1. Draw and label what cells look like in the following phases of mitosis and write bullet point description of important steps that are taking place in each phase.

- **G2 of Interphase**
  - A nuclear envelope encloses the nucleus.
  - The nucleus contains one or more nucleoli (nuclear bodies).
  - Two centrioles have formed by duplication of a single centriole. Centrioles are organelles in animal cells that organize the microtubules of the spindle. Each centriole contains two centrioles.
  - Chromosomes, duplicated during S phase, cannot be seen individually because they have not yet condensed.

- **Prophase**
  - The chromosomes become visible under the microscope.
  - The nucleolus disappears.
  - Each duplicated chromosome appears as two identical sister chromatids attached at their centromeres and, in some species, along their arms by cohesion (inter-chromatid cohesion).
  - The mitotic spindle (formed from microtubules) begins to form. It is composed of the centrioles and the microtubules that extend from them. The radial arrays of shorter microtubules that extend from the centrioles are called asters.
  - The centromeres move away from each other, propelled partly by the lengthening microtubules between them.

- **Prometaphase**
  - The nuclear envelope fragments.
  - The microtubules extending from each centromere now lie inside the nuclear area.
  - The chromosomes have become even more condensed.
  - Each of the two chromatids of each chromosome now lie a kinetochore, a specialized protein structure at the centromere.
  - Some of the microtubules attach to the kinetochores, becoming "kinetochore microtubules," which pull the chromosomes back and forth.
  - Mitotic spindle microtubules interact with those from the opposite pole of the spindle.

- **Metaphase**
  - The centromeres are now at opposite poles of the cell.
  - The chromosomes converge at the metaphase plate, a plane that is equidistant between the spindle's two poles. The chromosomes orientate at the metaphase plate.
  - For each chromosome, the kinetochores of the sister chromatids are attached to kinetochore microtubules extending from opposite poles.

- **Anaphase**
  - Anaphase is the shortest stage of mitosis, lasting only a few minutes.
  - Anaphase begins when the cohesin protein complexes are cleaved. This allows the two sister chromatids of each pair to part suddenly. Each chromatid then becomes a single-chromatid chromosome.
  - Two identical, daughter chromosomes begin moving toward opposite ends of the cell as their kinetochore microtubules shorten. Because these microtubules are attached at the centromere, the chromosomes move centromere first (at about 0.5 μm/min).
  - The cell elongates as the nonkinetochore microtubules lengthen.
  - By the end of anaphase, the two ends of the cell have clefted and complete collections of chromosomes.

- **Telophase**
  - Two daughter nuclei form in the cell. Nuclear envelopes arise from the fragments of the parent cell's nuclear envelope and other portions of the endosomatic system.
  - Nucleoli reappear.
  - The chromosomes become less condensed.
  - Any remaining spindle microtubules are depolymerized.
  - Mitosis, the division of one nucleus into two genetically identical nuclei, is now complete.

**Cytokinesis**
- The division of the cytoplasm is usually well under way by late telophase, so the two daughter cells appear shortly after the end of mitosis.
- In animal cells, cytokinesis involves the formation of a cleavage furrow, which pinches the cell in two.
2. The fruit fly, *Drosophila melanogaster*, has a diploid number of 8. Complete the following table for each phase of the cell cycle. (Imagine you condensed the chromatin even during interphase.)

<table>
<thead>
<tr>
<th>Cell cycle</th>
<th># of copies of gene encoding for wing length</th>
<th># of SINGLE chromatids</th>
<th># of PAIR of sister chromatids</th>
<th># of chromosomes</th>
<th># of pair/set of homologous chromosomes</th>
<th>Draw it out</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 phase</td>
<td>2</td>
<td>0*</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>I I I I (maternal) I I I I (paternal)</td>
</tr>
<tr>
<td>Shortly after S phase</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>8**</td>
<td>4</td>
<td>X X X X X X X X X X</td>
</tr>
<tr>
<td>G2 phase</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>8**</td>
<td>4</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>Metaphase</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>8**</td>
<td>4</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td>After mitosis, in a daughter cell</td>
<td>2</td>
<td>0*</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>I I I I</td>
</tr>
</tbody>
</table>

There was some confusion regarding terminology. So I modified the top row a little to clarify. See **BOLD CAPTIAL** letters.

*To avoid confusion, I’ve decided to apply the term chromatid only after DNA has replicated.

**To avoid confusion, let’s count chromosome by the centromere. So since sister chromatids share 1 single centromere in a replicated chromosome, we will consider that as 1 chromosome.

Take home message for question number 2 is to know that after DNA replication, there are 4 copies of a particular gene and to know when sister chromatids appear.

3. Down syndrome is characterized by cells having three copies of chromosome 21. As a cell in an individual with Down syndrome prepares to enter mitosis, how many **chromatids** would be present?

   a) 94        b) 98        c) 92        d) 23        e) 46

23 chromosomes from mother
+ 23 chromosomes from father
+ 1 extra chromosome
47 total chromosome

After S phase before mitosis, 47 chromosomes would have replicated and each chromosome will contain 2 chromatids.

47X2= 94 chromatids
4. A cell biologist carefully measured the quantity of DNA in grasshopper cells growing in cell culture. Cells examined during the G2 phase of the cell cycle contained 200 units of DNA. What would be the amount of DNA at G1 of the cell cycle in one of the grasshopper daughter cells?
   a) 400 units  b) 200 units  C) 100 units  d) between 50-100 units  e) 50 units

   G2 phase comes after S phase so we know that in G2 phase there is two times the amount of DNA of G1 phase.
   \[
   \frac{200}{2} = 100
   \]

5. A diploid human skin cell in G1 phase has ____23____ maternal chromosomes and ____0____ sister chromatids. Somatic human cells have a total of 46 chromosomes-23 from mother and 23 from father. G1 phase did not have DNA replication yet so there will not be any sister chromatids.