Elementary Science for Elementary Students

Demonstration: From Smell to Smoke Alarms

Core Concepts:	Odor, Chemical Sensors (artificial, natural)
Other Concepts:	Selectivity, Sensitivity, Transport proteins, Transport Molecules, Membrane
Equipment:	Olfactory Model (1), Velcro Balls (17), Extra Duplo Blocks (6), Toy Cars (3)
	Velcro-backed Vocabulary Words (6)
	Printed Circuit Boards with 1 chemical sensors (9)
	Sample Odors (5 per group)
Facilities:	Long table, working space for student experimentation

Introduction:

The focus of this demonstration is to investigate the differences between natural (nose) and artificial (chemical sensor) perception of odors (smell). Artificial smell sensors and natural smell sensors share many things in common but are also different in many ways. This demonstration discusses these differences in terms of:

- selectivity: what chemicals or odors are the sensors able to pick up?

- sensitivity: how much or how little of an odor are the sensors able to pick up?

The natural smell sensors (human nose) contain about 20 million sensors or receptors (the dog has 200 million) while most artificial sensors contain 10 or fewer sensors. The artificial sensors we discuss in this demonstration are made of a material called tin-oxide, whose electrical resistance decreases in the presence of an odor that can react with oxygen on the surface of the sensor. Many, many different types of artificial sensors are available. The tin-oxide sensors we discuss are termed physical sensors, since they directly convert an odor into an electrical signal. Other types of artificial sensors include:

- biological sensors: made of proteins that interact with odors, both in the nose and elsewhere.

- optical sensors: operate by sending light across air or liquid; the amount and way in which the light is received on the other side of the air or liquid varies with they type of odor present.

- electrolyte sensors: operate through the movement of ions that react with an odor rather than the reaction of electrons with the odor

- and many more...

This demonstration is divided into 3 major components as are all (ES)2 demonstrations. Each component along with its major highlights is described below:

- Pre-demonstration Exercise: This exercise explores preconceptions about both natural and artificial smell. Each student should complete the worksheet on page 8 of this document.

- Interactive Lecture: The lecture covers the core concepts and other concepts of the demonstration
  - Inside of the Nose (Lecture Board)
  - Inside an artificial chemical sensor, the smoke alarm (Lecture Board)

- Experimentation Exercise: allows groups of 2-3 students to experiment with a artificial (chemical) sensor circuit that is equivalent to the sensors in a smoke alarm. Students compare the sensing abilities of their own noses with that of the artificial nose or sensor. Students complete the worksheet on page 9 of this document. Experimentation solutions are included on page 10.

Analogy: Smell vs. Parking Garages

Since it is difficult to see the way our noses or our smoke alarms work, we compare artificial and natural smell to the assembly of building blocks. The fundamental concept in both the nose and in the tin-oxide sensors that we discussed in the introduction is that some pieces (odors) fit into other pieces (sensors or receptors) and some don't. We compare this selective fit to the placement of cars in garages. This analogy can be used by the demonstration instructor as deemed appropriate to clarify concepts of smell. The sensors (receptors) in the nose are more selective (picky) to which odors they will sense than the artificial tin-oxide sensor. One can think of the receptors in the nose as garages and the odors to which they are sensitive being a specific color, and make of car. For example, one type of receptor may react with only lavender scented perfumes; this is similar to a garage that only allows parking for red Ford cars. The car may be a mustang, escort, or pick-up truck, but it must be a Ford for the receptor (garage) to allow it to be sensed. Artificial (tin-oxide) sensors, on the other hand, are most selective to a much broader characteristic of the car: for example the size. One type of artificial sensor (garage) may accept all trucks (Ford, Toyota, Chevy, etc...) while another type of artificial sensor (garage) may accept all types of sport cars (Ferrari, Corvette, etc...). For this reason, artificial sensors have trouble making fine distinctions among odors (the difference between a red Ferrari and a yellow corvette). We can make the following additional analogies between the chemical/odor sensor and the garage:

- Stimulus (the thing being sensed):
  - The odor travels into the receptor (sensor)
  - The car travels into the garage

- Receptor (sensor)
  - The sensor houses the odor temporarily (if it fits)
  - The garage houses the car temporarily (if it fits)

