

## Meiosis

The main reason we have meiosis is for sexual reproduction. It mixes up our genes (more on that later). But before we start to investigate this, let's talk a bit about reproduction in general:

### I. Reproduction (overview)

Two main types of reproduction:

Sexual - in this case (let's not worry about the definitions yet), chromosomes from two parents are passed on to the offspring.

Asexual - in this case, chromosomes come from a single parent.

An example might be a dividing amoeba (e.g. in your text)

Each “new” amoeba has exactly the same chromosomes that the original “adult” amoeba had.

This is not restricted to single celled organisms. Some animals as complicated as lizards will reproduce asexually (though in lizards, it gets complicated).

Sponges, jellyfish, various worms, starfish, can all reproduce asexually.

As you might guess, this usually involves some form of mitosis.

The text makes the point that you are not exact copies of your parents.

You may have features that make you look like your father or mother, but you're not an exact copy.

Humans reproduce sexually, and because of this, the chromosomes you get, are a mixture of information from both parents. You share traits of both your parents.

Your kids will have some of your traits, and some of those of your spouse.

Any siblings you have may look like you a bit, but won't be identical because they'll have inherited slightly different information (on chromosomes) from your parents.

(unless you have an identical twin).

Before we figure a lot of this out, we need to understand how an individual cell divides.

## Meiosis

Briefly, what meiosis does is to divide a single cell into four cells. Each daughter cell (four) will have half the number of chromosomes we started with.

There are two main steps - a first phase in which we divide the number of chromosomes in half.

A second phase in which we split the remaining chromosomes (this phase is virtually identical to Mitosis).

#### I. More terminology and background:

Chromosomes are arranged in pairs, called homologous chromosomes.

Each chromosome in a homologous pair carries genes that control the same thing [**OVERHEAD, fig. 8.11, p. 136**].

Important - although they control the same thing, the actual information may be different:

A chromosome may have a locus (“location”) that has a gene that codes for eye color.

The homologous chromosome will also have a gene at the same locus that codes for eye color.

**BUT**, the gene on one chromosome may say “blue eyes”, while the gene on the other chromosome may say “yellow eyes”

(This is an example, in reality, eye color is often more complicated than this).

Incidentally, different versions of genes that code for the same thing are also called “alleles”. We’ll do much more with this later.

In a normal body cell (a somatic cell) humans have 46 chromosomes.

These are arranged into 23 homologous pairs.

22 are “autosomes” - do not control the sex of an individual

1 pair are the “sex chromosomes” - control the sex of an individual

(Not all animals control sex with chromosomes)

Our gametes (egg or sperm) will have only one member of each homologous pair [**OVERHEAD, fig. 8.12A, p. 137**].

During fertilization, these come together and make a new individual, now with a complete set of chromosomes (everything is paired up again)

Cells with only half the number of chromosomes (one of each pair) are “haploid”.

Cells with chromosomes in pairs are called “diploid”.

Adult humans are diploid. Sperm and egg cells are haploid. They come together to make a new diploid individual.

Our diploid number (abbreviated  $2n$ ) is  $2n = 46$ .

Our haploid number is  $n = 23$ .

Thus, our gametes are all  $n = 23$ , and are haploid.

All life cycles that involve sexual reproduction have alternation of haploid and diploid stages. This is particularly pronounced in some plants (e.g. mosses are mostly haploid).

Meiosis is used to produce gametes.

## II. The process of meiosis

For meiosis, the phases are similar to mitosis, but they're described as I or II, depending on which cell division we're going through (we need two cell divisions to get to four cells total).

We use the terms “Meiosis I” and “Meiosis II” to refer to these.

### **[OVERHEAD, fig. 8.13, p. 138 - 139]**

Starts almost the same way as mitosis, with an interphase.

Chromosomes are not visible, but have been duplicated (they're chromatin)

#### Prophase I

Chromatin coils up, and chromosomes become visible

Homologous chromosomes come together and form tetrads. (each chromosome has two chromatids)

Nucleus disappears

Centrosomes begin to move to opposite ends of the cell & spindle starts to form

Crossing over can occur here

Parts of chromosomes (from homologous pairs) will exchange genetic information. This helps scramble genetic information. We'll describe this better shortly.

## Metaphase I

Tetrads line up along the midline of the cell, between the centrosomes.

The microtubules from each of the centrosomes attach to each member of a pair.

## Anaphase I

Chromosomes begin to move to opposite ends of the cell.

***Pairs separate!*** It is not the chromatids that separate, but each member of a pair of homologous chromosomes.

One member of each pair moves to opposite ends of a cell.

## Telophase I

Cytokinesis usually starts, and the cell physically divides in two.

Sometimes, the nucleus reforms and there is a short interphase, but usually, cell division continues.

