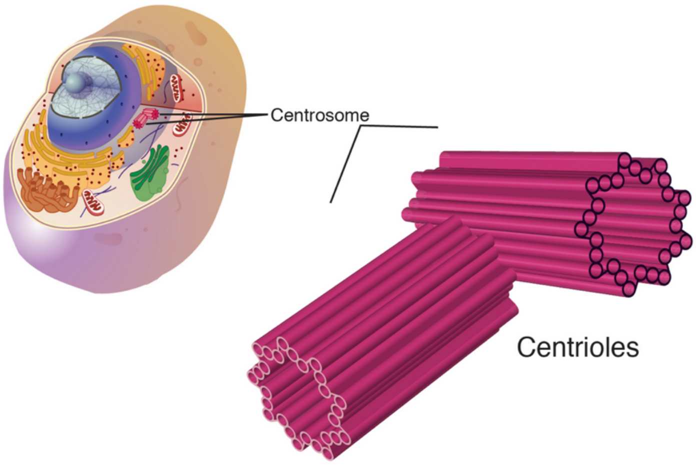
DNA (Note 3: Differentiation, Mitosis, and Meiosis)

A series of Notes that I am writing for my grandchildren many of whom want to go into Medicine. This Note is on Mitosis and Differentiation. The next Note (Note 4) will be on Meiosis.

Glossary

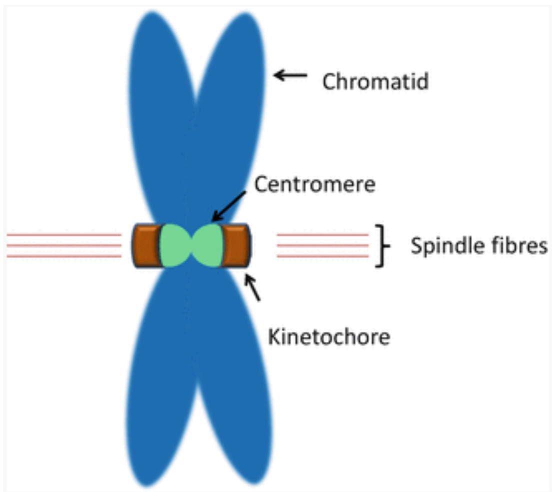
Centriole

Centrioles are tubular-shaped organelles located in each centrosome. The centrioles extend "spindles" to grab hold of the kinetochores that are attached to the centromeres of sister-chromatids (cf. the next diagramme on this page) and, during **Anaphase**, the spindles will pull individual chromatids apart (one sister-chromatid to one end of the cell, and the other sister to the other end of the cell).



Centromere

The centromere **is a sequence (in the DNA of a chromatid-chromosome)** at which a pair of sister-chromatids will become linked during Mitosis. (The centromeres are shown in light blue in the diagramme below).

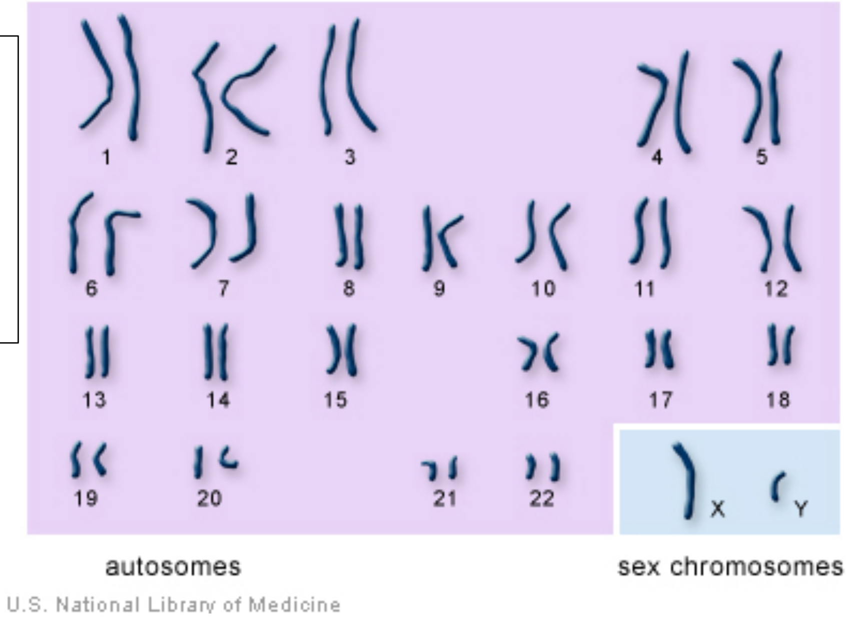


Centrosome

It is the centrosome (an organelle in the cytoplasm of a cell) that contains the two centrioles (the objects that look like red tubes above) that will extend their 'spindles' to attach the spindles to the kinetochores that are attached to the centromeres. (When I teach my grandchildren GCSE Biology, I liken a Centrosome with its Centrioles to an octopus and its tentacles. That gives them something that they can visualise.)

Chromatid When Chromatin fibre condenses into a very compressed format, then it forms a chromatid-chromosome (or **chromatid**). Every chromatid will be from either the individual's mother (maternal chromatid) or from the individual's father (paternal chromatid). The following diagramme shows 23 pairs of homologous chromatids (one maternal and one paternal).

The US NLB has labelled the 23rd set of homologous-chromosomes as "sex" chromosomes. They are **NOT** "***sex***" chromosomes. They do not allow someone to perform well at sexual intercourse. The 23rd set of homologous chromosomes are in fact ***GENDER*** chromatid-chromosomes.



Chromatin Chromatin is a long strand/a long sequence of DNA wrapped twice around histones and compressed into nucleosomes.

Chromosome When biologists talk about "**chromosomes**" they are referring most often to

i) **chromatid-chromosomes**, but they could also be referring to
ii) homologous chromosomes (cf. below)
iii) sister-chromatids (cf. below), or to
iv) X-shaped chromosomes.

(Biologists need to be more rigorous in the terminology that they use.)

Cohesin is a protein complex (a bit like 'glue') that holds together two duplicated chromatids in a pai**r** of X-shaped sister-chromatids. *Cohesin* glues replicated sister chromatids together until they are split apart in Anaphase.

Differentiation is the process by which unspecialised cells become specialised. Differentiation in cells allows a single zygote to grow into different sorts of body/somatic cells such as heart cells/lung cells/kidney cells/etc[1]. whereas it is **Mitosis** that allows one heart cell to grow into 2 heart cells and then into 4, 8, ….. , 2^n heart cells, or else it allows a lung cell to grow into 2^n lung cells, and so on.

DNA **D**eoxyribo**N**ucleic **A**cid is an helical structure of a double backbone made up of (i) a **Phosphate Group** coupled to (ii) a **Ribose sugar molecule**, linked to (iii) one of the four **Nitrogenous bases**: Adenine (A), Thymine (T), Cytosine (C), and Guanine (G). DNA is a crucial substance in all living things (and, even in viruses, either DNA or RNA is involved).

