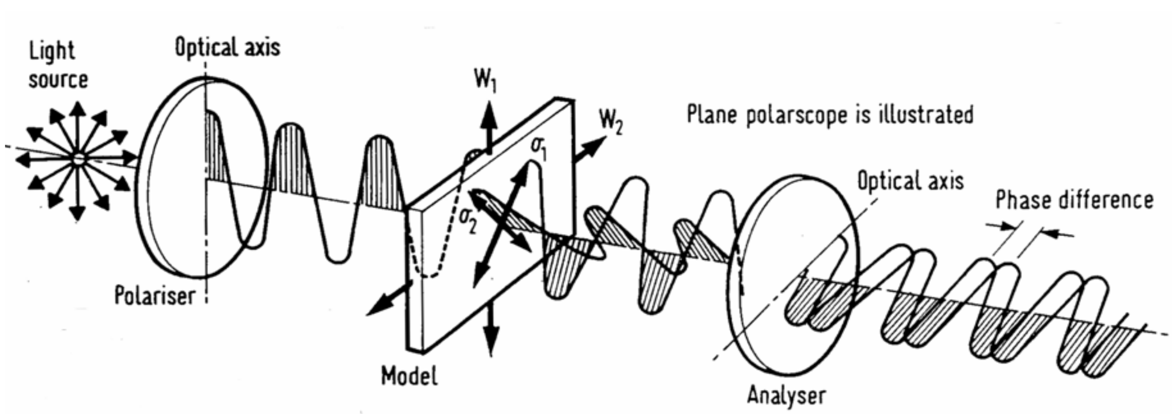
Burrowing by crack propagation

You will be observing *Nereis virens* burrowing in seawater gelatin, mixed up with twice the normal concentration of gelatin (unflavored). You will be observing the stress fields around Nereis using polarized light, a method called photoelastic stress analysis. Photoelastic stress analysis was commonly used by engineers to visualize stress patterns in models of structures and to identify areas where stress was concentrated in order to modify the final product. They would build a model out of some sort of plastic (often epoxy) and apply stress to the model. Now most engineers use numerical models, but photoelastic stress analysis still provides instructive visualization.

In photoelastic stress analysis, a birefringent model material (in our case, gelatin) is placed between crossed polarizers. Stress in the material causes the light to reorient in the directions of maximum and minimum principle stress and to slow down. This reoriented light can then pass through the second polarizer, showing the stress field as a light area. You will be using linear polarizers, as shown in the figure below. Because the light is reoriented in the direction of maximum and minimum principle stress, any light that happens to be already oriented in that direction is not altered and does not then pass through the second polarizer. This results in a dark 'line' indicating the directions of maximum and minimum principle stress.

From Wikipedia, **Birefringence**, or **double refraction**, is the decomposition of a ray of light into two rays (the **ordinary ray** and the **extraordinary ray**) when it passes through certain types of material, such as calcite crystals, depending on the polarization of the light. This effect can occur only if the structure of the material is anisotropic. While birefringence is often found naturally (especially in crystals), there are several ways to create it in optically isotropic materials. Birefringence results when isotropic materials are deformed such that the isotropy is lost in one direction (ie, stretched or bent). Many plastics are birefringent, because their molecules are 'frozen' in a stretched conformation when the plastic is moulded or extruded. For example, cellophane is a cheap birefringent material.



To get started, you will first need to set up the polarizers so they are crossed (and the gelatin appears dark) and clip them to the side of the aquarium. Use one or two microscope lights as your light source. Test your setup by gently pressing the surface of the gelatin with your finger. You should see the stress field resulting from the force of your finger. The area of the stress field is proportional to the force being applied. Convince yourself of this.

The next step is to put the worm in the gelatin. You will need to make a crack in the surface of the gelatin and put the worm in the crack, preferably head down. I would recommend making the crack in the middle of the tank, perpendicular to the polarizers. The worm may not immediately start burrowing, in which case you will need to keep the worm in the crack (without injuring the worm). While the worm is burrowing, describe:

1. the shape of the burrow
2. the behavior of the worm (describe one burrowing cycle)
3. when during the burrowing cycle and where the most stress is applied
4. how the stress patterns change through the burrowing cycle.

The reason we are using gelatin as a clear analog to mud is because it has similar mechanical properties. We will discuss this in lecture, but while you are observing the worm, think about how gelatin must be similar to sediment in order for it to be a reasonable analog. What differences exist between the two media?