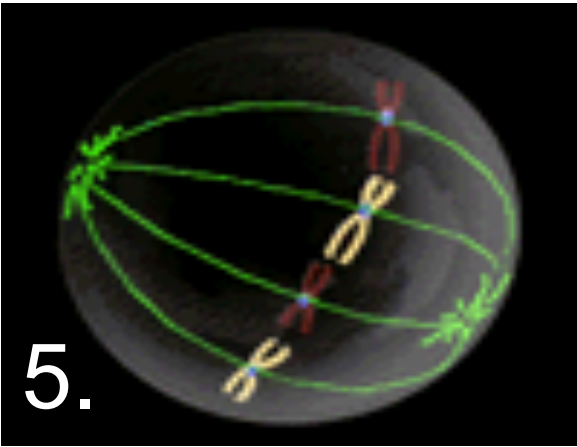
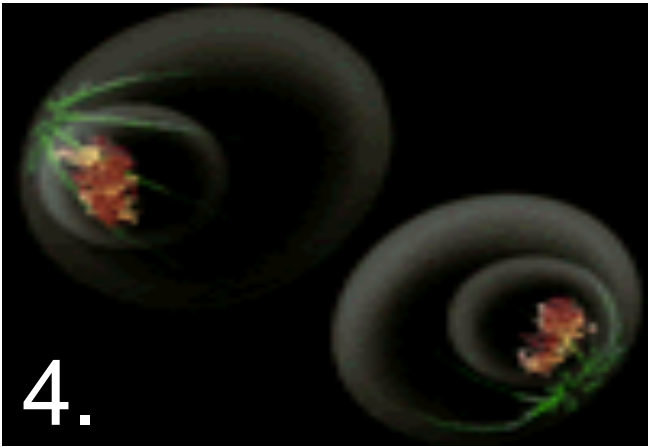
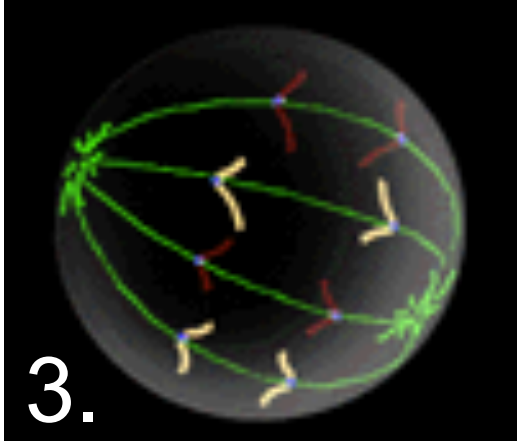
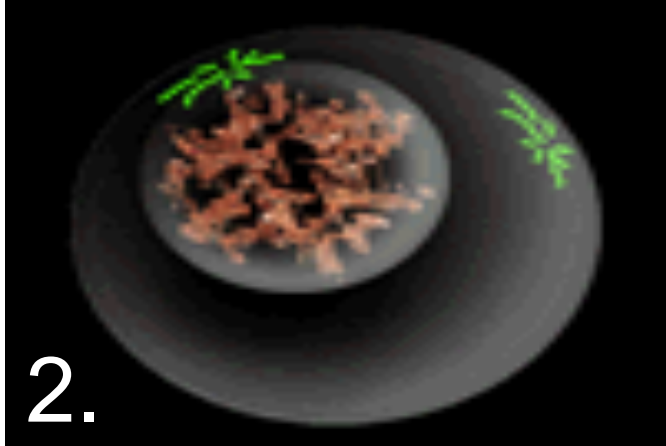
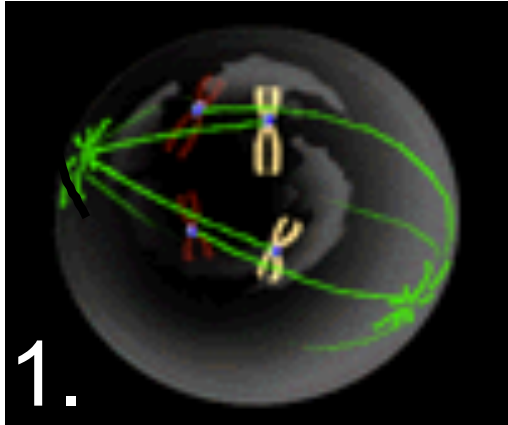
[Bozeman Mitosis \(13:35\)-watch](#)





Stage	Number of Cells	Time
Interphase	9	50%
Prophase	2	11%
Metaphase	3	17%
Anaphase	2	11%
Telophase	2	11%

Identify the stages!



1. Prophase

2. Interphase

3. Anaphase

4. Cytokinesis

5. Metaphase

6. Telophase

Cell division in pig kidney epithelial cells

What is the phase?

1. Chromosomes appear

prophase

2. Chromatin is present

interphase

3. Chromosomes line up at equator

metaphase

4. Cleavage furrow

telophase

What is the phase?