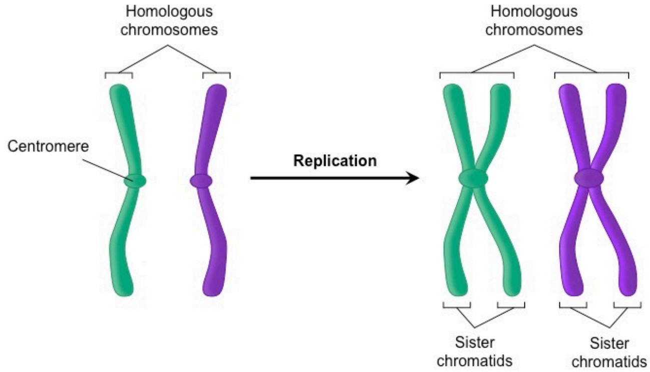
[1] The '**stem cells**' of an embryo are said to be "*pluripotent*" i.e. they can develop into any cell in the body: https://www.yourgenome.org/facts/what-is-a-stem-cell .

Gametes	are a human being's reproductive cells. Female gametes are called ova or **egg cells** (*ovum* is the singular form, and *ova* is the plural), and male gametes are called **sperm cells**. "Sperm" is short for "*spermatozoon*" (the plural for which is "*spermatozoa*").
Homologous Chromosomes	A maternal chromatid and a paternal chromatid together make up a pair of homologous chromatid-chromosomes. There are 23 such pairs of homologous chromosomes in every diploid cell (cf. above).
Kinetochore	A kinetochore is a protein structure that attaches to the centromeres in sister-chromatids. Spindles from Centrioles (located one at each end of the cell) will then attach to the kinetochores and, during **Anaphase**, the spindles will pull apart the Chromatids in the sister-chromatids – one sister to one end of the cell, and the other sister to the other end of the cell. It is because of this that, by the end of **Telophase**, there will be a complete set of 23 pairs of homologous chromatids at one end of the cell and another set of genetically identical 23 pairs of homologous chromatids at the other end of the cell. **THAT** is what Mitosis is all about viz. the growth (or the repair) of tissue and organs by the increase in the number genetically identical cells in the tissue or organ.
Nucleosome	Chromatin fibre wrapped twice around a histone and then compressed into a package of eight of such histones is called a nucleosome. Chromatin fibre in this form is often likened to '*beads-on-a-string*'.

Ploidy

The "Ploidy" of a cell indicates the number of sets of DNA present in a cell. For human beings,
'1n' means that there is one set of 23 (maternal or paternal) chromatids present e.g. as in egg cells and sperm cells.
'2n' means that there are **two** sets of chromatids present (maternal ***and*** paternal): 2 x 23 = 46 chromatids.
'4n' means that there are FOUR sets of chromatids present (2 maternal and 2 paternal): 2 x 46 = 92 chromatids, and '4n' will be the ploidy when replication/duplication has occurred in Mitosis.

Sister-Chromatids	When a Chromatid is replicated, then a genetically identical chromatid will be formed. In the **Prophase** of cell division, the two sisters are joined together by kinetochores at their centromeres.



Source: bioninja

X-shaped Chromosomes	In Mitosis, a pair of **sister-chromatids** i.e. a chromatid (maternal or paternal) and its replicated/duplicated chromatid joined together at their centromeres form an X-shaped chromosome of sister chromatids (cf. above).

All animals start life as a single cell that grows into an adult that then procreates. HOW?

I don't know **why** animals procreate (and Richard Dawkins has attempted to answer that question at the level of 'genes', but not particularly convincingly as far as I am concerned) – but I can tell you **how** animals and plants grow and **how** they procreate.

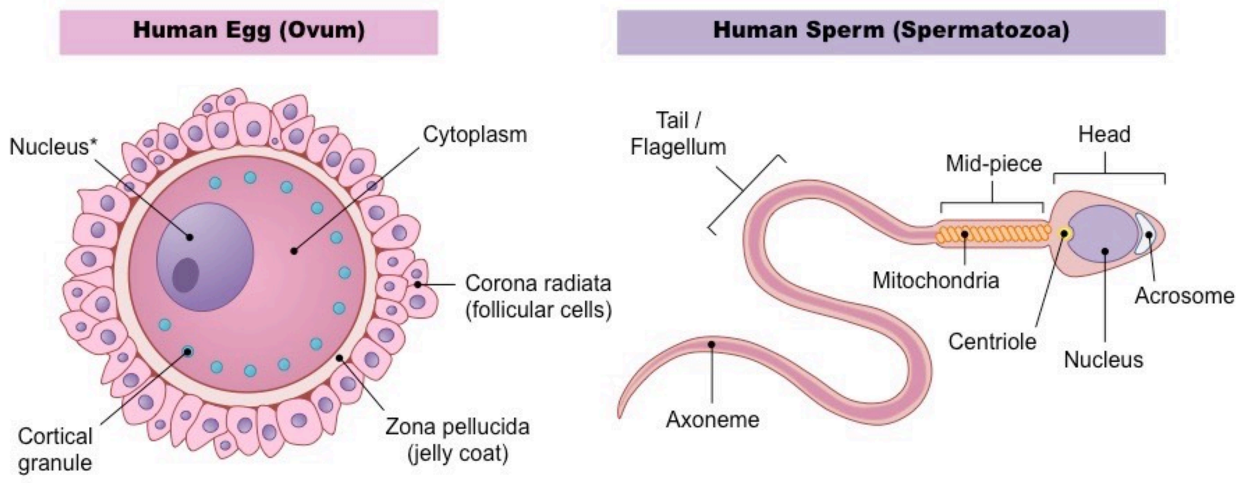
The answer to the question above lies in **Differentiation**, **Mitosis** , and **Meiosis** – but let me start by telling you about the important differences between the Mitosis and Meiosis.

1. Mitosis forms new body/somatic cells, but Meiosis forms new **gametes** from special cells called germ cells or germ line cells. ("**Gametes**" are sperm cells in males and egg cells in females).
2. Mitosis begins and ends with genetically identical diploid[2] cells, but Meiosis begins with a **diploid *germ* cell** and finishes with a **haploid gamete cell. A very *big* difference!**
3. There is only one set of PMAT cell division in Mitosis, but there are **TWO** sets of PMAT phases/two sets of cell division in Meiosis, and
4. There is no genetic variation in Mitosis but there is genetic variation in Meiosis, and this is caused by **the crossing-over** (also called *recombination*)**/the sharing of DNA between maternal and paternal chromatid-chromosomes that takes place in Meiosis.**

Every animal (and here I am going to concentrate exclusively on human beings, but most of what I say for human beings will be true for other animals) starts life as a **zygote** i.e. a female egg cell (an *oocyte*) that has been fertilised by a male sperm cell (a *spermatozoon*). There are therefore two lots of DNA in every somatic/body cell viz. the mother's or maternal DNA, **and** the father's or paternal DNA.

Gametes are a human being's reproductive cells. Female gametes are called ova or **egg cells** (*ovum* is the singular form, and *ova* is the plural), and male gametes are called **sperm cells**. "Sperm" is short for "*spermatozoon*" (the plural for which is "*spermatozoa*").

