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Mixing and Stirring

By: Lorraine Remer, Code 913, NASA/Goddard Space Flight Center, Greenbelt MD 20771 e-mail: remer@climate.gsfc.nasa.gov

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Concept: Combining two fluids (confluence of two rivers, Mediterranean water spilling over the straits of Gibraltar into the Atlantic) involves two processes: (1) stirring -- stretching of the bulk fluid, and (2) mixing -- exchange of materials on the molecular level (diffusion).

Materials: Dancing music (optional), Milk, chocolate milk, several shallow pie pans and spoons, cups for all...

Dancing Molecules: Move the desks so that you have a large, uncluttered area someplace in the room. Have all the students stand in this area. Divide into two teams. Have each team cluster together. Inform the students that each one of them has been transformed into a milk molecule and that all molecules dance. Class start dancing! (The dancing simulates the natural movement of molecules in a fluid -- vibrating, rotating and translation.) Music helps. After a short time, stop the dance and examine the two groups. If they were clustered together in the beginning, there shouldn't be too much mixing of groups. Now do some stirring. Have each team hold hands. Take the two team leaders and walk them around the open space in the room. Because they are holding hands the clusters should spread out as you move the team leaders. Make the two chains of students parallel to each other, in some kind of serpentine figure. OK, class, drop hands and start dancing! After a short time, this time you shouldn't be able to tell who belongs to which team. The fluids have mixed.

Chocolate Milk: Let's mix some fluids! Divide the class into groups of about 4 with each group in possession of a pie pan and a spoon. Pour equal amounts of chocolate and regular milk into the pie pans so that there is roughly 1/4 to 1/2 inch of combined milk in each pan. Pour gently so that you have a blob of chocolate milk residing in the white milk (or vice versa). Ask the question: Do the fluids mix? NO! Gently take the spoon and draw it through the milks. Do this several times. You will start to get long strings of different colored milk. Have the fluids mixed? NO! Play with the milks for awhile. You can make some very pretty patterns with the strands of different colored

milks getting thinner and thinner. As long as you can discriminate between the different colors, the fluids have not mixed. Eventually stir with more vigor and the fluids will mix. Then I always celebrate by passing out a sample of chocolate milk to all the students.

Physics: Molecular motions of molecules permit very little exchange between two neighboring fluids. Two rivers can flow together for miles, side by side, and not mix properties. Blobs of Mediterranean water can be traced, unmixed, in the Atlantic for years. Eventually, molecular diffusion will mix two fluids, but it has a very long time scale. Turbulent stirring stretches the two fluids and increases the amount of contact between the fluids. This permits mixing to occur much more quickly because molecular diffusion is randomly exchanging molecules in many more places (the surface where the two fluids touch has a larger area). **Stirring without diffusion is NOT mixing and CAN be reversed.** This would correspond to not permitting the student chains to drop hands and dance. Without the molecular mixing (dancing), you could just reverse your steps with the team leaders and package each team back up as separate clusters. You need both: the stretching of the fluids to increase contact area AND the irreversible exchange of materials on the molecular level. With the milks, you have to make the strands so thin that the distance of molecular movement is on the same scale as the strand width. If you had stopped stirring during one of the pretty patterns, after several hours you would notice that the thinnest strands might have disappeared. If you pour milk into hot coffee, you may notice the edges of the milk blob getting fuzzy before you stir. That's the molecular mixing at work. It goes faster than the milks because of the temperature. Hot molecules move faster. Still in coffee, you have to stretch out the milk blob by stirring in order to get the fluids to mix. So coffee has its advantages, but chocolate milk goes over much better with kids.

Note on ages: The material is appropriate for grades 6-8, although I've done this with slightly younger kids as well. I'm not sure how much the younger kids really understand (but they do like the chocolate milk!). Sometimes the 6-8th graders are too shy to dance. Eventually, with enough encouragement and by personal example, I get them up and moving.

Note to teachers: The concept of diffusion is difficult. The paragraph above may not be enough information for you to feel completely comfortable in introducing the concept to your students. Supplemental reference material can be found in books on oceanography (look under Mixing in the index), basic physics texts and Encyclopedias (look under Diffusion, Fluids and Fluid Mechanics or Fluid Dynamics and possibly Oceanography). A really nice example comes from oceanography with Gulf Stream meanders and rings. Two fluids are attempting to mix and the result looks a lot like chocolate milk mixing when viewed from space. Oceanography books often show these satellite images.