Module 1: Activity 1

What is Air?

IT'S OUR AIR

SUMMARY

The first step in learning about air pollution is learning about air. Through a variety of hands-on experiences presented as stations in the classroom, students will discover properties of air, including that air has volume, mass, and pressure; that it is compressible; and that it expands when heated. They will also learn about the major molecular components of our atmosphere (nitrogen, oxygen, argon), the four layers of our atmosphere, and that air contains water vapor.

ESSENTIAL QUESTIONS

- What is air made of?
- What are some of the properties of air?
- How can we demonstrate those properties when air is invisible?
- Is our atmosphere homogenous or does it change with elevation?

TIME NEEDED

One class period plus 20 minutes of setup and review/assessment on the next day.

North Carolina ESSENTIAL STANDARDS FOR EARTH/ENVIRONMENTAL SCIENCE

- EEn.2.3.1 Explain how water is an energy agent (currents and heat transfer).
- EEn.2.5.1 Summarize the structure and composition of our atmosphere.
- EEn.2.5.5 Explain how human activities affect air quality

A product of the NC Air Awareness Program 2014.

MAKING CONNECTIONS

Air is invisible yet it is essential to our survival. Many kinds of air pollution are invisible as well, yet they have very real consequences to human health, as well as the health of plants and animals. Students need to challenge themselves to think abstractly about invisible substances that are significant to humans. Finding ways to understand things that are invisible to the naked eye is an essential skill for studying any number of scientific topics from nuclear physics to medicine to nanotechnology.

BACKGROUND

COMPOSITION OF AIR

Dry air in our atmosphere consists primarily of nitrogen (about 78%), oxygen (about 21%) and argon (0.9%). As students will learn over the course of the curriculum, there are many other gases present in much smaller amounts: water vapor, carbon dioxide, methane, nitrogen oxides (NO_x), sulfur oxides (SO_x), ozone, etc. Furthermore, air also contains solids (such as pollen, dust, soot, and various pollutants) and liquids (such as droplets of water and liquid pollutants). (Students will review the composition of the atmosphere and learn how to express the relative amount of a gas in the atmosphere using "parts per million" and "parts per billion" in the activity "Investigating Parts Per Million, Drop by Drop.")

Volume of the Most Abundant Gases in Our Atmosphere

Gas	Volume in Parts Per Million (ppm)	Percent	Atomic Symbol	Bond
Nitrogen	780,840 ppm	78.0840%	N_2	triple
Oxygen	209,460 ppm	20.946%	O_2	double
Argon	9,340 ppm	0.934%	Ar	none
Carbon dioxide	400 ppm*	0.040%*	CO_2	double
Neon	18.18 ppm	0.001818%	Ne	none
Helium	5.24 ppm	0.000524%	He	none
Methane	1.79 ppm	0.000179%	CH_4	single
Krypton	1.14 ppm	0.000114%	Kr	none
Water vapor	40,000 ppm	0 to 4%	H_2O	single

Source: American Meteorological Society
**levels change both seasonally and over time*

PROPERTIES OF AIR

As you read about the following properties of air, keep in mind that they are interrelated. It is not possible to change one property of air without changing another property of air.

Air takes up space. Air has volume and, if enclosed in a container, will expand to fill the container. Students will discover that air has volume when they try to put their hand into a jar that's sealed with a dishwashing glove. You can push the glove in a little way, but not very far because air in the jar takes up space.

Air has mass. Air doesn't have as much mass per unit volume compared to say, gold, but it does weigh something. Note that in common usage, people often use the terms weight and mass interchangeably, because at sea level on Earth they are the same. However, out in space, an object still has mass although it would have almost no weight because almost no gravity would be acting on it. At sea level, a liter of air weighs 1.2 grams – about half the weight of a penny.

Air exerts pressure. Atmospheric air pressure is a very important concept in meteorology – it refers to the weight of air in a column above a particular point. Atmospheric air pressure is higher at sea level than the top of Mt. Everest because there is a bigger pile of air above a point at sea level than a point on the top of Mt. Everest. We don't notice air pressure much in our day-to-day lives, except perhaps when our ears pop when we gain or lose a lot of altitude in a plane or car. However, students may have had experience blowing up a balloon, or pumping up a bicycle tire or car tire. When we force more and more air into the tire, we increase the air pressure inside the tire relative to the atmospheric air pressure outside of it. What this means is that air molecules inside the tire are exerting more force against the inside of the tire compared to the force exerted by air molecules on the outside of the tire. Students will be able to observe and experience air pressure when they experiment with the glove-and-jar set-up. As they push a hand in, they'll feel increasing pressure on all surfaces of the glove. When they try to pull the glove out, they'll notice the sides of the glove being pulled in as the air pressure in the jar lowers due to the increasing volume. For extra help explaining air pressure, be sure to check out the demos in the video that illustrate air pressure.