The diagrammes below are those of a female ovum (or egg cell) and of a male sperm cell. When a male sperm cell impregnates and fertilises a female egg cell, then a **zygote** (a fertilised egg cell) is formed. The **zygote** will travel down the female's fallopian tube and become a **blastocyst**, and then become an **embryo**, and then a **foetus**, and then (nine months after conception) it will come out of the mother's womb/her uterus as a human **baby**. Other animals have longer gestation periods (e.g. elephants) while others have shorter ones (e.g. mice).



Source: https://ib.bioninja.com.au/higher-level/topic-11-animal-physiology/114-sexual-reproduction/egg-and-sperm.html

[2] cf. page 3.

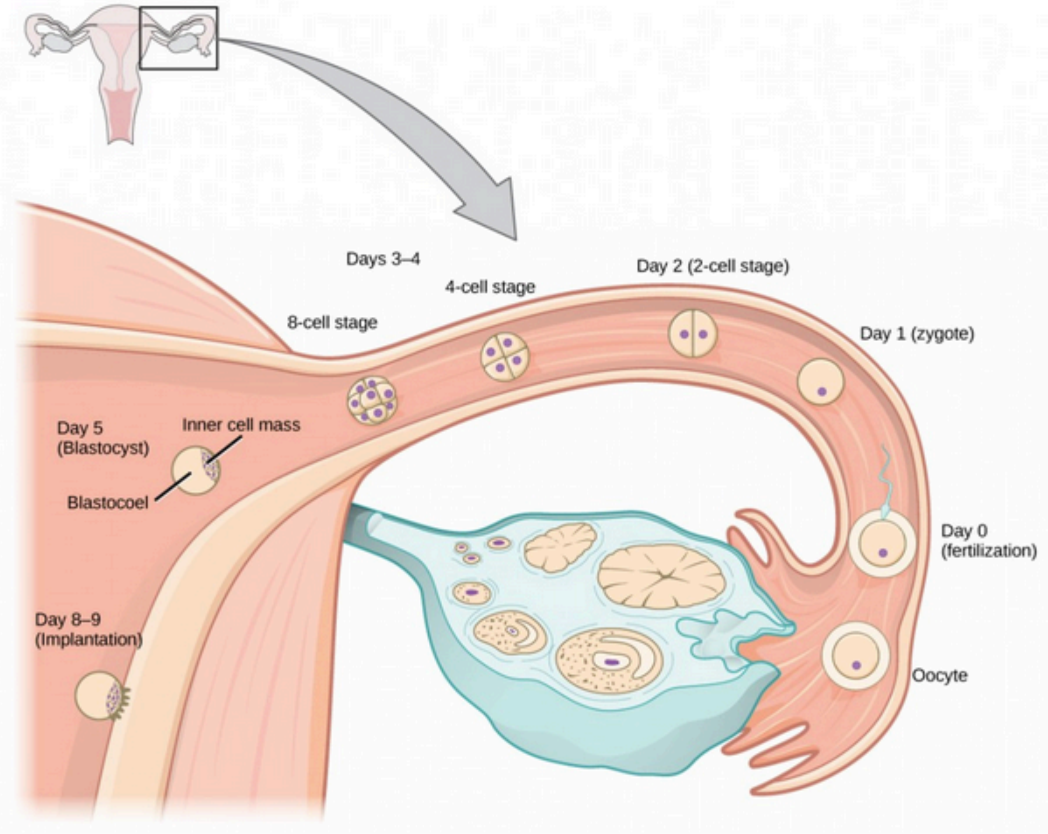


Figure 24.18. In humans, fertilization occurs soon after the oocyte leaves the ovary. Implantation occurs eight or nine days later.(credit: Ed Uthman)

When a female egg cell/a gamete becomes fertilised, it becomes a zygote. It then divides again and again by the process of **MITOSIS** until (by day 5 after fertilisation) it has become a blastocyst. After that, the blastocyst implants itself in the mother's womb/the mother's uterus and keeps growing first into an embryo and then into a foetus. During this period, **DIFFERNTIATION** of the original zygote into specialised cells (such as heart cells/lung cells/ kidney cells/blood cells/ etc) will take place.

When the zygote reaches the mother's uterus, it implants itself in the wall of the uterus.

Do not worry about the term"blastocoel".

Differentiation

A zygote will (normally) travel down the fallopian tube and lodge itself/implant itself in the wall of the mother's uterus/the mother's womb, and there the cells of the blastocyst will differentiate into all the different cells of the organs in the body (i.e. liver cells/brain cells/heart cells/lung cells/…. and so on).

Weekly development of the foetus

The CK-12 Foundation says that During the third week (20+ days) after fertilisation, the embryo begins to undergo **cellular differentiation**. Differentiation is the process by which unspecialised cells become specialised into heart cells/lung cells/liver cells/kidney cells/etc[3]. During differentiation, cells develop unique structures as well as the abilities that suit them for their specialised functions.

One of the most important cells into which a zygote will differentiate is a "germ cell" (also called a "germ line cell"), because it is from germ cells that gametes are formed by the process of **Meiosis**. Gametes do **not** develop from body/somatic cells. **Gametes develop from GERM CELLS**.

[3] The '**stem cells**' of an embryo are said to be "*pluripotent*" i.e. they can develop into any cell in the body: https://www.yourgenome.org/facts/what-is-a-stem-cell .

Mitosis concerns the replication of body (also called 'somatic') cells to allow an individual to repair itself or to enable it to grow bigger. Mitosis will enable a single **zygote** to grow from a single fertilised female egg cell into a 60-kilo (c.130 lbs) female human being (that has two female 'X' chromosomes) or into a 90-kilo (c.200 lbs) male human being (that has an 'X' chromosome and a 'Y' chromosome).

Differentiation in cells allows a single zygote to grow into different sorts of body/somatic cells such as heart cells/lung cells/kidney cells/etc, whereas it is **Mitosis** that allows one heart cell to grow into two heart cells and then into 2^n heart cells, or it allows a lung cell to grow into two lung cells/etc. *In this Note I shall not touch on how **stem** cells can differentiate into many different sorts of cells (heart cells/lung cells/kidney cells/etc).* One of the most important cells that is created by differentiation is a "germ cell" – because it is from germ cells that gametes i.e. female egg cells (or oocytes) and male sperm cells/spermatozoa) are formed. *Gametes are **not** formed from ordinary body/somatic cells.*

Meiosis is about the production of **haploid** gametes. "*Haploid*" means that the cell contains only 23 maternal chromatids or only 23 paternal chromatids). **Haploid** gametes are produced from **DIPLOID** germ cells – where "*diploid*" means that the cell contains **BOTH** 23 maternal chromatids and 23 paternal chromatids.

"**Homologous Chromosomes**" consist of a pair of chromatids (one from the mother of the individual, and the corresponding one from the father of the individual).

For your exams, you must know all this stuff forwards/backwards/upside-down and in your sleep!

MITOSIS is about the **GROWTH**/and the **REPAIR** of body/somatic cells while,
MEIOSIS is about the production of **GAMETES**.

Some scientists consider viruses to be alive, and others do not. (The distinction is *purely* one of definition.) I shall therefore exclude viruses from this Note. However, given the importance of Covid-19 in recent years, a study of viruses (in a separate Note) will be essential.

