QA Cell Cycle & Division

Sona Singh

Popularly confused Questions

Cell Cycle and Division, Grade IX, CBSE

1. Deoxyribonucleotides, DNA, Chromatin, Chromosome, Chromatids, genes; Yikes!!

Solution: Information for any organism is encoded in molecules called Deoxyribonucleotides. Deoxyribonucleotides are joined end to end to form long chains called Deoxyribonucleic Acid (**DNA)**. Every characteristic, say skin colour, might be attributed to protein(s), directly or indirectly. These proteins are read off from messenger Ribonucleic Acid, which in turn is produced from DNA. Now you can imagine, there are numerous proteins in our body, hence there must be huge length of DNA. But instead of having one single huge DNA thread there are more than one, the number being fixed for DIFFERENT species (atleast for those individuals that are normal. If the number changes, we will show abnormal symptoms). Now the length is huge, for humans it is so long that an individual's DNA can be wrapped around equator 2.5 million times. To contain all this in a cell which is of the order micrometers the DNA thread must have some sort of condensed arrangement. The DNA thread is complexed with proteins which helps them condense. This strand of DNA together with proteins is called chromatin. Chromatin condenses on itself. Imagine it like a thread wound around. This condensation gives rise to distinctly visibly identifiable structure called chromosome. Now since number of DNA strands is specific for individual species, so will be the number of chromosomes. Shortly before division, DNA undergoes replication, a process of creating a copy. This copy and the original, are visible as two arms, called chromatids, joined at a point called the centromere.

Gene, is a stretch of DNA that codes for a polypeptide. As a chromosome is a very long thread of DNA, it may contain numerous such stretches.

While gene is then a functional structure, others are structural builds at various stages of cell observed at different scales of formation.

2. n, 2n, 2C !!! How are these related?

Answer: Genetic Material in cells, DNA (Deoxyribonucleic Acid), is composed of units (Deoxyribonucleotides) joined end to end like a thread. Imagine it as a string of currency notes. These threads are called chromosomes. Now there are more than one such threads. But in most organism, they are present in duplicates, like AA', BB', CC', DD' and so on; one copy from each parent. The two copies have small changes, since they are from two individuals, but they affect the same characters. Now if there are a total of 8 strings(chromosomes) but only 4 unique types. So 4 is n, number of unique such strings, and 2n is the total number of such strings, which equals 8 in this case.

Now, you need to know the total value of money you have in form of currency threads, now obviously you might have more than one 10 Rs note, say 2 notes, together they make 20 right. This total amount of DNA is expressed as multiple of two i.e 2C, It is similar to shoes. You always count shoes in pairs, even though there are two individual pieces, right!

So we represent chromosome number (2n) and content (2C) as multiples of two, just to give an idea that they are present as two copies, one from each parent.

3. Okay gotcha but how do they change, why do they change, before division? What does 2C goes to 4C, ?

Answer: Cell has got to make its copy. It must divide to produce new cells to accommodate for cell death. But, if you are going to have two flats, you must arrange- buy furniture twice the normal quantity. SO, the cell first copies its DNA, by a process called replication. 2C REPLICATES to give 4C amount of DNA. Now this DNA is present in form of long fine threads, chromatin, thin enough to be invisible to naked eye forming together the chromatin network. So there is actually no sense talking about number of chromosomes, because you can't quite count them, they are there. The chromatin, the threads have replicated, had been made into a copy, and the two copies remain attached at a point called centromere. This is only visible when the chromatin threads condense, shorten and become chromosomes, during the cell division.

Now remember we had 2n chromosomes- AA', BB', CC' and so on. A duplicated to **A.** A' replicated to **A';** B replicated to **B** and B' replicated to **B'.** So A**A** *are the two chromatids joined at centromere;* A'**A'** *are two chromatids joined at centromere and so on.* This process of replication however did not increase the chromosome number from 2n to 4n because the replicated segment is attached as another arm, which we call chromatid, Hence the chromosome number stays 2n

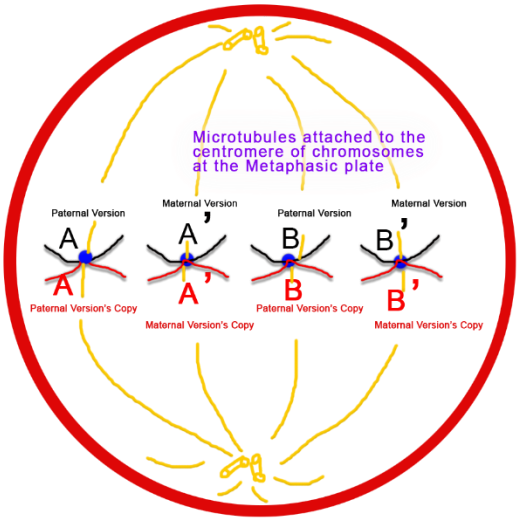
Now the cell is ready to divide mitotically or meiotically depending on the type of cell.