5. Spindle fibres appear

prophase

6. Spindle fibres disappear

telophase

7. Centromeres divide

Anaphase

8. Chromosomes move to opposite poles

Anaphase

What is the phase?

9. Protein synthesis

Interphase (G1 & G2)

10. Cell divides into two

Cytokinesis

11. Chromosomes divide

Anaphase

12. DNA replicates

Interphase

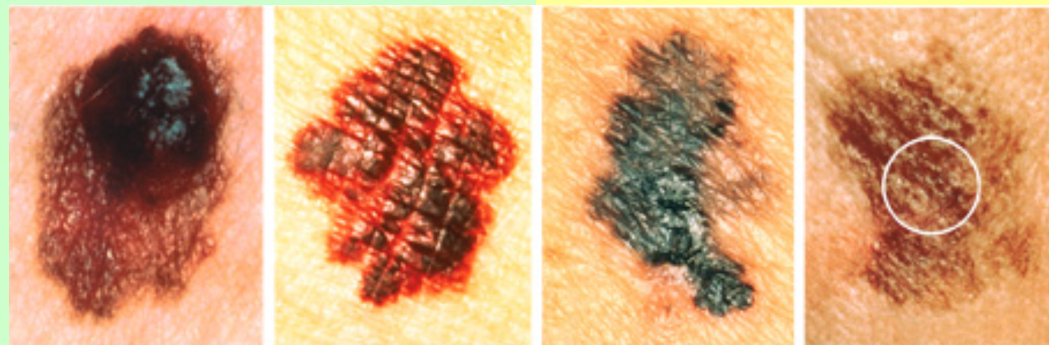
WORKBOOK

Pages 4,5,6(left side)

- Amoeba sisters
Mitosis and Cancer
and cell cycle
- <https://www.youtube.com/watch?v=QVCjdNxJreE&t=38s>

Normal cells vs. Cancer cells

- Reproduce exactly and stop reproducing when they are supposed to
 - If damaged – are destroyed (or repaired)
 - Stick together in the correct place and specialize/mature properly
- **Keep reproducing** – don't know when to stop – Abnormal Mitosis
 - **Don't die** if moved to another part of the body (metastasis)
 - Don't stick together and don't **specialize** (they stay immature)



Asymmetry

Border
irregularity

Color

Diameter:
 $\frac{1}{4}$ inch or
6mm

Interesting
thing about
cancer
telomeres...

Cloning: an application of mitosis

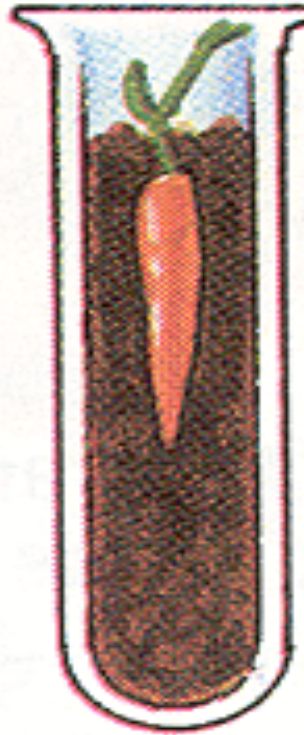
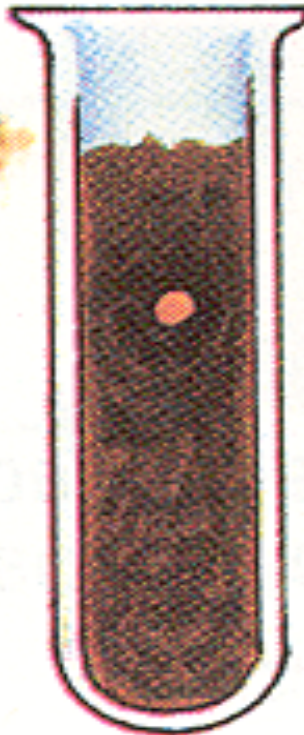
- Identical offspring forms from a **single** parent cell
- A form of **asexual** reproduction
- Originally done by taking **plant** cuttings
- Advantageous: parent provides nutrition, quick, doesn't require a **partner**
- Disadvantages: limited gene pool and genetic variation (**mutations** are passed on)



Plant tissue culture
and cloning
laid groundwork for
genetic engineering



Single cell
extracted from
carrot



Carrot cloned

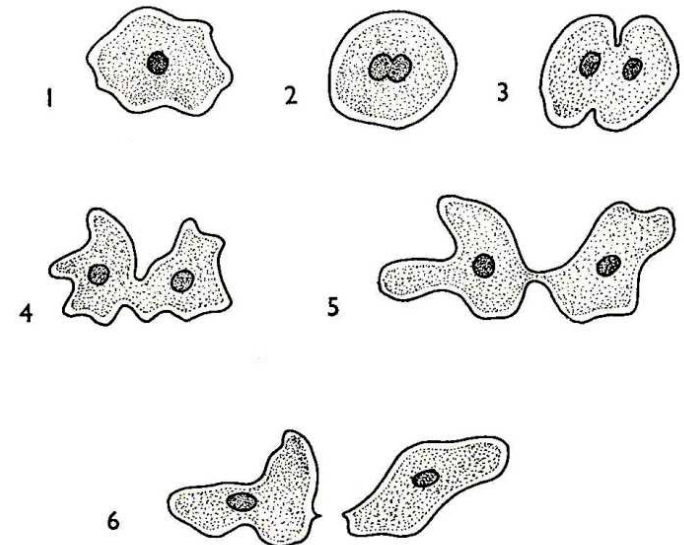
Simple cloning

Asexual Reproduction

- This is very common in plants
- The offspring are always genetically **IDENTICAL** to the parent.