- All 'life-forms' as we know them on Earth are based on "cells" consisting of organelles enclosed within a phospho-lipid bi-layer cell membrane.
- The most important organelle in a cell may be considered to be the nucleus of the cell, and this is so because it is the nucleus that contains the DeoxyriboNucleic Acid (DNA) of all animals and plants – and it is DNA that makes every individual animal and/or plant into a **unique** individual.
- Every single eukaryote that has ever existed/that currently exists/and that will ever exist, is different from every other one, and it is its DNA that makes every individual genetically different from every other one. However, that is **not** the case with **prokaryotes** such as bacteria/fungi/etc where the "offspring" of a bacterium are all genetically identical to each other i.e. when a bacterium grows and divides into 2 and then into 4 and then into 8/16/32/64/…../2^n bacteria, then all the resulting "offspring" will be genetically *identical* to each other and also to the original "parent" bacterium – and that is exactly the opposite of **eukaryotes** where every individual is genetically unique.
- It is **not** the purpose of this Note to talk about the "Cell Cycle" as such (I will write a separate Note on that). In Notes 3 and 4, I want to concentrate on getting you to understand Differentiation, Mitosis and Meiosis and the mechanics of Genetic (*as opposed to the mechanics of Physical*) Reproduction.
- I will start by explaining the different phases of **IPMAT** where

  I = Interphase
  P = Prophase
  M = Metaphase
  A = Anaphase
  T = Telophase,

  > Technically, it is only **PMAT** that forms part of Mitosis and Meiosis – but it makes sense to talk about all the phases together, because that sets the context for what happens in Mitosis and Meiosis.

  Telophase is followed by **Cytokinesis** i.e. the process where a cell that has replicated its genetic material gets pinched in the middle and then forms into two cells.

The *US National Human Genome Research Institute* depicts Mitosis as follows.

It is in **Interphase** that Chromatin is (and also Centrosomes are) replicated, and the '**condensation**'/the compression of Chromatin into Chromatids starts to happen in Interphase and is then completed in **Prophase**.

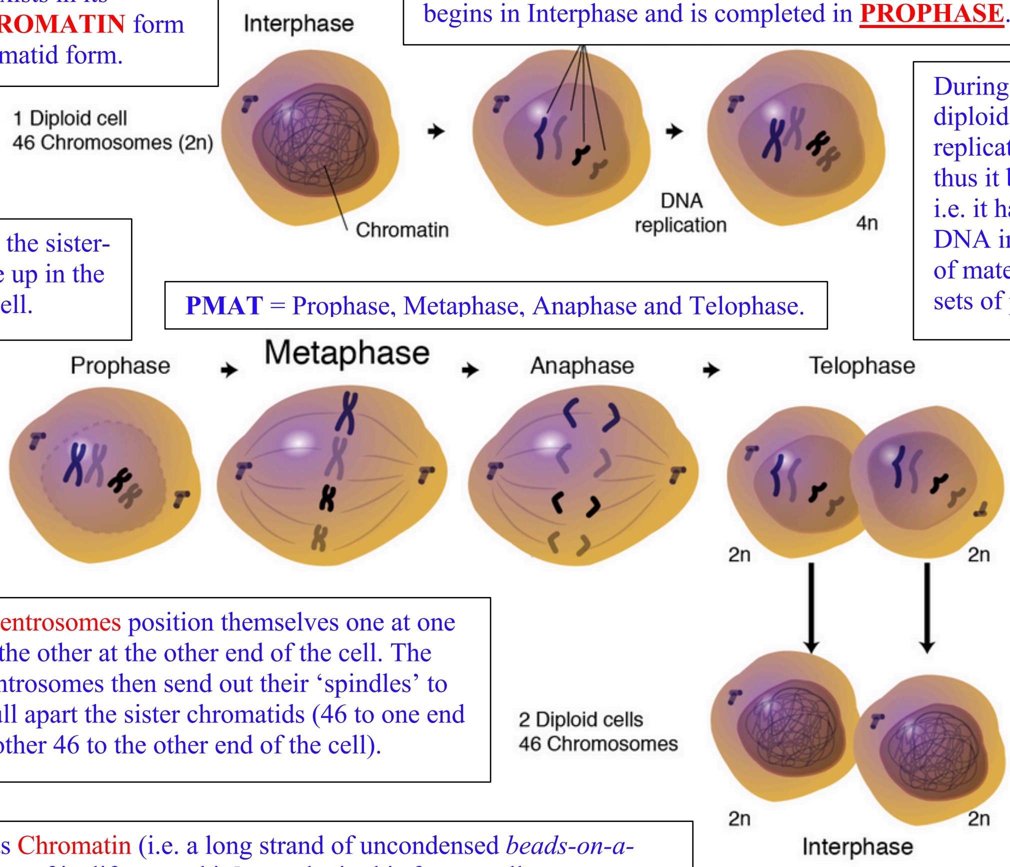
A cell will spend 90% of its life in Interphase, and please note that in Interphase, DNA exists in its **unconcensed CHROMATIN** form and not in its Chromatid form.

The process of the condensation of Chromatin into Chromatids begins in Interphase and is completed in **PROPHASE**.

During Interphase, one diploid (2n) cell will replicate its DNA and thus it becomes '4n' i.e. it has four sets of DNA in it (viz. 2 sets of maternal DNA and 2 sets of paternal DNA).

In **Metaphase**, the sister-chromatids line up in the middle of the cell.

PMAT = Prophase, Metaphase, Anaphase and Telophase.



In Anaphase, two centrosomes position themselves one at one end of the cell and the other at the other end of the cell. The centrioles in the centrosomes then send out their 'spindles' to grab hold of and pull apart the sister chromatids (46 to one end of the cell and the other 46 to the other end of the cell).

The DNA is now back in the form of uncondensed Chromatin.

DNA exists as Chromatin (i.e. a long strand of uncondensed *beads-on-a-string*) for most of its life – and it **has** to be in this form to allow easy access to different stretches of the DNA for processes such as Transcription.

Diagramme: US NHGRI (the comments are mine)

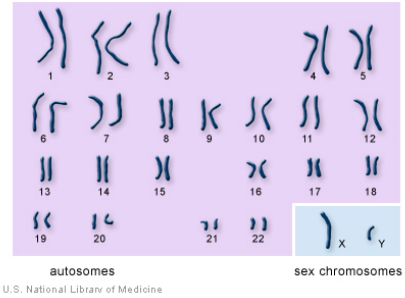
It will be helpful to understand **PMAT** by first explaining the phrase "**sister chromatids**".

DNA exists as Chromatin (i.e. a long strand of uncondensed *beads-on-a-string* DNA) for most of its life – and it has to be in this form to allow easy access to different stretches of the DNA for processes such as Transcription/etc. It is in **Interphase** that Chromatin is duplicated/replicated. The result is that there will then be two sets of 23 maternal (2 x 23 = 46 maternal Chromatids) and two sets of 23 paternal (2 x 23 = 46 paternal) Chromatid-Chromosomes. **At the end of Interphase there will be four sets of Chromatin = 92 (NINETY-TWO) strands of Chromatin in the cell – two sets from the mother and two sets from the father.**

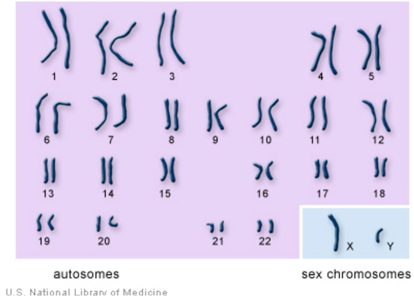
In Interphase, Chromatin starts to condense into Chromatid-Chromosomes, and this condensation will be completed in Prophase.