2n corresponds to 2C; Amount increases before division depending on the need

4. How the course of 2C changes during mitosis?

Answer: Once 2C becomes 4C, the cell is ready to divide. Now it may divide, mitotically or meiotically. Mitosis is very much like your parents giving equal pocket money to both you and your sister. Hence a cell divides into two cells, each receiving equal amount of DNA. The duplicated chromatin, present as chromosome, each containing two chromatids (copies), hence called sister chromatids are aligned at equator. All chromosomes will follow this, both paternal and maternal: A**A,** A'**A'**, B**B,** B'**B'**, C**C,** C'**C'**, D**D,** D'**D'.** The Regular letters in black represent the original chromatids while the letters in red bold represents the products of replication attached at centromeres Nuclear membrane dissolves. Microtubules attach to the centromere, via recruited protein complex called Kinetochore. They start contracting, pulling the chromatids of a chromosome away in the process.

Remember that chromatids are identical because they are the products of replication. The two chromatids in a chromosome are called "sister chromatids" but that is a misnomer, they are more alike than sisters, they are clones i.e. exact copies.

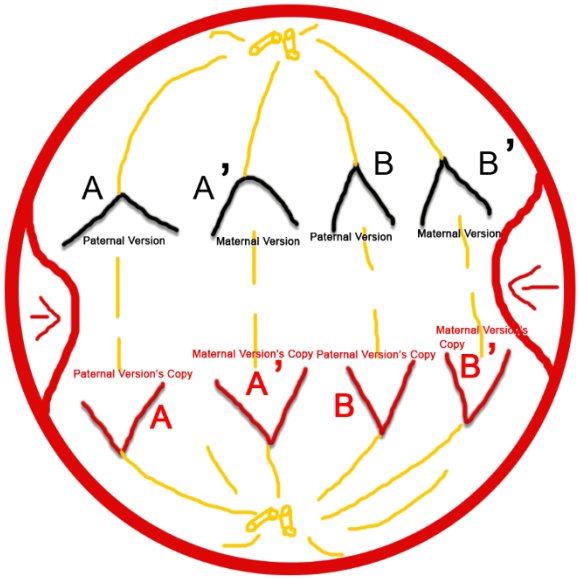


The cell also starts to divide externally, via development of a wedge or formation of plate. At the end each of the two cells receive one of the chromatids from the chromosome. Hence one cell will have A,B,C,D as the paternal copy and A',B',C',D' as the maternal copy; the other may have **A,B,C,D** as the paternal copy and **A',B',C',D'** as the maternal copy. Since A=**A,** B=**B**, C=**C,** D=**D;** A'=**A',** B'=**B'**, C'=**C',** D'=**D'** we get 2 daughter cells with same genetic constitution. Now obviously I have represented it too simply here, all initial

chromosomes from Father and mother A,A',B,B',C,C',D,D' remained together and all replicated chromosomes **AA'BB'CC'DD'** remained together but it doesn't have to in real cell divisions. But the thing is, it makes no difference because they are exact copies. **The information must duplicate and hence the amount of DNA must duplicate to ensure equal distribution to daughter cells**

5. Does 2n also goes to 4n?

Chromosome is the condensed chromatin. Yes, the DNA replication adds chromatids, so there are 4n chromatids but only 2n chromosomes because the chromatids are joined at centromere. When the chromatids are pulled apart in Anaphase they are no longer joined. So it is okay to say that number of chromosomes is now 4n and so is the number of chromatids.



But only until Telophase, after that when cytoplasm divides, chromosome number is 2n per cell. **Chromosome is the name given to single condensed thread. A thread may have the normal DNA content or the duplicated content as well (as chromatids) attached via centromere**

6. How the course of 2n, 2C changes during meiosis?

Answer: Before the cell divides, DNA must replicate, as described above. It goes from 2C to 4C while the number of chromosomes remain same. The replicated segment is present as an extra arm called a chromatid. Hence one chromosome has two chromatids.

