INTRODUCTION

BINARY FISSION: Prokaryotic cells (bacteria) reproduce asexually by binary fission. Bacterial cells have a single circular chromosome, which is not enclosed by a nuclear envelope. During binary fission the bacterial chromosome is duplicated, the cell elongates, and the two chromosomes migrate to opposite ends of the cell. Each daughter cell receives one chromosome and is identical to the parent cell. Binary fission is a relatively fast and simple process.

MITOSIS:
The increased complexity of eukaryotic cells causes several logistical problems during cell division. Eukaryotes are diploid, which means they have two sets of chromosomes; one set of chromosomes is inherited from each parent. Eukaryotic DNA is enclosed by a nuclear envelope. The proper sorting and distribution of multiple chromosomes during cell division is a complex process that requires the temporary dissolution of the nuclear envelope. Eukaryotic organisms carry out mitosis throughout their entire life to grow and to replace old or damaged cells. Some eukaryotic organisms use mitosis to reproduce asexually. The daughter cells produced by mitosis are diploid and genetically identical to each other and the parent cells that produced them.

CELL CYCLE = INTERPHASE + MITOSIS
Cells only spend a small part of their life dividing. The time between consecutive mitotic divisions is referred to as interphase. Eukaryotic cells spend most of their time in interphase. During interphase the cell’s genetic material is in the form of chromatin (uncoiled DNA), nucleoli are present, and the nuclear envelope is clearly visible. Shortly before mitosis, the cell duplicates its DNA during the S (synthesis) phase of interphase.
Mitosis can be divided into four distinct phases:

I. Prophase: Nuclear envelope and nucleoli disappear. Chromatin condenses into chromosomes, which are made up of two identical sister chromatids joined by a centromere. In animal cells, centrioles start migrating to opposite ends of the cell (centrioles are not present in plant cells). The mitotic spindle forms and begins to move chromosomes towards the center of the cell.

II. Metaphase: Brief stage in which chromosomes line up in the equatorial plane of the cell. In animal cells, one pair of centrioles are visible at both ends of the cell. The mitotic spindle is fully formed.

III. Anaphase: Sister chromatids begin to separate, becoming individual chromosomes, which begin to migrate to opposite ends of the cell.

IV. Telophase: A full set of chromosomes reaches each pole of the cell. The mitotic spindle begins to disappear. The nucleus and nucleoli begin to reappear. Chromosomes begin to unravel into chromatin.

Cytokinesis or cytoplasmic division usually occurs at the end of telophase. In plant cells cytokinesis is accomplished by the formation of a cell plate. Animal cells separate by forming a cleavage furrow.

MITOSIS EXERCISE:

1. Examine prepared microscope slides of both animal cells (whitefish blastula) and plant cells (onion/allium root tip). Even though the cells in these tissues are rapidly dividing, most of the cells you will observe will be in interphase (between cell divisions). Using your microscope, scan the slides to find a cell in interphase and each one of the four stages of mitosis. Draw a schematic representation of your observations for both plant and animal cells at each stage in the space provided below. Indicate and clearly label the important features or events of each stage.

2. Using the Micro-Slide Viewers, examine the prepared microslides of:
   A. Plant Mitosis: Onion (Allium) Root Tip. The diploid number of chromosomes of allium is 16. The total magnification of the images is 1000 X.
   B. Animal Mitosis: Ascaris egg sac. The diploid number of chromosomes of ascaris is 4. The total magnification of the images is 750 X.
<table>
<thead>
<tr>
<th>Animal Cell (Whitefish Blastula)</th>
<th>Plant Cell (Onion Root Tip)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnification: __________</td>
<td>Magnification: __________</td>
</tr>
<tr>
<td>Interphase</td>
<td></td>
</tr>
<tr>
<td>Prophase</td>
<td></td>
</tr>
<tr>
<td>Metaphase</td>
<td></td>
</tr>
<tr>
<td>Anaphase</td>
<td></td>
</tr>
<tr>
<td>Telophase</td>
<td></td>
</tr>
</tbody>
</table>
MEIOSIS:
During sexual reproduction in eukaryotes, a haploid sperm cell fuses with a haploid egg cell to produce a diploid zygote or fertilized egg. In most species, it is very important that the offspring produced by fertilization have the same number of chromosomes as the parents. Even a single extra or missing chromosome can be lethal or extremely deleterious to an individual (e.g.: Down’s syndrome in humans). Meiosis is a special type of cell division that produces haploid gametes (sperm cells or ova). Meiosis only occurs in an individual’s gonads, during their reproductive years.
Meiosis involves two cell divisions and ultimately produces four haploid gametes. The haploid gametes produced by meiosis are different from each other as well as from the parent cells due to the crossing over of genetic material between homologous chromosomes and the random distribution of homologous chromosomes.
Meiosis is different in males and females:
Spermatogenesis: In males four functional sperm cells are produced by meiosis.
Oogenesis: Due to unequal distribution of cytoplasm during meiosis, one large functional egg (ova) and three small polar bodies are produced.