In **Prophase** the Chromatin is condensed and then becomes visible under a powerful light microscope.

The original set of maternal and paternal Chromatids



The duplicated set of maternal and paternal Chromatids

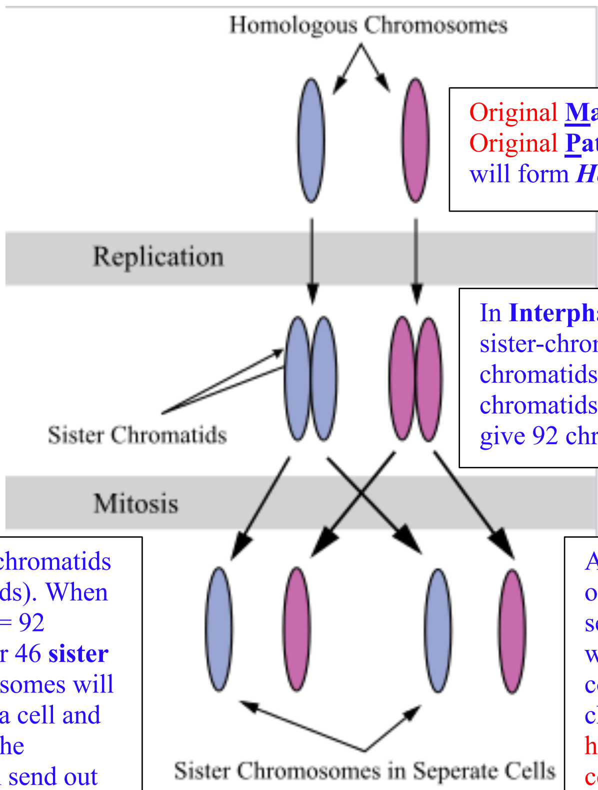


Source: The US National Library of Medicine

After Interphase and Prophase, there will be 92 Chromatids in the cell, but they are **NOT** grouped as above. Instead they are physically grouped in pairs of Sister-Chromatids.

SISTER-CHROMATIDS

The Original Maternal Chromatid 1 will be joined at a centromere to the Duplicated Maternal Chromatid 1
The Original Maternal Chromatid 2 will be joined at centromere to the Duplicated Maternal Chromatid 2
…… and so on for all the 23 Chromatids – and the conjoined Chromatids are now referred to as "**SISTER-CHROMATIDS**".
Paternal chromatids joined in a similar manner also form **sister-chromatids**.



Original **Maternal** Chromatid 1 and
Original **Paternal** Chromatid 1
will form ***Homologous*** Chromatid-Chromosomes.

In **Interphase**, there will be 23 *pairs* of **maternal** sister-chromatids (2 x 23 = 46 maternal chromatids), and 23 pairs of **paternal** sister-chromatids (2 x 23 = 46 paternal chromatids) to give 92 chromatids in total in one cell.

In a normal cell there are 2 x 23 = 46 chromatids (23 maternal and 23 paternal chromatids). When the cell replicates there will be 2 x 46 = 92 chromatids (46 chromatids and another 46 **sister** chromatids). In **Anaphase**, two centrosomes will position themselves one at one end of a cell and the other at the other end of the cell. The centrioles in the centrosomes will then send out their "spindles" to grab hold of one set of 46 Chromatids and pull them to one end of the cell while the other grabs hold of the other set of 46 Chromatids and pulls them to the other end of the cell. The cell then splits into two in **Cytokinesis** and then two ***genetically identical*** cells will have been created.

As we shall see shortly, in the **Anaphase** of Mitosis, the sister-chromatids will be separated, and after **Cytokinesis**, there will be two cells each of which has a complete set of 23 homologous chromosomes and the original cell will have become two genetically identical cells (as in the NLM diagramme at the top of this page).

Source" Wikipedia at https://en.wikipedia.org/wiki/Sister_chromatids
(but the comments are mine)

In a simplified model, the following will occur in **IPMAT**.

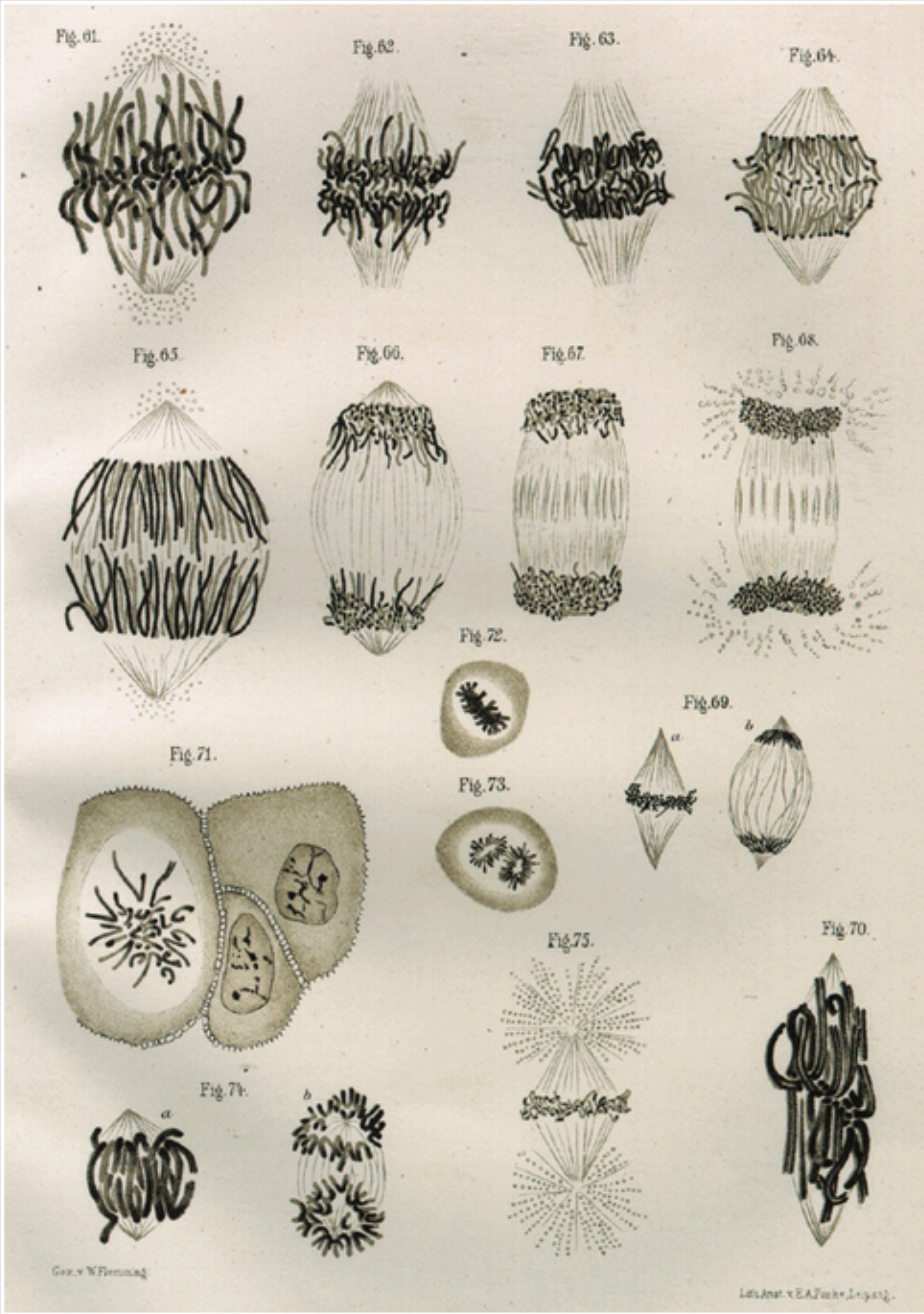
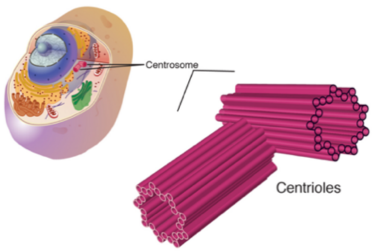