- Proteins: natural smell (nose) only
  - Proteins direct the odor in the olfactory mucus on which sensor to go to
  - A policeman directs the cars into which garage they should go

- Membrane
  - The surface of the inside of the nose houses receptors (sensors)
  - The surface of a chemical sensor has a chemically sensitive material (such as tin-oxide) on it
  - In order to stand upright, the garage needs a concrete surface as a foundation

- Cilia (natural smell (nose))
  - Cilia clean particles off incoming air so that an odor can be properly recognized
  - A car wash would clean a car sufficiently to recognize the color of the car

- Selectivity:
  - Each type of sensors senses only a certain group of odors
  - Each garage houses only a certain type of car

- Sensitivity:
  - Each sensor (receptor) recognizes only a certain number of odors to which it is selective
  - Each garage can only house so many cars Interactive Lecture: Static Electricity

Interactive Lecture: Natural Smell

Part 1: What does the nose do? (introduction)

Request student input on what the nose does. It smells. Yes, but what does it smell? Odors like roses, food, body odor, and gasoline just to name a few. Are there any smells that it doesn't smell? Examples are carbon monoxide, air, desks, and oxygen. Are there some smells like flowers that we like to smell? Are there some smells like body odor that we don't want to smell? The nose is important because it helps us breathe, helps us determine what is good to eat, and smells some odors that are harmful to humans (e.g. smoke). Ask students what they think is inside the nose.

**Part 2: How the nose works (introduction)**

This part of the lecture focuses on an introduction to the nose. We use the diagram of ear, nose and throat on the leftmost section of the lecture board (see figure below). The ear, nose, and throat (taste) interact to create a complex sense of smell. Some things to note here in this introduction are:

- When we breathe, air is filtered through our noses past our smell receptors. How dry the air is, how well we are, and how much mucus is in the nose all play a part in determining we perceive odors. Little hairs called cilia filter the incoming air to remove particles just like the filters in our furnaces at home. All the smell sensors (receptors) are covered by a layer of mucus which acts as a buffer to prevent the nose from being overwhelmed by particular smells if too much of that smell or odor is present.

- Smell and taste are the ONLY two human senses that are affected by emotion. When we go to the grocery store hungry, things we would normally not prefer to eat suddenly look appetizing (YUMMY!). Nerves go both to and from the nose: they travel from the nose to report to the brain what is being smelled. Nerves travel from the brain to the nose to increase sensitivity if we are hungry, if we are scared, etc...

- The human nose contains about 2 million olfactory receptors (smell sensors). Smell sensors (receptors) communicate almost directly in the brain with little circuitry or wiring in between the nose and the brain.

Part 3: The transport of odor molecules to the olfactory receptors (smell sensors)

For this part of the interactive lecture, refer to the middle block of the lecture board that depicts nose hairs (cilia) attached to the olfactory epithelium or membrane. A layer of mucus covers the receptors to try to minimize the possibility of being overwhelmed by too much of a single odor or smell (especially if it is painful or offensive). The receptors reside underneath the mucus and receive odors as transporting mechanism called proteins deliver the odors to them. Proteins can be thought of as cars. They are selective in their transport of odors. Some odors or passengers may be too large for certain proteins (cars). Toy cars may be used to illustrate this concept as they drive up and down the nasal highway seeking garages (receptors) that are suited to accept them. The following analogies are suitable for describing the interaction between transport proteins (cars), mucus (highway), and smell receptors (garages):

We can travel in two different directions on a highway as we breathe in two different directions (inhaling and exhaling). Cars transport people to their destinations. But do all different sizes of people fit into every sized car? No. Can we fit inside a Monster truck? Yes. Can Barney fit inside the same truck? No, he is too big! Suppose we are cruising up and down the highway in the Monster truck, but they are tired and to go home. Where are they going to park at their house? They must park in the garage, of course! The nose works the same way. When we breathe in air, proteins (the Monster truck) transports the odor (the students) to a receptor cell (the garage) that tells the brain what is being smelled. Suppose then that the students were driving a semi-truck instead. Will the semi fit inside the garage? No, because the semi is too big. Can the receptor cell (or garage) smell the odor? No. What if the students were driving a jaguar. Could the car fit inside the Monster truck's garage? Yes, Can that receptor cell smell what was inside the jaguar? Yes.