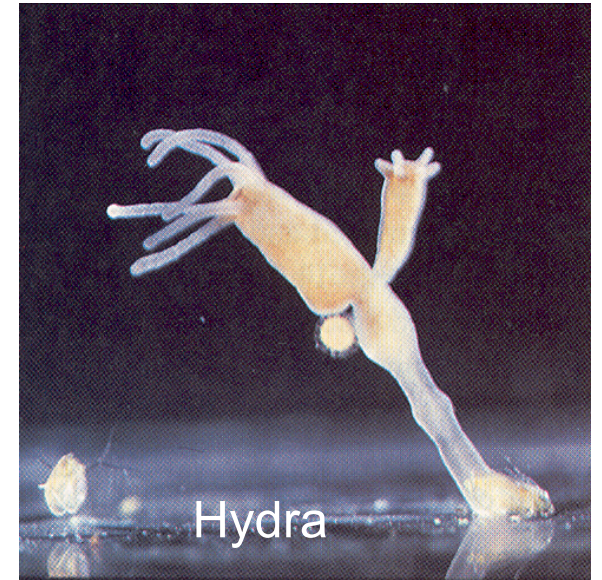
Through process of MITOSIS!

- Examples:
 - **Strawberry** plants can reproduce by sending out runners
 - Removed **willow** branches send out roots when immersed in water
 - **Amoebas** divide into two (binary fission)



Asexual Reproduction

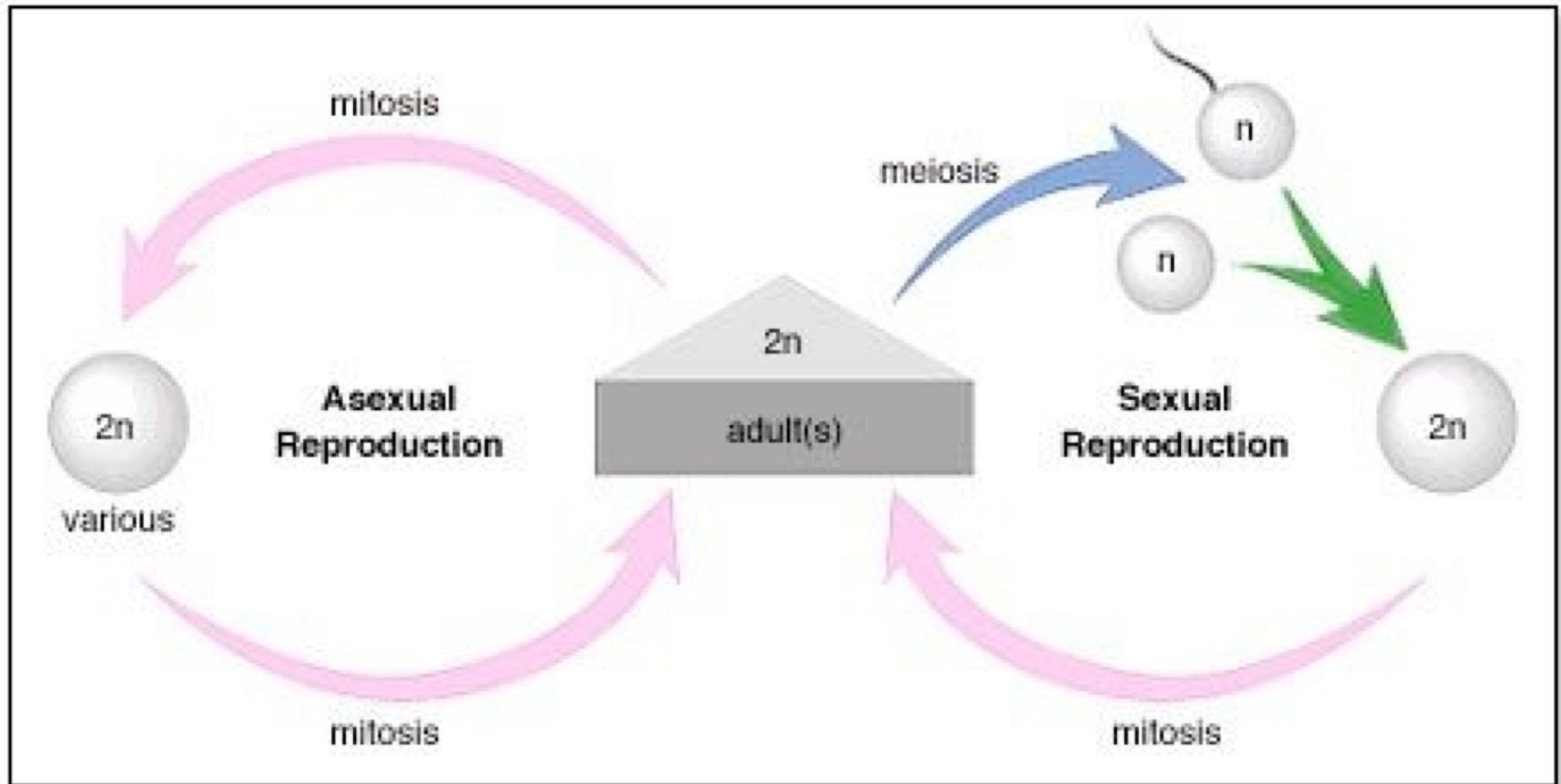
- Examples:
 - hydra form new hydra by **budding**
 - Some animals can reproduce by **parthenogenesis (unfertilized egg)**
 - mushrooms can release **spores**
- Asexual reproduction brought upon the first ideas of simple cloning experiments