Air can be compressed and decompressed. When air is compressed (high pressure), its molecules are closer together; when it is decompressed (low pressure), its molecules are farther away from each other. This property allows you to push the glove a small distance into the jar (compressing the air) and to pull it out a small amount (decompressing it). In comparison, water is essentially incompressible. Water at the bottom of the ocean is a little more dense than water above it, but the difference is very small. When you try to force the glove into a jar of air, you are able to move it into the jar a little bit because you are compressing the air. You would be unable to do this if the jar were filled with water; the water would spill out immediately if you tried to push your hand in.

Air expands when heated. This is how hot-air balloons work. The warmer air expands and becomes less dense. Because it is less dense than the surrounding cooler air, the balloon rises. The fact that hot air rises can also be demonstrated with a common Christmas decoration consisting of small candles that, when lit, power windmill blades that cause a carousel or other figures to spin in a circle. (One of these carousels is demonstrated in the video.)

Many of the properties of air are interrelated, and when one property is changed, the others will change in predictable ways. Here are some examples: When the volume of a certain amount of air is decreased, the air is compressed, the air pressure increases and the temperature of the air will initially rise before equalizing with the surroundings. If you rapidly release air under pressure it will cool quickly and the water in the air will condense to a visible cloud. When air is heated it expands, takes up more volume, and has less pressure.

WATER IS IN AIR

The amount of water in the atmosphere varies, but even on a hot humid day, it is less than 4% of the total mass of the air. The amount of water in the atmosphere is only 0.001% of the total amount of water on Earth.

Students may have learned about cloud formation before, and they may have misconceptions about water vapor, water condensation, and cloud formation.

Water vapor is the gaseous form of water. It's invisible. Mist, fog, and clouds are not water vapor. They are water droplets – water that has condensed out of the air.

Latent heat is the heat given off when water condenses, and the heat absorbed when water evaporates. Everyone has experience with the heat absorbed when water evaporates – that's why your skin feels cool when sweat or water on it evaporates in a breeze.

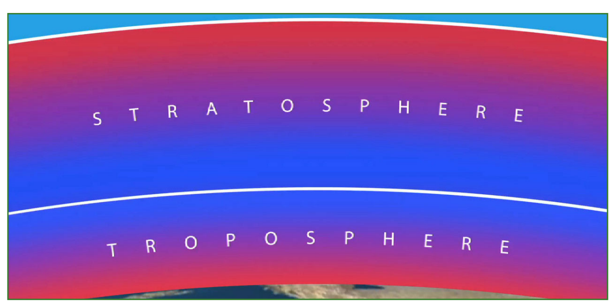
Cold air holds less water vapor than warm air. What this means is that when a particular parcel of moist air gets cool enough, water vapor changes to liquid water (water droplets). That's why clouds form when warm parcels of air rise into the atmosphere and encounter cooler temperatures aloft. It's also why dew forms when temperatures cool overnight.

LAYERS OF THE ATMOSPHERE

Scientists have divided the atmosphere into different layers based primarily on temperature gradients within the layers. Density decreases as you travel up in the atmosphere. Temperature, on the other hand, rises or falls with altitude depending on which layer you are talking about.

Temperatures in the troposphere – the lowest layer, which contains the air we breathe – decrease as you go up. That's why it's cooler in the mountains. Much of the heat in the troposphere comes from heat (from the sun) radiating back from the Earth's surface. For this reason, the parts of the troposphere closest to the Earth get the warmest. Because the troposphere is coolest at the top and because hot air rises, there is always a lot of mixing going on (instability) and that means weather! Weather rarely reaches into the stratosphere, which is the next layer up, although occasionally the tops of big thunderstorms poke up a little bit into the stratosphere. The height of the troposphere can vary from 4 miles to 12 miles (6 to 20 kilometers) depending on location, season, and weather conditions.

Temperatures rise with height in the stratosphere, which makes the air in the stratosphere relatively stable because the cooler air at the bottom tends to stay at the bottom and the warmer air at the top tends to stay at the top. Because the stratosphere is not very turbulent, commercial airlines often cruise just above the tropopause – the boundary between the troposphere and the stratosphere. There is not much moisture in the stratosphere, so virtually all clouds you see are in the troposphere. The stratosphere is the layer with "good" ozone.



The bottom two layers of the atmosphere – the troposphere and the stratosphere – contain 99.9% of the mass of the atmosphere. The two upper layers – the mesosphere and the thermosphere – take up a lot of space, but they are very low in density.

