Curtis *et al.*
Il nuovo Invito alla biologia.blu

BIOLOGY HIGHLIGHTS – *KEYS*

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> MITOSIS

2. WARM UP

a) Each daughter cell gets 24 chromosomes, since mitosis maintains the original number of chromosomes. Cells produced by mitosis are identical.
b) Every living thing relies on the internal regulation of its environment (*homeostasis*), the transformation of energy (*metabolism*), the ability to change over time (*evolution*), and the ability to produce new individual organisms (*reproduction*).
c) Reproduction guarantees cell continuity, because every cell derives from living cells of the same type.

3. VISUAL LEARNING

1. mitosis; 2. division; 3. S; 4. genetic; 5. chromatids; 6. cytokinesis; 7. nuclear; 8. cell

4. VOCABULARY

a) division; b) chromosomes; c) interphase; cycle; d) identical; e) genetic; f) inheritance

5. LISTENING

Track A1

Transcript

The issue of dividing exactly the genetic material of eukaryotic cells is complex. A typical eukaryotic cell contains about a thousand times more DNA than a prokaryotic cell. The DNA is linear, and forms a number of distinct chromosomes. For instance, the human somatic cells that make up our body have 46 chromosomes, and each one is different from the others. When these cells divide, each daughter cell receives one copy only of each of the 46 chromosomes. The nucleus contains chromosomes and controls the activities of the cell. In a process that is called mitosis, a complete set of chromosomes is allocated to each of the two daughter nuclei. Before a cell can begin mitosis and actually divide, it must replicate its DNA and synthesize more of the proteins associated with the DNA in the chromosomes. Moreover, it must produce a supply of organelles adequate for two daughter cells. These preparatory processes occur during the G1, S and G2 phases of the cycle, which are collectively known as interphase.

Keys

a) mitosis; b) cells; chromosomes; c) nucleus; genetic information d) cell cycle; life; f) organisms; grow

6. READING

Track A2

a) F (*The function of mitosis is to manoeuvre the replicated chromosomes so that each new cell gets a full set*); b) T; c) F (*By the beginning of mitosis they are sufficiently condensed to become visible under the light microscope*); d) T; e) F (*Each chromosome can be seen to consist of two replicas, called chromatids)*; f) F (*The process of mitosis is conventionally divided into four phases: prophase, metaphase, anaphase and telophase (sometimes a fifth phase can be described, called pro-metaphase*); g) T; h) T

7. PAIR WORK

a) A chromosome consists of a DNA double helix bearing a linear sequence of genes. The DNA is coiled and recoiled around proteins called histones. The resulting complex is called chromatin.

In the nucleus, the DNA double helix is packaged by special proteins to form a complex called chromatin. The chromatin undergoes further condensation to form the chromosome. Chromosomes are very long and thin, and they are not visible in the interphase. The threadlike chromosomes slowly begin to condense after their synthesis in the S phase and by the beginning of mitosis they are sufficiently condensed to become visible under the light microscope.

b) During the cell division, more precisely during the S-phase of interphase, DNA is replicated. The resulting two identical copies of DNA are connected to each other at the centromere. Each copy is called a chromatid. Before cell division a chromosome is formed by one chromatid, while it is formed of two chromatids after cell division.

c) Centromeres separate simultaneously in all the chromatid pairs. The chromatids of each pair move apart, and each chromatid becomes a separate chromosome, which is apparently drawn towards the opposite pole by the kinetochore fibres.

d) In single–celled organisms, mitosis increases the number of individuals in the population, whereas in many-celled organisms it is the means by which organisms grow and repair injured tissues.

8. APPLY YOUR NEW KNOWLEDGE

A-2, B-1, C-5, D-6, E-4, F-3

9. VIDEO

Video A1

Transcript

Let's go out of the nucleus and into the cytoplasm. Few organelles are displayed for the sake of clarity. Mitosis involves a sequence of characteristic events which can be divided into five stages.