Find some more examples of animals that reproduce through asexual reproduction.



Asexual vs Sexual Reproduction



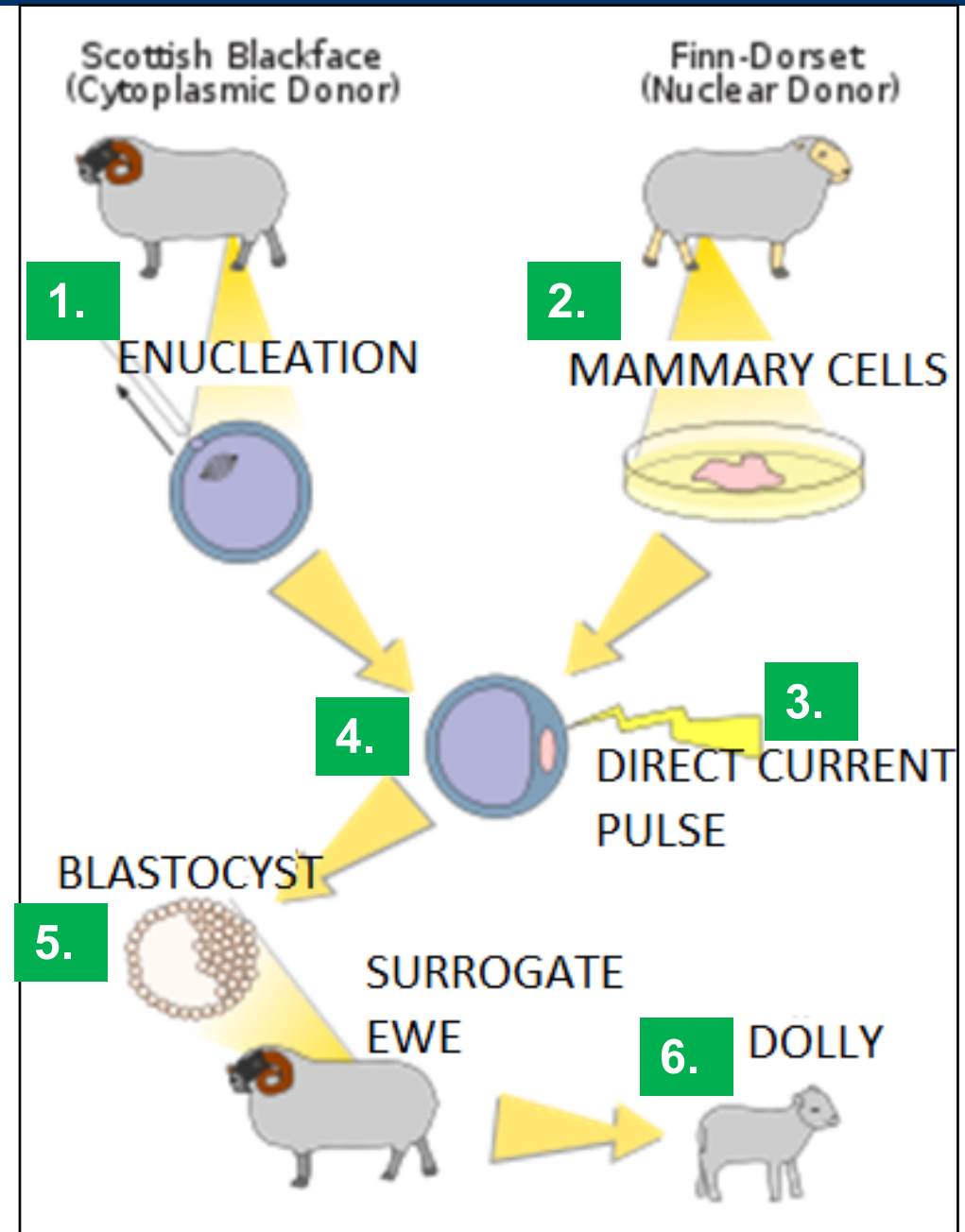
No genetic variation

Genetic variation

Cloning of Sheep

1. **Haploid nucleus removed** from egg cell of surrogate sheep (**enucleated egg**)
2. **Diploid mammary cell nucleus** from animal to be cloned is inserted into **enucleated egg**
3. Electric shock is used to trigger cell division
4. Embryo develops **in vitro** (outside of womb)
5. **Blastula** stage implanted into surrogate
6. Genetically identical sheep are developed

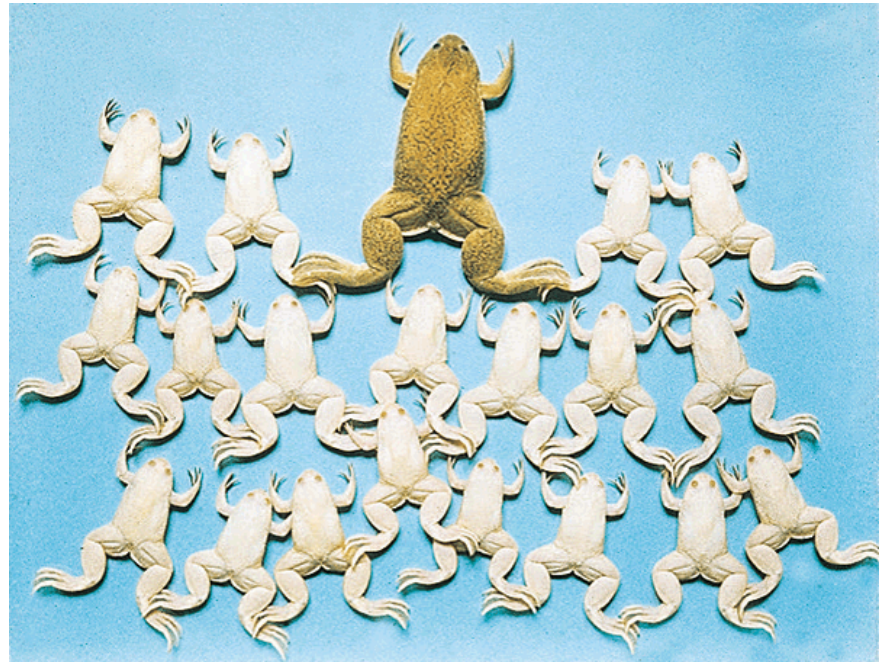
[Clone your own mouse!](#)