Each of these cells is now “haploid”. Each has half the number of chromosomes, and half the genetic information that we started with.

## Meiosis II

Is virtually identical to Mitosis. Sister chromatids separate, move to opposite ends of the cell, the cell divides.

End result:

Four daughter cells, each now haploid (with a single set of chromosomes).

**[OVERHEAD, fig. 8.15, p. 140]** Quick review and comparison of mitosis and meiosis.

### III. Factors affecting meiosis, and some of the results of meiosis

Meiosis scrambles the information coming from the parent cell.

during metaphase I, chromosomes can line up differently **[OVERHEAD, fig. 8.15, p. 141]**.

Figure demonstrates that with just two chromosomes we can get four ( $2^n = 4$ ) different arrangements (four different gametes).

Big blue might go with little blue, or big blue might go with little orange.

In humans, we have 46 chromosomes. So we have:

$$2^{23} = 8,388,608 \text{ possible combinations}$$

When we produce gametes, we have 8,388,608 different possible ways to sort our chromosomes into the gametes.

Of course, this is true for both men and women, so when fertilization takes place, we get:

$8,388,608 \times 8,388,608 = 70,368,744,177,664$  different possibilities for each offspring.

No wonder brothers and sisters are different!

And, as the book points out, there is still more variation.

(One of the main reasons organisms use sexual reproduction is to provide variation!)

Review: homologous chromosomes can carry different versions of genes

They can also be the same version!!

**[OVERHEAD, fig. 8.16A, p. 142]**

Each chromosome carries more than one gene:

Suppose we have a gene for coat color and eye color on the same gene.

There may be different versions of these genes (alleles) on these homologous chromosomes.

Suppose we have the set up as in the figure (one tetrad).

Meiosis will yield four cells, each with a single chromosome.

Two cells would have a chromosome with alleles for Brown coat and black eyes

Two cells would have a chromosome with alleles for white coat and pink eyes.

Normally, black coat would stick with black eyes, and white coat would stick with pink eyes.

By using *crossing over*, we can mix up this information.

During crossing over, one chromatid in each of the homologous pairs breaks, and the broken piece is re-attached to the opposite chromatid.

**[OVERHEAD, fig. 1.17B, p. 143]**

Now our cell can actually produce four different cells, because there is no longer a guarantee that black coat goes with black eyes or vice versa.

This increases genetic variation beyond that due to random line up in metaphase I (often called independent assortment (sometimes “random” assortment)).

When chromosomes increase variation in this way, we term it genetic recombination (genes are arranged in a way they couldn't be otherwise, they are recombined).

The site of crossing over is often termed a *chiasma*

## Karyotyping

Some genetic defects can be traced an incorrect number of chromosomes. This condition can easily be determined from a karyotype.

**[OVERHEAD, fig. 8.19, p. 144]**

Essentially a blue print of your chromosomes (incidentally, this is not directly related to such things as DNA fingerprinting).

Take blood --> add chemical that induces mitosis --> add chemical that stops mitosis at metaphase I --> get rid of red blood cells --> take chromosomes from white blood cells, photograph, & sort.

Some genetic defects are easy to determine: Down's syndrome is due to an extra copy of chromosome 21 (have three instead of a pair).

Down's syndrome usually causes some mental retardation, and shortened lifespan. Most people with Down's are also sterile. Facial features are also usually distinctive. (Book lists some more symptoms).

Risk of Down's increases with age of the mother

**[OVERHEAD, similar to fig. 8.19A & B, p. 145]**

## Mistakes in meiosis

How can these errors arise?

Non-disjunction: essentially, in one of the steps of meiosis I or II, chromosomes fail to separate the way they should.

**[OVERHEAD, fig. 8.21A & B, p. 146 & one figure not in text]**

When a sperm or egg cell that has been affected by non-disjunction joins up to form a zygote (zygote = “fertilized egg”), the resulting individual may not have the correct number of chromosomes.

Other examples include an incorrect number of sex chromosomes.

**[Table 8.21, p. 147]**

All individuals are usually of normal intelligence, though XO and XXY individuals will show visible signs.

**[OVERHEAD, not in text]**

XXX and XYY individuals are completely normal - only a karyotype will show that they have an extra chromosome.

Other defects in chromosome structure **[OVERHEAD, fig. 8.23A, & B, p. 148]**

Breakages can lead to deletions, duplications, inversions.

Inversions are usually okay, but the others can cause serious problems (in an inversion, all genes are usually still there in the normal number).

Translocations - exchanging information with a non-homologous chromosome.

May or may not be harmful

So far we've been talking about defects in the sex chromosomes. But some defects (e.g. translocations) may also happen in the somatic cells (i.e. during mitosis)

The example shows how this might activate a cancer causing gene.

Cancer can often be traced to changes in the somatic chromosomes (therefore many cancers are not inherited).