Competitive Exams: Cell Cycles

Mitosis

The term “mitosis” can be somewhat ambiguous. In the original histological sense, mitosis was usually understood to refer to the entire process of cell division, which includes both nuclear division (karyokinesis) and cytoplasmic division (cytokinesis). However, the term “mitosis” is also used more narrowly to refer specifically to the process of nuclear division, which, in turn, can be subdivided into four (or five) well-defined stages:

1. Prophase refers of the early stages of mitosis during which the interphase chromosomes become sufficiently condensed so they can be seen as distinct “structures” with the light microscope
2. Metaphase refers to the period during which the centromeres of the condensed chromosomes become aligned at the midpoint between the poles of the mitotic spindle (many authors now refer to a separate prometaphase characterized by breakdown of the nuclear envelope and movement of chromosomes toward the metaphase position)
3. Anaphase begins with the abrupt separation of the duplicated centromeres and encompasses the period during which the chromosomes are physically separating and migrating toward the two spindle poles
4. Telophase refers to the final aspect of nuclear division in which the nuclear membranes are reconstituted around the two daughter nuclei and the chromosomes begin to decondense.

Interphase

After methods were developed for measuring when DNA is synthesized, interphase was subdivided into three distinct parts: Although the original basis for this terminology has become obsolete, the terminology itself is still widely used.

- G1 was defined as the (“gap”) in time extending from the end of mitosis to the start of DNA synthesis during which it was not known what, if anything, the cell was doing (G1 is now known to be a busy time of growth in size of the cell and preparation for DNA synthesis).
- S was defomed as the time during which DNA synthesis was actually occurring.
- G2 was defined as the second (“gap”), which extended from the end of DNA synthesis to the start of mitosis (M). It is now known that G2 is also a busy period in which many biochemical and regulatory processes are taking place in preparation for M.

Mitotic Cycle

Prior to the development of methods for determining the exact timing of DNA synthesis, classical histologists typically divided the mitotic cell cycle into two major parts, mitosis (the period during which the actual process of division could be observed microscopically) and interphase (the time that cells spent “resting” between divisions).

Meiosis

Three distinct processes of major genetic importance occur during meiosis:

1. a reduction in chromosome number from diploid to haploid
2. independent assortment of chromosomes of maternal and paternal origin into the gametes (or other haploid progeny of meiosis)
3. recombination, such that complementary portions of homologous chromosomes are joined together to generate a single recombined chromosome with genetic contributions from both parents. The independent assortment and recombination that occur during meiosis stand in sharp contrast to the rigid conservation of the genetic composition of the parental cell that occurs as its chromosomes are duplicated and distributed strictly equally to the two daughter cells in mitosis.

Phases

- Meiotic prophase The extended prophase that occurs prior to the first meiotic division (meiosis I) is typically divided into five stages, identified primarily by cytologic appearance
- Leptonema (leptotene stage) (thin thread) is the earliest stage in which visible chromosome condensation can be seen
- Zygonema (zygotene stage) (yoked thread) exhibits the beginnings of side-by-side pairing (synapsis) of homologous chromosomes, which have already replicated and thus form a four stranded structure known as a tetrad Pachynema (Pachytene stage) (thick thread) is characterized by further condensation of the chromosomes, and is also the period during which genetic recombination occurs between maternal and paternal chromosomes
- Diplonema (Diplotene stage) (double thread) is characterized by the beginning of separation of homologues, with residual areas of close contact called chiasmata, which are sites of recombination
- Diakinesis is characterized by shortening of the chromosomes, due to further condensation, and by migration of chiasmata toward the ends of the chromosomes.

Meiotic Divisions

During the first meiotic division, the bonding between homologous chromosomes separates, but the centromeres of duplicated chromosomes stay together. For each chromosome pair, the maternal chromosome will go to one pole and the paternal to the other. Because the orientation

of each pair (relative to the spindle) is random, there is independent assortment of maternal and paternal chromosomes at this division. This gives each daughter cell a haploid number of duplicated, but not yet separated chromosomes. The second division occurs without further DNA synthesis. The centromeres separate in this division, generating a haploid number of normal chromosomes.