Cloning of Dolly and other mammals?



What is cloning? Natural fertilization vs. somatic nucleus transfer.





Identical vs. Fraternal Twins

Twins

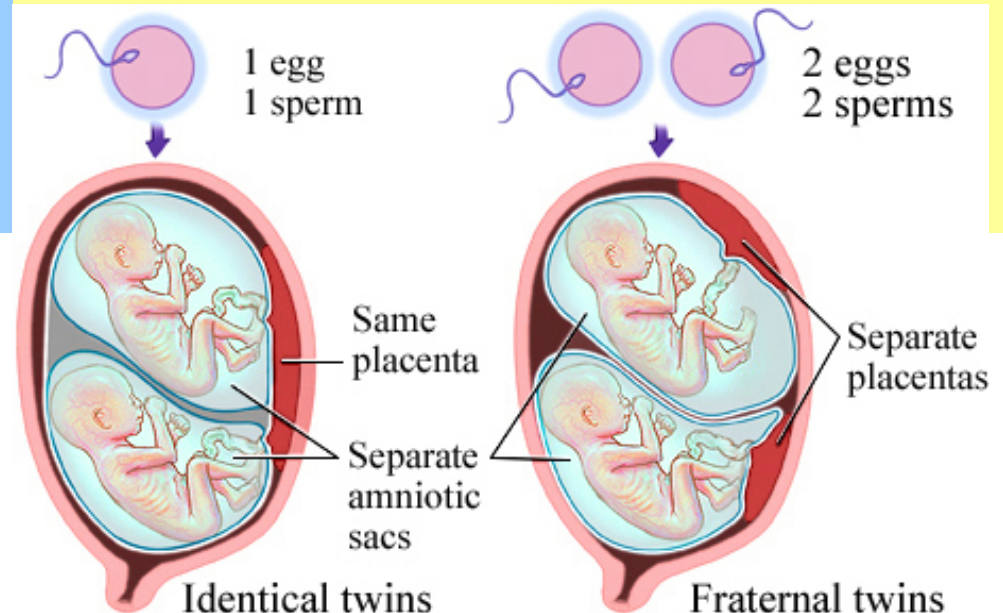
Identical Clones

- 1 egg fertilized by 1 sperm
- During mitosis a single cell breaks free and a second embryo develops
- Same sex, blood type and genetic make up

Fraternal Not clones

- 2 different eggs and 2 different sperm
- Do not have the same genetic make up (genes)
- No more similar than regular siblings but share uterus

Remember: less or more than 46 chromosomes in a cell can lead to major developmental problems or not a viable zygote at all



FYI: Twins

Here's an interesting thought...