Receptors located here (under mucus)

Proteins (cars) travel through nasal pathways
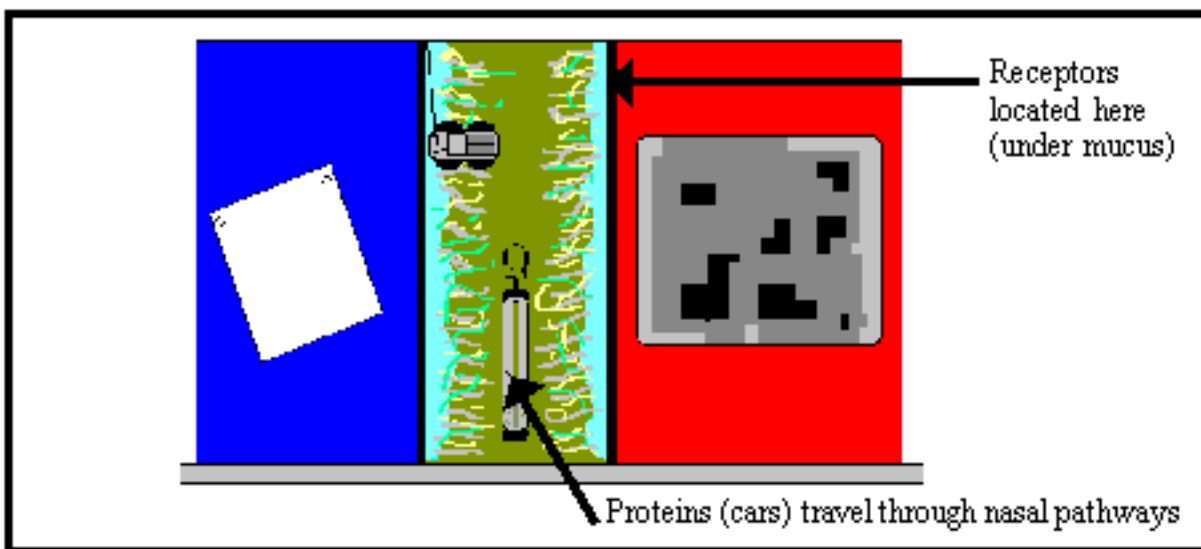
Part 4: The perception of smell by the olfactory receptors

The rightmost half of the lecture board is now used to explain how the smell sensors or olfactory receptors interact with an odor and send a signal to the brain indicating that odor has been smelled. The point we emphasize here is that olfactory receptors are very selective compared to artificial sensors. One type of receptor senses a small group of odors depending on its three-dimensional shape, size, and other physical characteristics. The board of lego blocks is used to illustrate this point. Certain shapes will fit into certain slots while others will not. Allow students to experimenting with fitting different shaped blocks into the slots on the lecture board. The green areas are receptor cells and the yellow blocks are odors. Allow students to discover the solution. Ask the class as a whole after the "proteins" have been placed if the

cell can "smell" the odor being transported by the protein.

Ear, Nose and Throat Diagram

Olfactory Epithelium (Interior of Nose)

Olfactory Receptor
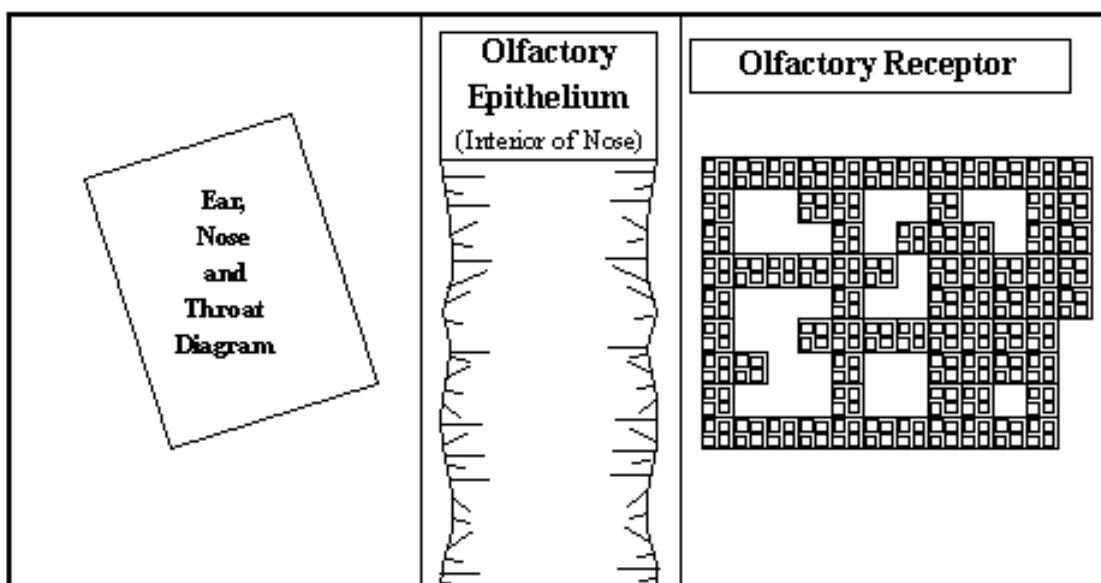
# *Interactive Lecture: Artificial Smell*