MATERIALS

- Videos (streaming from www.itsourair.com or downloaded for playback):
  - *What Is Air?* Part I
  - *What Is Air?* Part II

STATION 1: What are the Components of Air?

- Molecule sets (or construction paper and pipe cleaners or Styrofoam balls and toothpicks)
- Transparent jar or plastic bag containing 100 marbles or beads in these proportions: 78 in one color, 21 in another color, 1 in a third color.

STATION 2: Can We Feel Air Pressure?

- One-quart or larger wide-mouth Mason jar or pickle jar (the mouth should be big enough to insert a large hand, yet small enough to cover with a dishwashing glove)
- Dishwashing glove (or nitrile glove)

STATION 3: How Do Heating and Cooling Affect Air?

- Two empty glass bottles (e.g., wine bottle, Perrier bottle)
- Balloons to fit on the neck of the bottles
- Container of hot water, big enough to submerge bottom half of bottle
- Container of ice water, big enough to submerge bottom half of bottle

STATION 4: How Do Temperature, Volume, and Pressure Interact?

- Glass jar (large, wide-mouth mason jar)
- Water balloons, several, in case one breaks
- Several tea candles
- Matches
- Metal tongs to lower tea candle(s) into the jar (or use fireplace matches or lighter to light Candle after you've placed it in jar)
- Plastic tray or dishpan, optional

STATION 5(A): What Happens When Water Vapor in the Air Condenses?

- One-quart or larger wide-mouth jar
- Hot water from a faucet (or in an insulated pitcher or kettle)
- Small non-disposable plate (to fit over mouth of jar)
- Gallon freezer bag filled with ice cubes

STATION 5(B): What Happens When Water Evaporates into the Air?

- Two thermometers
- Fan
- Small amount of gauze
- Water
- Rubber band
- Sling psychrometer (optional)

Classwork or Homework: The Atmosphere has Layers

- Data sheet (included)
- Graph paper (included)

WARM**UP**

In a class discussion, review the states of matter with your students: solid, liquid, gas, and plasma. (Stars are made of plasma, which is uncommon here on Earth.) Ask students to list similarities and differences among solid, liquid, and gas states.

Ask students to define air, either in writing or in a class discussion. Ask them whether air takes up space. Does it weigh anything? What are some ways we use air?

Ask students if they can name any of the gases in our atmosphere, in writing or in a class discussion. Ask if anyone knows what the most abundant gas in our atmosphere is.

WHAT IS AIR? VIDEO

PART I

- Introduces and provides animation and live demonstrations of the basic properties of air (air has volume and mass; air exerts pressure; hot air rises; air is a fluid).
- Introduces to the basic components of air (nitrogen, oxygen and argon).
- Explains that the other commonly known components of air are measured in parts per million or parts per billion.
- Introduces the concept of water in air in the form of water vapor and clouds.

Video Length: 11:30 minutes
Key elements: demonstrations, animation, video footage

PART II

- Reviews the hydrologic cycle with an emphasis on how water enters and exits air via evaporation, condensation, precipitation, and transpiration.
- Demonstrates how clouds are formed by creating a cloud in a bottle.
- Introduces and provides animation of the layers of the atmosphere with an emphasis on how their structure affects air movement and weather.
- Demonstrates how air moves in the atmosphere by causing movement in a tub of water by applying heat.

Video Length: 10:00 minutes
Key elements: animation, demonstrations, video footage

Teacher Tips

Set-up Time: 20 Mins. **Activity Time:** One Class Period

I recommend groups of three or four for these activities with station changes every 10-15 minutes depending on total class time (15 minutes for block schedule, 10 minutes for traditional schedule [45-60 minutes] with students answering questions for homework). The time can also vary based on how advanced your students are. Set the stations up around the room so that students aren't crossing each other's paths during changeovers. Before we begin, I emphasize proper set-up at each station and tie activity points to the set-up – that is, if the next group notices that the station is set up incorrectly when they rotate, then the first group does not get the full points awarded for that station.

I save the review and student assessments for the next day.

One of my favorite aspects of this activity is that it can be used as a formative assessment for your students. Place a small shoe box with a hole in the top at each station and have the students anonymously rate the difficulty from 1-4 with a note card. When the activity is complete, you will have some excellent data to use to help assess your students' understanding of these concepts. I get very honest answers from my students when it is done anonymously, and this allows me to re-teach or change my focus accordingly.

– Mark Townley

THE ACTIVITY

This activity contains several components that need to be done in the following order:

PART A: Video (Part I) and Demonstration Stations

a. Show Part I of What Is Air? video and have students fill out video worksheet.
b. Have students rotate through stations.

PART B: Video (Part II) and Layers of the Atmosphere Worksheet

a. Show Part II of What Is Air? video and have students fill out video worksheet.
b. Have students complete Layers of the Atmosphere Worksheet (in class or as homework).