If male identical twins produced offspring with female identical twins....

Genetically, the relations of the offspring would be closer to being siblings than being cousins.

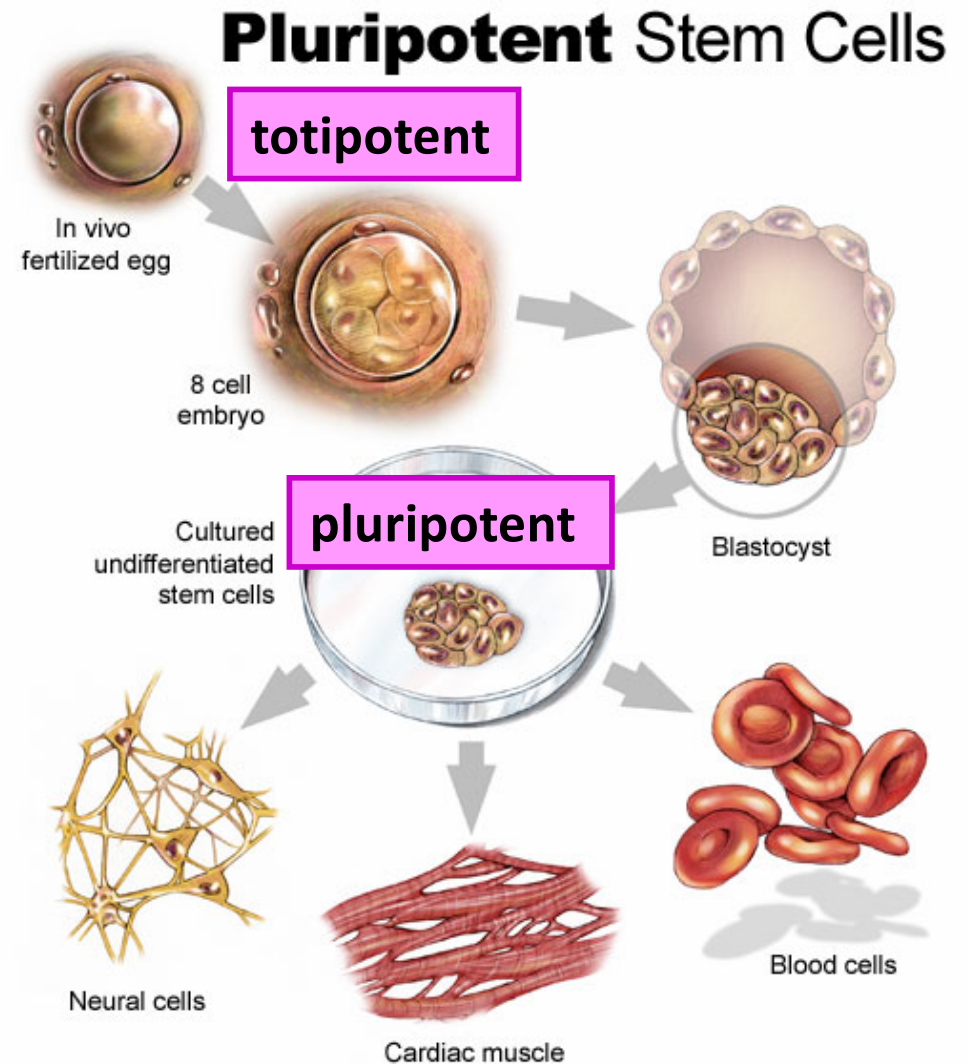
Siblings share about 50% of their genetics while first cousins share about 12.5%



Stem Cell Research

- Stem cells are cells that are capable of replicating and **differentiating** into many **different cells**, such as a skin cell, muscle cell or nerve cell

