Science Excursion

The "gee!" in Microgravity

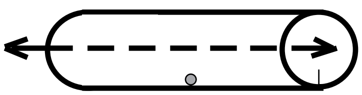
Objective: Using simple materials, students will build a working model of an apparatus (a clinostat) that illustrates the basic operating principles of a bioreactor. The bioreactor is used to explore how gravity affects the ability of cells to join together to form tissues.

Materials:

- large, cylindrical bottle of shampoo (a very light-colored shampoo in a clear bottle is recommended)
- spherical beads or marbles of various densities and diameters (can be obtained from old jewelry or from a craft store)
- stopwatch
- marker or pencil

Background: Tissue culturing is a basic tool of medical research required for developing medical technologies such as therapy design and tissue transplatation. Chambers called *bioreactors* are used to culture tissues outside the body, and research is underway which investigates the role of physical forces on tissue formation. NASA is exploring the potential of tissue culture in the microgravity environment, where improved reduction in stresses on growing tissue samples allow tissue masses to develop and mature. To accomplish this, a ground based bioreactor was developed to produce some of the results of a microgravity environment. In this chamber, sedimentation effects are nearly eliminated, thereby permitting cells to cluster together three-dimensionally -- a process which encourages tissue formation. The bioreactor design produces results similar to those expected in microgravity by using horizontal rotation to suspend different cells types (including liver, muscle, cartilage and bone) and reduce the fluid forces influencing cell growth. Additionally, the design creates an environment which promotes cell aggregation and growth while providing nutrients to cells and removing their waste.

Procedure:



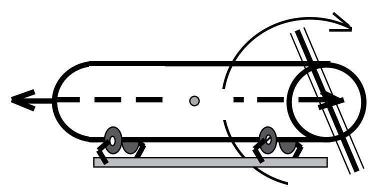
Part I

1. Drop a bead (cell) into the bottle (bioreactor model) and reclose the bottle.
2. Lay the bottle in a horizontal, motionless position on a tabletop. Allow the bead to settle to rest on the interior of the bottle's side. Mark this bottom position on the bottle cap (as in at 6 o'clock on a watchface.)

4. With the stopwatch set at zero, quickly rotate the bottle 180 degrees about its horizontal axis so that the bead is now at the top (or 12 o'clock) position. At the moment the rotation positions the bead at this topmost position, start the stopwatch. Record the time it takes the bead to fall vertically back to rest at the 6 o'clock position.
5. Replace the bead with other beads of various densities and sizes and repeat steps 1-4 for each bead.

Questions: What is the relationship between bead density and time of fall? bead size and time of fall? How does the distance that the bead drops affect the time of fall? What effect does the *viscosity* ("gooeyness") of the shampoo have on the rate of fall?

Part II



1. Start with a bead dropping from the 12 o'clock position as in step 4, Part I. When the bead reaches the central axis, begin rotating the bottle, maintaining the bead in one position without rising or falling. [Note: Smooth rotation may be facilitated by cradling the bottle in a four-caster crib, using a pencil duct-taped securely to the end of the bottle as a crank.]
2. When you have perfected the rotation, have a partner time the rate of rotation. Start and stop the stopwatch for a total of ten complete cycles of the cap marker (for each cycle, the marker moves from 12 o'clock to 12 o'clock.) Record this time. Divide this time by ten to obtain the average time of a single rotation cycle.
3. Repeat steps 1 and 2 of Part II for different types of beads or marbles.

Questions: What statements can you make about the relationship between bead density and time of rotation? Is the bead still falling even though it appears suspended without movement? If not, has gravity changed? If so, why does the bead never reach the bottom of the bottle? How accurately does this setup represent the actual function of a real bioreactor? How is this setup *not* analogous to the way in which the astronauts seem to float inside the orbiting shuttle? How is it both like and unlike falling in an elevator that has had the cable cut?