The first stage is called prophase. At the beginning of prophase the centrosomes begin to move away from each other and to organize the mitotic spindle, which is made of microtubules. At the same time, inside the nucleus the DNA is condensed into compact structures, called chromosomes. The number of chromosomes varies from one organism to another.

Each chromosome consists of two strands called sister chromatids. Each chromatid is made up of a single DNA molecule. The DNA molecules that form the two chromatids are identical, because they are the product of duplication, which, as we said, took place during interphase (S phase).

The chromosomes have a constriction in the centre, called the centromere, and the pairs of chromatids are held closely together by specific proteins. This arrangement ensures that the genetic material is divided correctly between the two daughter cells.

Disintegration of the nuclear envelope marks the beginning of prometaphase.

At this point there is no longer any barrier separating the chromosomes from the cytoplasm. The fibers of the mitotic spindle, which branch off from the two poles, can reach and 'capture' the chromosomes. The spindle fibers attach at the centromere to protein complexes called kinetochores.

There are two kinetochores, one for each chromatid, which face in opposite directions, making them more likely to bind to fibers from opposite poles of the spindle. The correct bonds are formed by trial and error.

The chromosomes are now arranged in a disorderly fashion and begin to move. The mitotic spindle is a very dynamic structure. It includes kinetochore microtubules and interpolar microtubules, which, as the name implies, stretch from one pole of the spindle to the other, or bind to each other.

Returning to an overview of the cell the spindle poles can be seen. They are located in diametrically opposite points and coincide with the centrosomes, organized around the

centrioles. Here we can also see a final component of the mitotic spindle: aster microtubules. These microtubules connect the centrosomes to the cell membrane.
Movements of the mitotic spindle bring the chromosomes into the equatorial zone, in the middle of the cell between the two spindle poles. When all the chromosomes are lined up, the cell enters metaphase. At this point, the sister chromatids are correctly attached to microtubules connected to opposite poles and can be separated.

Keys
a. F (*prophase*); b. T; c. F (*chromosomes*); d. F (*It varies*); e. T; f. T; g. F (*There are only two kinetochores, one for each chromatid*); h. F (*They stretch from one pole of the spindle to the other*). i. T; j. T.

Video A2
Transcript
Anaphase, the penultimate stage of mitosis, begins with the separation of the sister chromatids. The protein bonds that hold sister chromatids together are broken in all the chromosomes at the same time, and the chromatids are pulled to opposite poles of the mitotic spindle. From now on sister chromatids are called daughter chromosomes.
During early anaphase the chromosomes are dragged towards the poles by shortening of the kinetochore microtubules. These microtubules break down and interact with motor proteins, by mechanisms that are still unknown. As anaphase continues, two other forces separate the poles.
The first involves interpolar microtubules. The microtubules from opposite poles slide over each other, pushing the poles apart.
At the same time a driving force is exerted by the aster microtubules. These microtubules are located at the poles of the spindle and interact with the cell membrane.
The cell starts to become more oval in shape. Anaphase ends when the daughter chromosomes reach the centrosomes.
The next stage is telophase. The mitotic spindle disintegrates. Some vesicles around the two groups of daughter chromosomes fuse, reforming the nuclear envelopes. The DNA within the two nuclei resumes a less compact form, characteristic of interphase. DNA information can be read again and the nucleolus reappears.
At this point mitosis ends and the two new nuclei are ready to enter interphase.

Keys
a. T; b. F (*Sister chromatids change their names into sister chromosomes*); c T; d. T; e. F (*Aster microtubules interact with the cell membrane*); f. T; f. F (*It disintegrates at the beginning of the telophase*); h. T.

10. DISCUSSION
a) By the end of prophase, the chromosomes are fully condensed and are no longer separated from the cytoplasm. The kinetochore fibres, attached to the kinetochores of the chromosomes, have also formed.
b) The spindle is the thread-like structure formed from pole to pole for chromosomes to become attached to. During early metaphase, the chromatid pairs move back and forth within the spindle, apparently manoeuvred by the spindle fibres.
c) DNA replication occurs during the S (*synthesis*) phase of the cell cycle, which is the key of the process. Over this time, many of the histones and other DNA-associated proteins are also synthesized.
d) During telophase, two new nuclei form in each daughter cell: the chromosomes reach the poles as the nuclear membranes re-form around each set of chromatids, the nucleoli also reappear. The chromosomes also unwind back into the expanded chromatin, present during interphase.