STAGES OF MEIOSIS
MEIOSIS I: Reductive Division (Diploid → Haploid)
Prophase I: Similar to prophase of mitosis with one important difference:
Crossing Over: Pairs of homologous chromosomes synapse together to form tetrads and exchange genetic information (DNA). Crossing over creates new, recombinant chromosomes.
Homologous chromosomes code for the same genetic information and are of the same size, but are different because one comes from an individual’s mother, while the other comes from the individual’s father.
Metaphase I: Brief stage in which tetrads line up in the equatorial plane of the cell
Anaphase I: Homologous chromosomes separate and migrate to opposite ends of cell.
Telophase I: A full set of chromosomes reaches each pole of the cell.
The cells produced are haploid, only contain half of the original number of chromosomes.
Interphase may be very brief or absent between meiosis I and meiosis II.

**MEIOSIS II**: Very similar to mitosis.

**Prophase II**: DNA condenses into chromosomes. No crossing over occurs.

**Metaphase II**: Individual chromosomes line up in the equatorial plane of the cell.

**Anaphase II**: Chromatids separate and begin to migrate to opposite poles of the cell.

**Telophase II and Cytokinesis**: A full set of chromosomes reaches each pole of the cell.

Four different gametes are produced.

**MEIOSIS EXERCISE**

1. **Stages of Meiosis**: Using the chromosome bead models construct a single pair of **homologous chromosomes**, each with two sister chromatids. Use red for maternal chromosome and yellow for paternal chromosome). Use the magnets for centromeres and attach 10 beads to each end of the small tubes.

To illustrate crossing over, exchange several of the beads between your chromosomes.

Represent each stage of meiosis and clearly depict and label the behavior of chromosomes below. Use different colors (ink and pencil or blue and red) to indicate maternal and paternal chromosomes.

---

**MEIOSIS I**

**Important Events**

**Prophase I**

- Tetrad formation
- and crossing over

**Metaphase I**

- Alignment of tetrads
Important Events

Anaphase I
Separation of homologous chromosomes

Telophase I and Cytokinesis
Two haploid cells produced

MEIOSIS II

Prophase II

Metaphase II
Alignment of individual chromosomes

Anaphase II
Chromatids separate

Telophase II and Cytokinesis
Four gametes produced
2. **Independent assortment of chromosomes**: Chromosomes are shuffled randomly and distributed into daughter cells independently from one another during meiosis I.

Independent assortment creates a staggering number of possible gamete combinations as the number of chromosomes in a cell increases.

The number of possible gametes generated by independent assortment alone is $2^n$, where $n$ is the haploid number of chromosomes in a cell. A human cell can produce over 8 million different gametes by independent assortment $2^{23} = 8.3$ million.

Additionally, crossing over further increases the number of possible gametes generated by an individual.

**INDEPENDENT ASSORTMENT EXERCISE**

**Independent Assortment in Meiosis:**

Using the chromosome bead models, find all of the possible gametes formed by a cell with one, two, and three pairs of homologous chromosomes.

Use red for maternal chromosomes and yellow for paternal chromosomes.

**Note**: We will disregard the production of recombinant chromosomes by crossing over for this portion of the exercise.

**A. A cell with one pair of homologous chromosomes (Diploid number 2)**

Chromosomes # 1 have 10 beads on each end of centromere.

Use the following abbreviations to represent the chromosomes:

- **M1** = Maternal chromosome # 1
- **P1** = Paternal chromosome # 1

**Possible Gametes Produced by Cell:**

- [Diagram of gametes]
- [Diagram of gametes]
B. A cell with two pairs of homologous chromosomes (Diploid number 4)
Chromosomes # 1 have 10 beads on each end of centromere (M1 and P1).
Chromosomes # 2 have 5 beads on each end of centromere (M2 and P2).
Possible Gametes Produced by Cell:

C. A cell with three pairs of homologous chromosomes (Diploid number 6)
Chromosomes # 1 have 10 beads on each end of centromere (M1 and P1).
Chromosomes # 2 have 5 beads on each end of centromere (M2 and P2).
Chromosomes # 3 have 3 beads on each end of centromere (M3 and P3).
Possible Gametes Produced by Cell:

**Question:** How many gametes would be produced by independent assortment alone, in a cell with 7 pairs of homologous chromosomes? ________________