Part 1: The smoke alarm

Ask students if they recognize the smoke detector on the other side of the lecture board (opposite to the natural nose). Take apart the spare smoke alarm and ask students to identify certain parts (batteries, speakers, sensor). Some smoke detectors detect the particles in smoke while other detectors chemically react with the chemicals in smoke. The type of smoke detector we are looking at is a particle detector; the particle detectors is the big black chamber in the base of the detector. It passes a light through a dark chamber and sensors evaluate how much the light is blocked; if smoke is present, the light will not reach the sensors very well and the alarm goes off. In the other type of smoke alarm, a sensor conducts more current when it reacts with smoke, again setting off the alarm. These two types of alarms or artificial noses are similar in that they are not very selective. Neither is nearly as selective as the nose is; each type of smoke detector responds to a wide variety of things in the air from burning wood to burning cookies, etc...

Part 2: Analog to the artificial nose

The artificial nose, just like the natural nose, interacts with odors (smoke in this case) just as the human nose does. However, the one sensor in the artificial nose compared to the millions of senors in the human nose reacts to many things and does a poor job of distinguishing among them.

To demonstrate this decreased selectivity in the artificial nose, choose several students to find where the "odor" balls will stick on the artificial sensors. Some of the balls will stick to some sensors better than others and some of the balls will not stick at all. After the volunteers are finished, ask the class if one particular ball sticks to the sensor. If it does, then that sensor can "smell" that "odor". Repeat this with balls that stick and do not stick to the sensors. Artificial noses are important because they "smell" some odors that we humans can smell, cannot smell some odors that we humans can, and can smell some odors that we humans cannot. The sensors are very important since they can "smell" odors that we humans cannot, such as carbon monoxide and smoke.