11. VOCABULARY
1-f; 2-e; 3-a; 4-b; 5-c; 6-d

12. REVISION
Free answer

FINAL TEST
1-D; 2-C; 3-D; 4-A; 5-B; 6-T; 7-F; 8-T; 9-T; 10-T

<u>> MEIOSIS</u>

14. WARM UP
a) All organisms need to reproduce so as to avoid the extinction of their species. The role of reproduction is the continuation of species, because no organism on Earth is immortal.
b) There are two different types of reproduction: *asexual reproduction* (involving only one organism), and *sexual reproduction* (requiring a female and a male organism). The fusion of gametes (sexual cells) takes place in the sexual reproduction.
c) The most advanced plants reproduce sexually: they produce male and female sex cells which must meet so as to kick-start the process of reproduction called pollination.
d) Meiosis consists of two successive nuclear divisions. The sex cells (or gametes) have exactly half the number of chromosomes (haploid) that is characteristic of the somatic cells of the organism (diploid). When a sperm fertilizes an egg, two haploid nuclei fuse to produce a diploid nucleus, and the diploid number is so restored.

15. LISTENING
Track A3
Transcript
Meiosis consists of two successive divisions, conventionally called "meiosis I" and "meiosis II". In meiosis I, homologous chromosomes pair and then separate from one another; in meiosis II, the chromatids of each homologue separate.
We are now going to describe the process of meiosis in a plant cell in which the diploid number is 6 (n=3). Three of the six chromosomes were originally derived from one parent, and three from the other parent. For each chromosome from one parent, there is a homologous chromosome, or homologue, from the other parent.
During the interphase preceding meiosis, the chromosomes are replicated, so that by the beginning of meiosis each chromosome consists of two identical sister chromatids held together at the centromere region. The first of the two nuclear divisions in meiosis then proceeds through the stages of prophase, metaphase, anaphase, and telophase.
At the beginning of meiosis (prophase I), the chromatin condenses and the chromosomes come into view. By this time, an event has occurred: the homologous chromosomes have come together in pairs. Since each chromosome consists of two identical chromatids, the pairing of the homologous chromosomes actually involves four chromatids; this complex of paired homologous chromosomes is known as a "tetrad".
At this point, a process that could alter the genetic makeup of the chromosomes occurs. This process is known as "crossing over", and involves the exchange of segments of the chromosome with corresponding segments from its homologous chromosome. At the sites of crossing over, portions of the chromatids of one homologue are broken and exchanged with the corresponding portions of one or the other of the chromatids of the second homologue. The maternal homologue now contains portions of the paternal homologue and vice versa. Thus, crossing over is an important mechanism for recombining the genetic material from the two parents.

Keys
a) The homologues (consisting of two sister chromatids each) separate, as if pulled apart by the spindle fibres attached to the kinetochores. However, the two sister chromatids of each homologue do not separate as they do in mitosis.
b) Sperm cells.

The cells develop into gametes, which are produced from a diploid cell carried only by one member of each homologous. Male gametes are called "sperm cells", and female gametes "egg cells". At fertilization, the chromosomes in the sperm and in the egg come together producing once again pairs of homologous chromosomes.
c) The number of chromosomes in the gametes is referred to as the haploid (single set) number, and the number in the somatic cells as the diploid (double set) number. The haploid number is designated "n", and the diploid number is "2n". In humans, for example, n=23 and therefore 2n=46.
d) During prophase I of meiosis. At this stage, each homologous pair consists of four chromatids, and the *crossing over* involves the exchange of segments.
e) At the sites of crossing over, portions of the chromatids of one homologue are broken and exchanged with the corresponding segments of one or the other of the chromatids of the second homologue. The result is that the sister chromatids of a single homologue no longer contain identical genetic material.