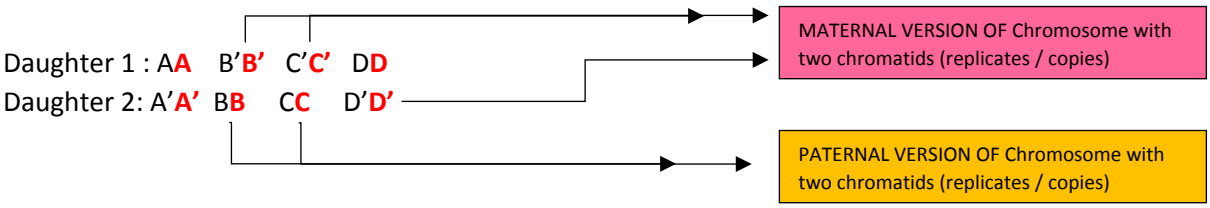
Meiosis is reduction division- it produces four cells with half the number of chromosomes that of the original. It is carried in two phases Meiosis I and Meiosis II. Meiosis I is reductional, it reduces the chromosome number to half while Meiosis II is equational, the reduced number remains same. The cells with half the number of chromosomes are called haploid. They contain only one version of the chromosomes as single copy.

As Meiosis I sets in, 2C has already gone to 4C- AA, A'A', BB, B'B', CC, C'C', DD, D'D'. While A' is the maternal version of A, A is an exact copy of A and so on. A paternal version and its copy, together as a chromosome comes together with the maternal version and its copy. So AA comes together with A'A'. This group is called bivalent. So out virtual 8 chromosome cell might be like this during Meiosis I

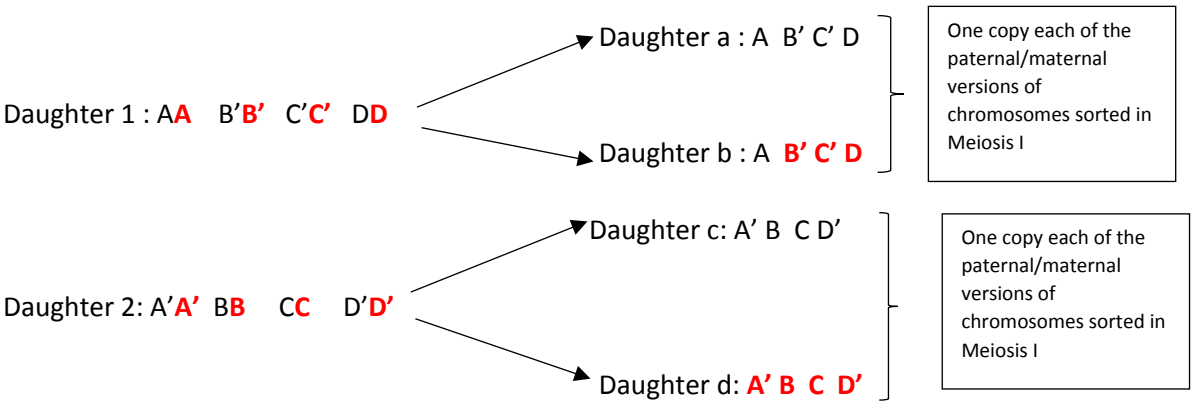
AA B'B' C'C' DD
A'A' BB CC D'D'

You can see that paternal and maternal versions sort themselves randomly. Now during the Metaphase I, Microtubules will pull one set of chromosome version and its copy to one pole and other to the opposite. In contrast, in mitosis, chromatids are pulled apart, ensuring that chromosome number remains same, and since chromatids are exact copies, the daughter cells receive same genetic information.

On the contrary on Meiosis, one daughter cell might have paternal version and its copy, the other might have the maternal version and its copy. Since maternal and paternal versions are different, we will have two daughter cells having two copies of one version (paternal or maternal), hence two copies of different genetic codes.



Meiosis II is equational. Now the Chromosomes are brought to equator and chromatids (copies) are pulled apart creating two exact copies of the daughter cells produced by Meiosis I by a process quite similar to Mitosis. At the end we have four daughter cells



As we can see the initial chromosome number was 8- AA', BB', CC', DD'. But now they remain to be just 4. Hence these cells are haploid.

7. How are these related with genes?

Answer: By definition, a gene is a stretch of DNA that codes for a polypeptide. A chromosome is a long stretch of chromosomes, hence has several such segments that code for different polypeptides. Now since all chromosomes (paternal and maternal) get replicated as chromatids before division, and these chromatids are pulled into the daughter cells during mitosis, both daughter cells will have same genes, hence they are identical.