PLURIPOTENT- cells that can turn into ANY BODY cell

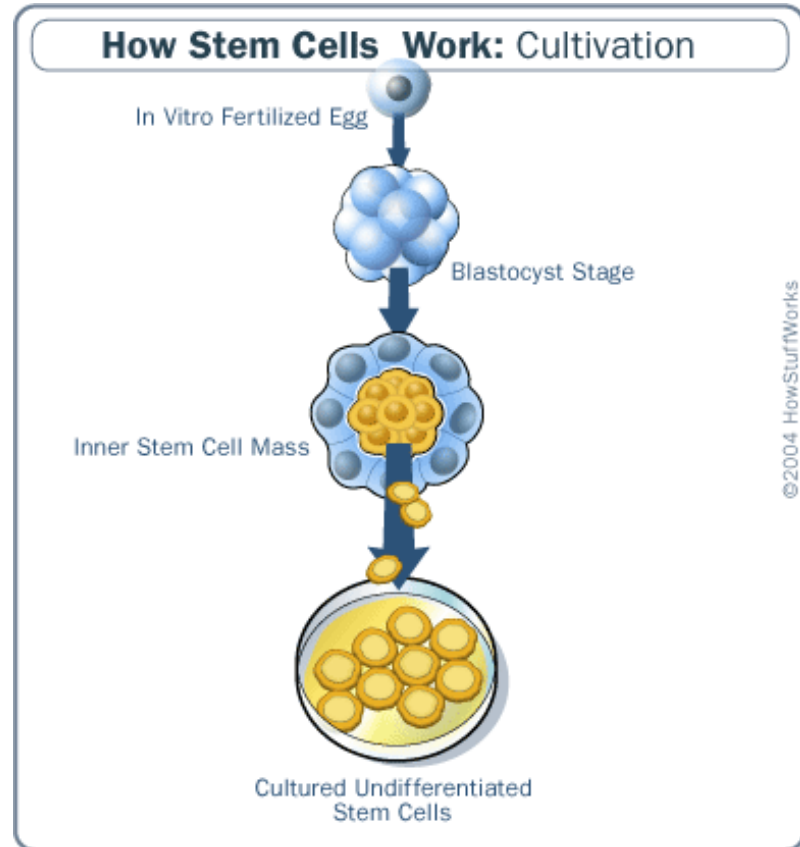


[Stem Cells in Our Bodies](#)

Stem Cells

Stem cells can be derived from:

1. **Embryonic Stem Cells**
(taken from **morula** or **the blastula**)
 - Either **totipotent** or **pluripotent**
(Can become virtually any cell)
2. **Umbilical Cord Stem Cells** (found in blood and tissue)
3. **Adult Stem Cells**



Where do Stem Cell come from? For more information...

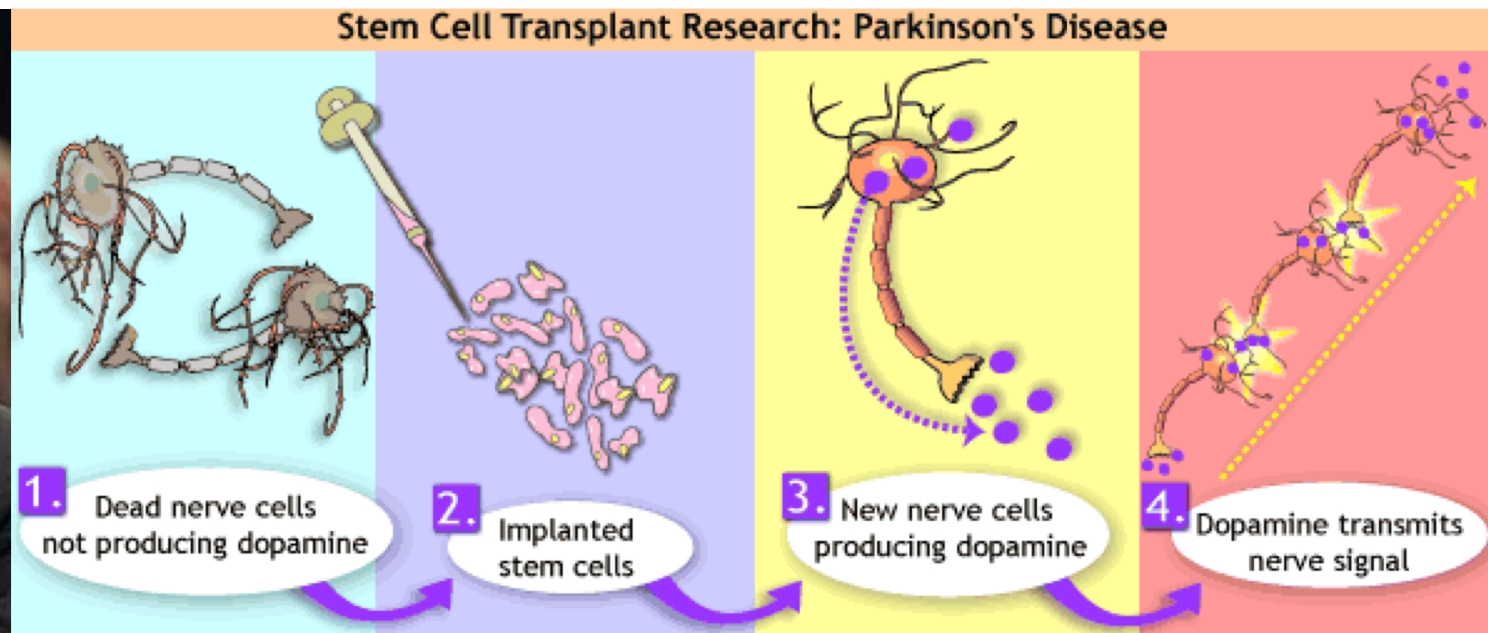
<http://learn.genetics.utah.edu/content/stemcells/>