Figure 1: Drawing of chromosomes during mitosis by Walther Flemming, circa 1880
This illustration is one of more than one hundred drawings from Flemming's \"Cell Substance, Nucleus, and Cell Division.\" Flemming repeatedly observed the different forms of chromosomes leading up to and during cytokinesis, the ultimate division of one cell into two during the last stage of mitosis.

This is what happens in the different phases of Mitosis.

Interphase (in which phase a cell spends 90% of its time)

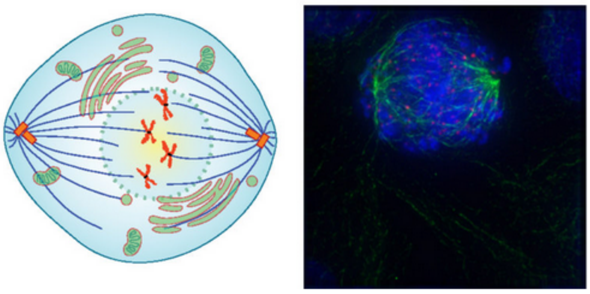
Libretexts (where "*libre*" in Latin means "free") *says that* a cell spends **much** more time (90% of the time) in **Interphase** than in any other phase – and, because Chromatin allows other processes (such as Transcription) to take place, it would be difficult for these to take place if Chromatin were in its condensed Chromatid-Chromosome form. *Nature Education at Scitable says that* during **Interphase**, Chromatin may be *hundreds or even thousands* of times less condensed than it is during Mitosis, and it is during the Synthesis ('S') part of Interphase that genetic material is replicated and duplicated. For the most part, *it is only cells that have successfully copied their DNA that will proceed to Mitosis.* It is during Interphase also that the **centrioles** in a centrosome are duplicated.



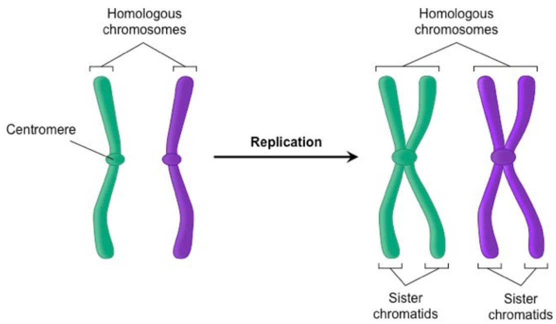
It is the centrioles in the centrosomes that send out the 'spindles' that, in **Anaphase**, grab hold of the appropriate sisters in the sister-chromatids and pull one set of sisters to one end of the cell and the other set to the other end of the cell.

Source: US National Human Genome Research Institute

Prophase (P)



Source: lumenlearning



Source: bioninja

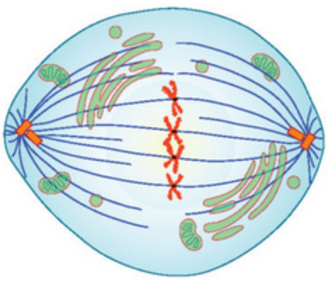
- Chromatin finishes condensing into Chromatids.
- Kinetochores attach to the Centromeres (cf. diagramme on page 1).
- **Sister-chromatids** form.
- Spindles emerge from the **Centrioles** of the Centrosomes.
- The envelope of the *nucleus* disintegrates to enable the spindles to attach to the Chromatids[4].

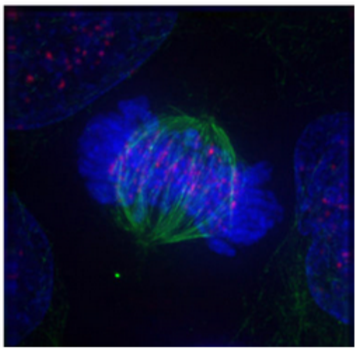
During Prophase the Chromatin in a cell is condensed into chromatid-chromosomes, and *Nature.com says that* because the two **sister-chromatids** are joined at a point called the **centromere**, these sister-chromatids now appear as X-shaped bodies when viewed under a microscope. During Prophase, one centrosome moves to one end of the cell and the other centrosome moves to the other end of the cell, and the centrioles in the centrosomes begin to extend 'spindles' that will attach to the kinetochores of the pairs of sister-chromatids (rather as an octopus would extend its tentacles to grab hold of something).

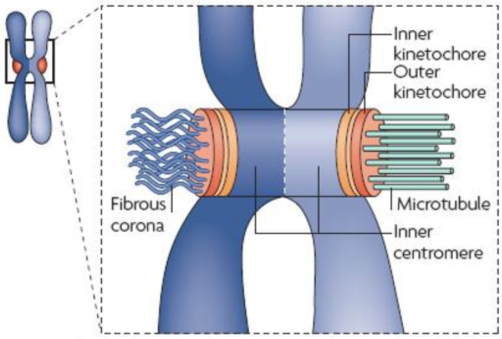
[4] The envelope/the membrane surrounding the **nucleus** is referred to as the "nuclear envelope". DNA always resides inside the *nucleus* of a cell *(it is too precious to be kept anywhere else)*, but the centrosomes are not in the nucleoplasm. The centrosomes are in the *cytoplasm* therefore the envelope surrounding the nucleus must break down so that the spindles that will be thrown out by the centrosomes can attach themselves to the kinetochores at the centromeres of the Sister-Chromatids.

Metaphse (M)

Don't worry about the details of the kinetochores. I want you to know only where they are. The spindles from the centrioles in the centrosomes will attach to the kinetochores to pull apart the sister-chromatids.