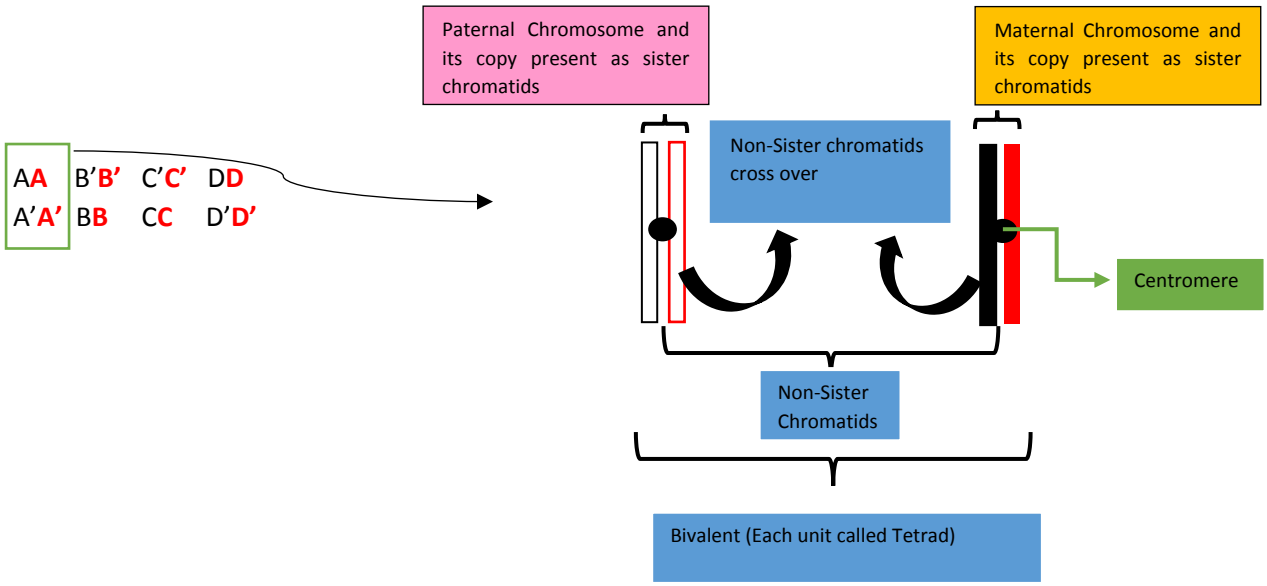
In meiosis I, chromosomes sort into daughter cells, one cell may receive the maternal version and its copy whereas the other may receive paternal version and its copy. The two daughter cells then divide into two in each case. In this division the replicated chromatids separate creating two identical cells in each case. Over all we have two cell types of two in duplicates.

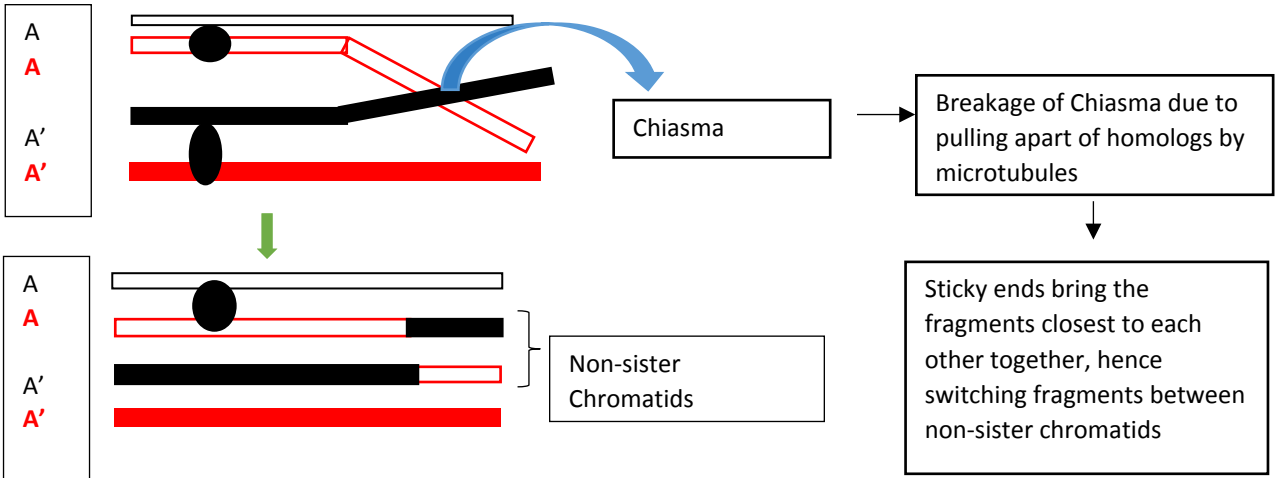
A gene is just functional attribution of DNA segments. It changes with the structural changes

8. Crossing over introduces variation? How and why?

Answer: During meiosis a crucial event takes place that exchanges DNA between the non-sister chromatids of homologous chromosomes. Let us examine the homologous chromosome pairs. Let's assume this is how homologous chromosomes arrange themselves on equator during MEIOSIS I

Now let us visualize first pair of them as chromosomes:





As we can see there is an exchange of DNA segment between **A** and A'. Hence genes thus will also be switched.