Stem Cells

- The goal of stem cell research is to **repair damaged tissue**
 - Ex. Parkinson's Disease
 - Stem cells are transplanted in the brain to produce functioning dopamine neurons
 - Bone marrow transplants provide new stem cells for patients battling **leukemia**

[Stem Cell Interactive Growth & Repair](#)

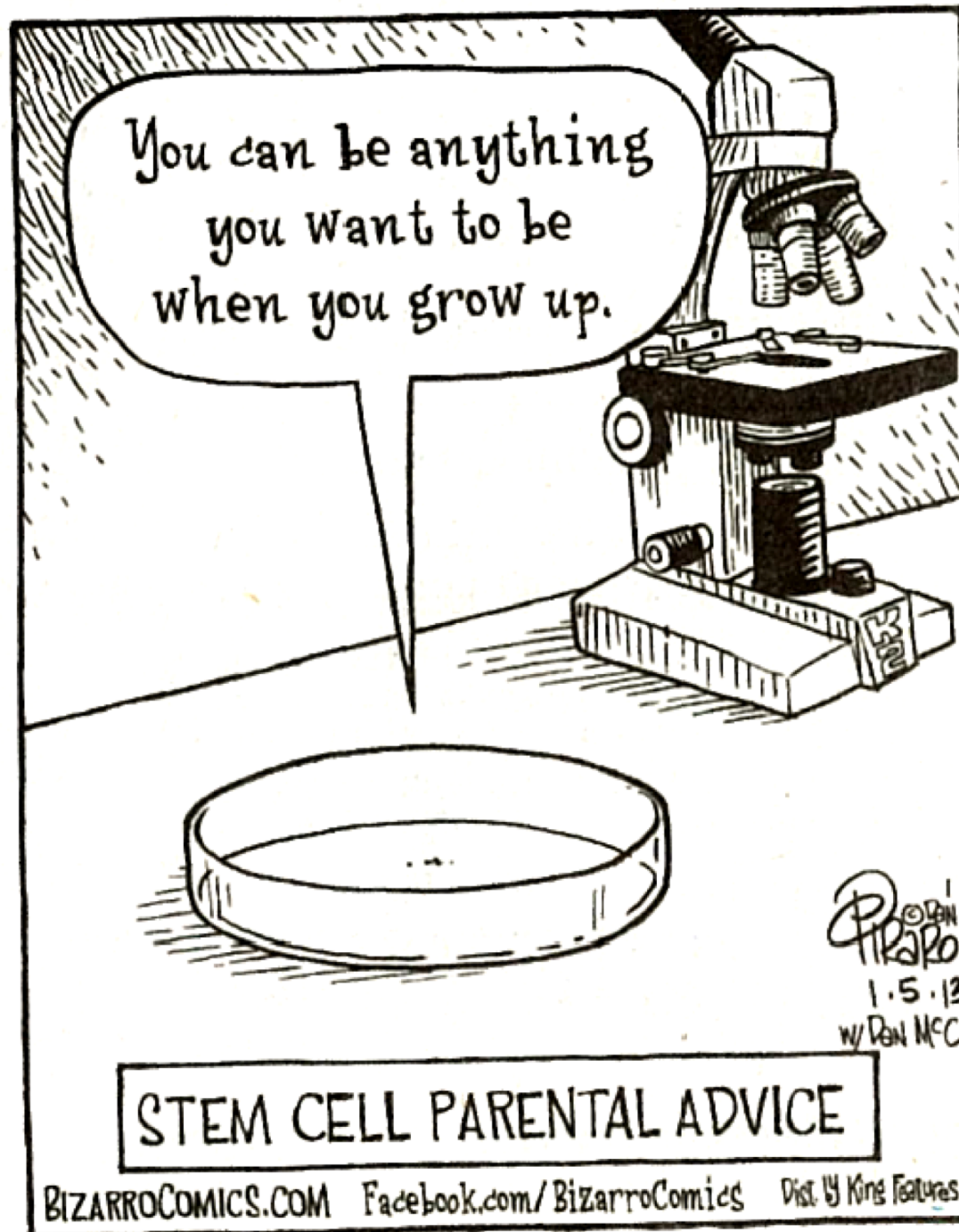


What are some issues in stem cell research?

- Embryonic stem cells
 - How do we obtain stem cells?
- **Cost?**
- Can we use this to clone humans or just to treat disease?



“Went in for a simple blood test and got cloned by mistake.”



LIFE BEGINS
AT THE PETRI
DISH!

EVEN THE HUMAN
EMBRYOS ARE
DIVIDED...

CLONING FOR
RESEARCH!

SCIENTIFIC
RESEARCH



I DIED WAITING FOR
EMBRYONIC STEM CELL
RESEARCH TO FIND A CURE.
WHAT ABOUT YOU?

I WAS THE
EMBRYO

Garry Shandling
THE ANIMATED SERIES
© 2004 CREATOR'S S.A.D.