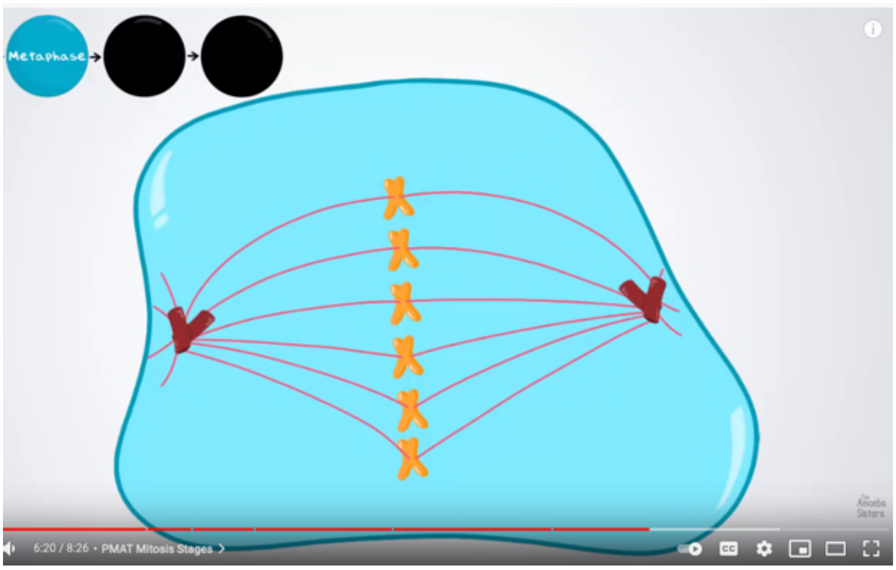


Source: (Cheeseman and Desai, 2008)

- Sister-chromatids line up in the middle of the cell.
- Spindles attach to the kinetochores at the centromeres of the sister-chromatids.

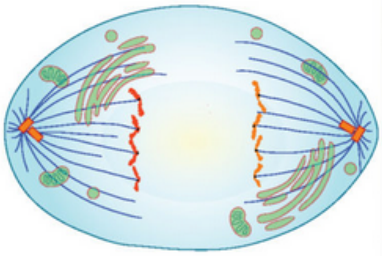
There is a phospho-lipid bi-layer membrane that envelopes the nucleus of a cell, and it is called the '*nuclear envelope*'. There is also a phospho-lipid bi-layer membrane that surrounds the whole cell and that phospho-lipid bi-layer is called the '**cell membrane**' – and the two membranes are **not** the same.

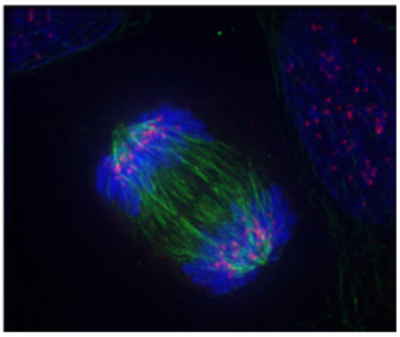
In Metaphase the *nuclear envelope* breaks down/it disintegrates. It is essential for this to happen, because the centrioles are **not** inside the **nucleus** of the cell and could not reach the sister-chromatids in the nucleus if the nuclear envelope did not break down. While this is happening, the X-shaped Chromosomes line up in the middle of the cell with the mitotic spindles attached to them *at the kinetochores at their centromeres* (cf. diagramme from the Amoeba Sisters below), and the cell has self-adjusting mechanisms such that it is only those cells that have correctly attached spindles that will then progress to Anaphase.



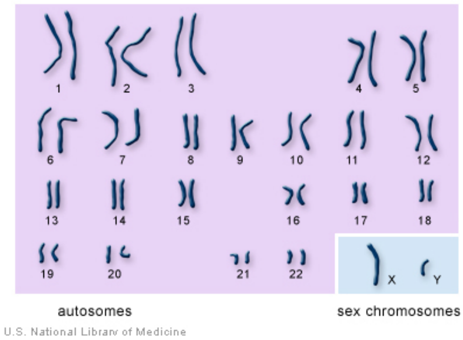
Source: The Amoeba Sisters

Anaphase (A)



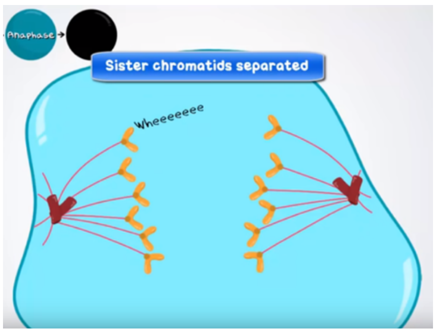


- The 'cohesin' proteins that held the sister-chromatids together now breaks down.
- The spindles then pull the sister-chromatids apart. One sister in each of the sister-chromatids will go to one end of the cell while the other sister will go to the other end of the cell.
- A single body cell started with 46 chromatids (23 maternal and 23 paternal) and there will now be one set of 46 replicated chromatids at one end of the cell and another set of genetically identical 46 chromatids at the other end of the cell.
- There is therefore now a complete set of 46 chromatid-chromosomes (23 **maternal** and 23 **paternal**) at **EACH end** of the cell.



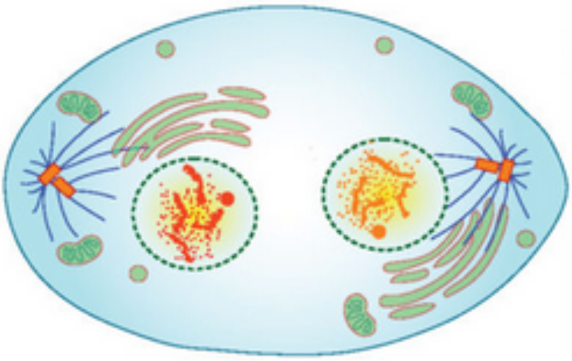
In this diagramme there is just one set of (maternal and paternal) homologous chromatids, and (after Anaphase) at **EACH end** of the cell there will be two complete sets of 23 maternal chromatids and 23 paternal chromatids making 46 chromatids in all.

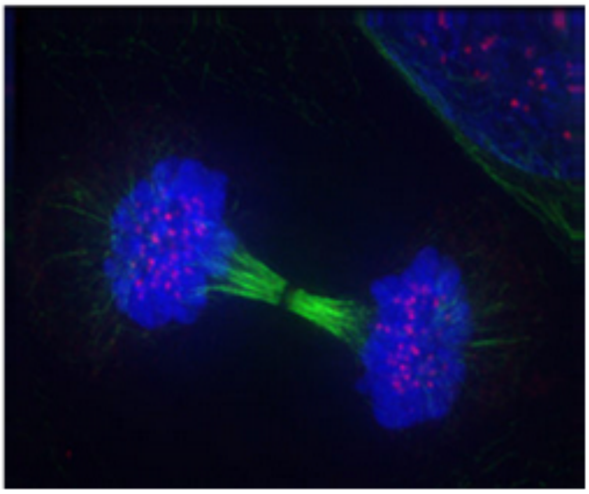
In Anaphase, the spindles of the centrioles will pull on the kinetochores and
- tear one Chromatid in a pair of sister-chromatids apart from the other Chromatid. This happens to all the 46 **pairs** of sister-chromatids thus giving 92 separate Chromatids. The technical reason as to how the 46 pairs of sister-chromatids are torn apart into 92 separate Chromatids has to do with the different protein structures and enzymes that have been engaged in the process of Mitosis – but I am not going to discuss here substances such as cohesin/separase/etc.
- The 92 separated **Chromatids** are pulled 46 to one end of the cell and 46 to the other end of the cell. **At EACH end of the cell** there will now be a complete set of **23 paired Chromatids** (with one maternal Chromatid and one paternal Chromatid in each pair) – and it is in Telophase and Cytokinesis that the cell will split into two cells, each of which is genetically identical to the cell and genetically identical to the original cell.