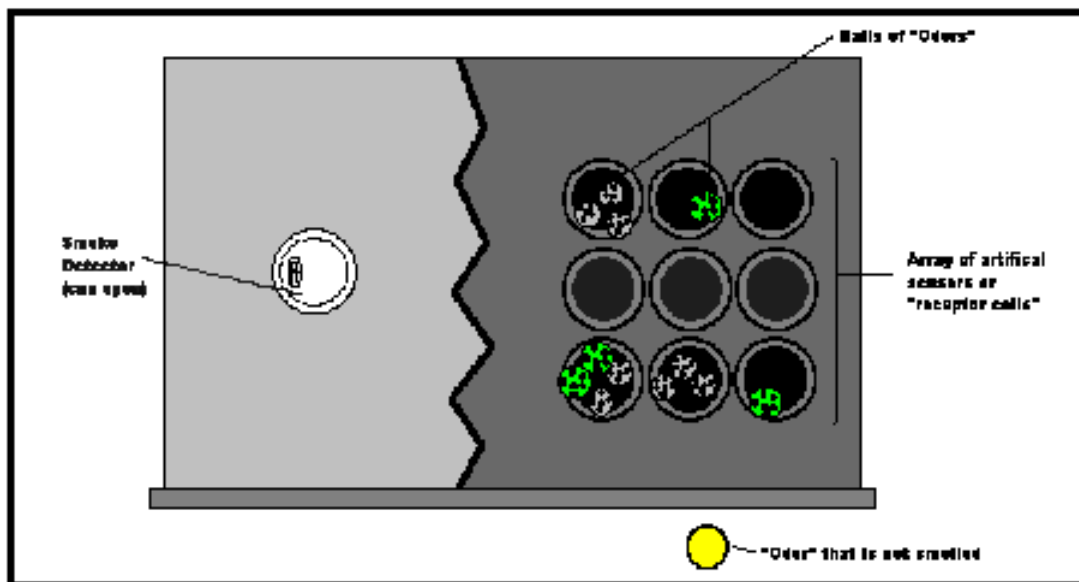
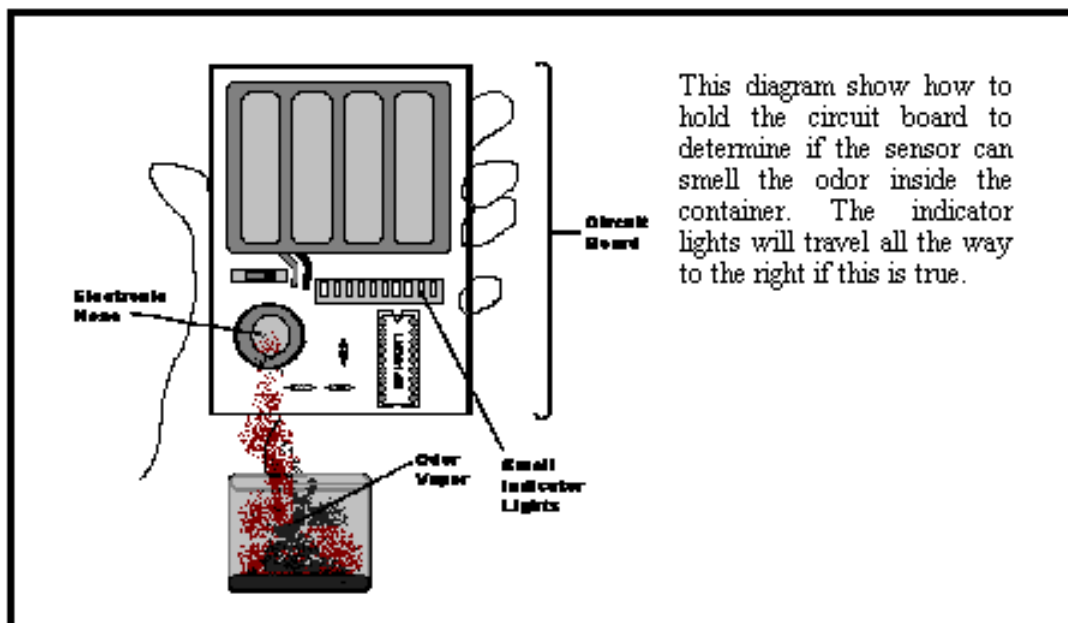# *Experimentation: Artificial vs. Natural Smell*

[Note: while lecturing, switch the circuit boards ON so the sensors can warm up.]

Pass out a hands-on circuit board to each group of 4-5 students. Before handing them out, please encourage the students to be very careful; electronic components are extremely fragile and should be handled carefully. It is especially important for students not to touch the wires on the back of each board. No liquid should be poured on the artificial noses (orange sensors) on the circuit boards: Do you like liquid poured up your nose: the sensors wouldn't like that either.

An engineer is a person who solves problems. The problem the students are solving today is to discover whether or not they can smell a particular odor, if a sensor can smell the same odor, and to determine what is the odor.

Hand out odors (in baby food jars) one at a time; students will be filling out their experimentation workshops as they move through odors 1-5. Starting with odor 1, ask students to open the jar, smell it and then hold it close to the sensor on their circuit board to see if the sensor can smell the odor. Odors should be fanned toward the natural nose (child) or the artificial sensors. If the sensors smells the odor, the indicator light will move to the right. The stronger the odor is to the sensor, the further to the right the indicator light will move. Students should complete their worksheets for odor 1 at this time. Can they smell the odor? Can the artificial nose smell it? Can they name the smell?

Repeat this process for odors 2, 3, 4, and 5.

This diagram show how to hold the circuit board to determine if the sensor can smell the odor inside the container. The indicator lights will travel all the way to the right if this is true.

Clean up: ask each group to remove the 4 AA batteries and return the circuit boards to the teacher so they can be put away.