16. READING
Track A4
Mitosis: c; *Meiosis*: a, b, d

17. VOCABULARY
a) homologous; b) chromatids; c) chromosomes; d) four; e) haploid

18. PAIR WORK
Mitosis is a process of cell division resulting in two genetically identical daughter cells developing from a single parent cell; meiosis involves two fissions of the nucleus, producing four gametes or sex cells (sperm and egg).
Mitosis is used by unicellular organisms to reproduce, and for the organic growth of tissues in multicellular organisms. Meiosis takes place during sexual reproduction; crossing over (mixing of chromosomes) may occur, thus ensuring genetic diversity.
In meiosis, homologous chromosomes separate, leading to 4 genetically non-identical daughter cells. In mitosis the 2 daughter cells are identical to the parent as well as to each other.

19. VIDEO

Video A3
Transcript
Let's look at the overall balance of meiosis by going back to the initial diagram, where our cell model has only two types of chromosomes, a short one and a long one.
Being diploid, the cell has two copies of each chromosome, one of maternal origin and one of paternal origin. Consequently, there are four chromosomes altogether. At the beginning of meiosis I the DNA was duplicated, so we have 8 molecules of DNA, which form 8 chromatids. With the first meiotic division the chromosome is halved: the two daughter cells are haploid, i.e. they receive only one copy of each chromosome, and therefore have two chromosomes each. Each chromosome is still composed of two chromatids, so each cell has 4 chromatids. In the diagram one cell has both paternal chromosomes and the other both maternal ones, but this occurred by chance, they could also have been mixed up. In fact, shuffling is usually the rule, and is a source of genetic variability. Another source of variability is the crossing over that occurs during prophase I and is responsible for the exchange of DNA between homologous chromosomes.
With the second meiotic division each daughter cell divides in two. This time, the chromatids of each chromosome separate. Therefore the number of chromosomes in these daughter cells remains unchanged, but the number of chromatids, and thus the number of molecules of DNA, is halved. As can be seen from the colors, all four cells are genetically different.

Keys
a. T; b. F (*haploid*); c. T; d. T; e. F (*non-sister chromatids*); f. F (*Meiosis I*)

20. DISCUSSION
a) Prophase I gives way to the process known as "crossing over", i.e. a fundamental mechanism for recombining the genetic material. Crossing over does not occur in mitosis.
In metaphase I, homologous pairs line up along the equatorial plane of the cell. In the metaphase of mitosis, replicated chromosomes align in a single line with no sign of pairing of homologues. During anaphase I, the homologues - consisting of two sister chromatids each – separate; however, the two sister chromatids of each homologue do not separate in meiosis as they do in mitosis.
b) Mitosis is a process that divides the cell into two new cells, each of which contains a nucleus with a full chromosome complement. During meiosis, each diploid nucleus divides producing a total of four nuclei containing half the number of chromosomes.
c) Chromosomes of maternal or paternal origin do not stay together, but are assorted independently, and the number of possible combinations in the gametes is enormous.
d) In egg cells the nucleus is haploid (n), whereas it is diploid ($2n$) in somatic cells.

21. APPLY YOUR NEW KNOWLEDGE
A) mitosis; B) replication; C) division; D) diploid daughter cells
E) meiosis; F) replication and crossing over; G) division; H) division; I) haploid daughter cells

22. EXPLORE FURTHER
a) Karyotype: the number and appearance of chromosomes in the nucleus of a eukaryotic cell.

b) Sex Chromosome: either of a pair of chromosomes that determine whether an individual is male or female.

c) Autosomes: any chromosome that is not a sex chromosome.

d) Non-disjunction: failure either of two homologous chromosomes to pass to separate cells during the first meiotic division, or of the two chromatids of a chromosome to pass to separate cells during mitosis or during the second meiotic division.

e) Trisomy: a condition in which an extra copy of a chromosome is present in the cell nuclei, causing developmental abnormalities.

23. REVISION
Free answer

FINAL TEST
1-B; 2-D; 3-B; 4-A; 5-B; 6-T; 7-T; 8-F; 9-F; 10-F