Source: The Amoeba Sisters

Telophase

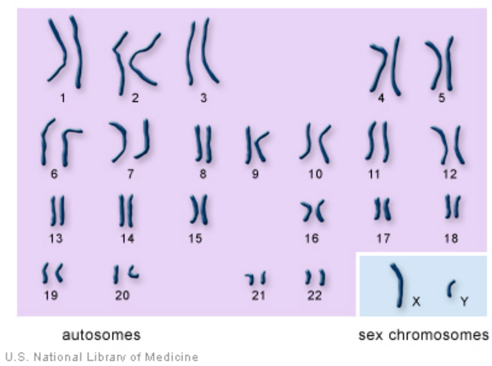




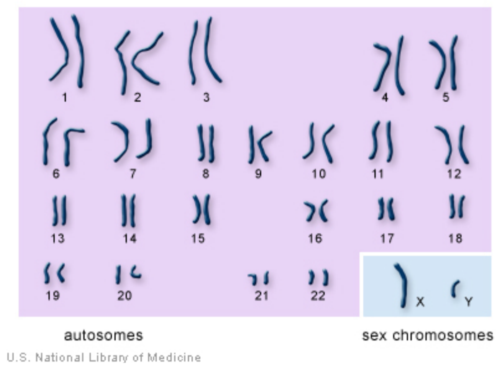
- The nuclear envelope reforms around each set of 46 chromatids (23 maternal and 23 paternal). This **must** happen because DNA is so precious that it has to be protected by its own nuclear envelope at all times. DNA always resides in the nucleoplasm, and the nucleoplasm resides inside the cytoplasm.
- The spindles have served their purpose and they are no longer needed therefore they break down.

In Telophase, a nuclear envelope will now form around a complete set of **23 paired Chromatids** (one maternal Chromatid and one paternal Chromatid in each pair) one at each end of the cell – and when that has happened the cell will be ready to be pinched/split into two separate but genetically identical cells each with its own nucleus/organelles/and cytoplasm , and we now have the following as two separate cells.

The **original** set of 23 pairs of Chromatids

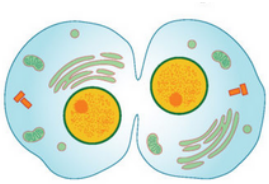
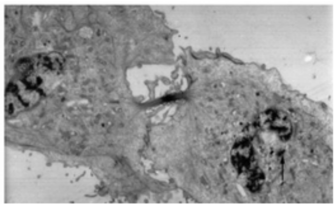


The **duplicated** set of 23 pairs of Chromatids



Source: The US National Library of Medicine

Cytokinesis

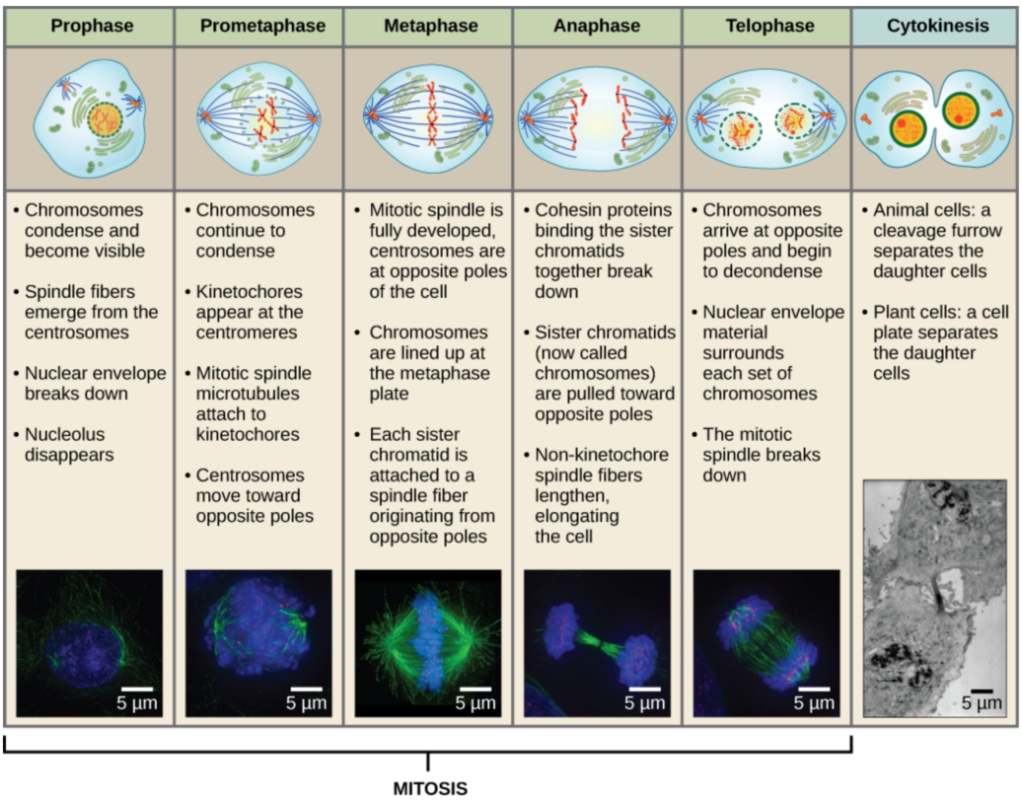
- Now that the cell has duplicated itself, it splits into two separate cells – and one cell has thus now become two genetically identical cells.
- In a *subsequent* mitotic cell replication/duplication, each cell will split again, and then there will be 4 genetically identical cells. 1 cell became 2 / 2 become 4 / 4 will become 8 / then 16, 32, 64, 128, .., 2^n – and a 3.5 kg baby will become a 70 kg adult and it will have all happened through the process of **MITOSIS**!

Since the 23 pairs of Chromatids have been replicated and duplicated,
then each set of 23 pairs must be **genetically identical** to the other set.

The end process by which the duplicated cell splits into two cells is called **Cytokinesis** and it is not considered to be a part of Mitosis.

The purpose of, and the result of Mitosis is to replicat/duplicate a cell into two genetically identical cells.

The different phases of the Cell Cycle in Mitosis can be summed up in the mnemonic PMAT
(You do not need this much detail at GCSE Level – but you would need it at 'A' Level and you would most certainly need it if you want to get into Med School.)



All animals and plants are genetically different from each other, and they are so because each animal and each plant has a different and a ***unique*** set of genes.

I do hope that you can see how I am gradually building up a picture of how Inheritance takes place.

Inheritance is about DNA – and I am gradually taking you through the mechanics of **Inheritance**. Were I to put it all into one Note, then you might find it difficult to assimilate it all in one go. I hope that by splitting it into the different aspects of DNA, it will thereby be easier for you to take it all in.

The next DNA Note (Note 4) will be on **Meiosis**.