PART A: Video (Part I) and Demonstration Stations

Set up the classroom as detailed below, then show Part I of the video, What is Air? Because it contains so much fundamental information about the properties of air, the video is integral to this activity. Have students fill out the video worksheet as they watch it. If practical, you could have the students watch the video at home the day before you do the activity in class.

SET UP

Set up the following stations around your classroom. At each station, place the listed materials and the appropriate student activity sheets on a desk or counter. Ideally, Stations 3 and 5 will be near sinks with a source of hot water. For the first part of Station 5, you will need enough hot water for each group to fill or refresh the jar with about 2 inches of water – try using an insulated pitcher or tea kettle if you don't have a faucet.

VIDEO – PART I WORKSHEET ANSWER KEY

1. List the four states of matter: [Answer: solid, liquid, gas, plasma] Mark an X through the one that is not relevant to understanding air. [Answer: plasma]
2. Is air a solid, liquid or gas? [Answer: mixture of gasses]
3. Water doesn't fill the upside down glass because... [Answer: air has volume]
4. The crushed bottle weighs less than the one with air because... [Answer: air has mass]
5. At sea level, our atmosphere exerts a pressure of... [Answer: 14.7 lbs per square inch (PSI)]
6. What keeps everything on the surface of the earth from being crushed by the pressure of the atmosphere? [Answer: equilibrium]
7. When air is heated, it… [Answer: expands, becomes less dense, rises]
8. Write in the following words in the correct places on the flow chart to the left. Liquids, Gasses, Fluids [Answer: fluids on the top row, liquids and gasses on the bottom row]
9. Write in the names of the 3 major gases in our atmosphere and draw a line to the wedge on the pie chart that shows the percentage for each one. [Answer: Nitrogen (large blue wedge), Oxygen (smaller pink wedge), Argon (very small red wedge)]
10. What is the name of the invisible, gaseous form of water in air? [Answer: water vapor]

After students have watched the video, divide students into pairs or teams and have them move from station to station, filling out the worksheets at each one. Assign each group a starting station, then have them move through them in order from that station, circling back to Station 1 when they finish Station 5.

STATION 1: What are the Components of Air?

More than 99% of air is made of three gases: nitrogen, oxygen, and argon. Air contains other gases in very small quantities, including gaseous water, which is called water vapor. Air also contains solids and liquids. Solids in air include pollen, dust, and soot. Liquid in the air includes droplets of water (in clouds and fog) and certain pollutants.

1. Study the table titled "Volume of the Most Abundant Gases in Our Atmosphere." Using the information in the column labeled "Volume in parts per million (ppm)," fill in the column labeled "Percent." The first one has been done for you.
2. Which are the three most abundant gases? What percentage of the atmosphere does each make up? [nitrogen – 78.084%, oxygen – 20.946%, argon-0.934%]
3. The container filled with beads represents the proportions of the three major gases in the atmosphere. Which color corresponds to each of the three gases?
4. Use the molecule set to make models of nitrogen and oxygen.
5. Make models of at least two of the gases shown in the table that exist in much smaller quantities in our atmosphere.
6. Draw pictures of the molecular models you made, labeling the atoms.
7. Before moving to the next station, take apart the molecule models you made.

Volume of the Most Abundant Gases in Our Atmosphere

Gas	Volume in Parts Per Million (ppm)	Percent	Atomic Symbol	Bond
Nitrogen	780,840 ppm	[78.0840%]	N_2	triple
Oxygen	209,460 ppm	[20.946%]	O_2	double
Argon	9,340 ppm	[0.934%]	Ar	none
Carbon dioxide	400 ppm*	[0.040%]*	CO_2	double
Neon	18.18 ppm	[0.001818%]	Ne	none
Helium	5.24 ppm	[0.000524%]	He	none
Methane	1.79 ppm	[0.000179%]	CH_4	single
Krypton	1.14 ppm	[0.000114%]	Kr	none
Water vapor	40,000 ppm	[0 to 4%]	H_2O	single

Source: American Meteorological Society

**levels change both seasonally and over time*

STATION 2: Can We Feel Air Pressure?

Air may look like nothing, but it does take up space. In other words, it has volume. Air also exerts pressure.

1. Drape the glove into the jar, fingers down, and fold the cuff over the mouth of the jar. (If using a plastic bag instead of a glove, drape the bag into the jar, then use a rubber band to secure it to the rim of the jar, forming an air tight seal.)
2. Place your hand in the glove and attempt to push it in farther or pull it out. You will be able to push it in or pull it out a small amount, but after that your hand will meet serious resistance. Why? [Answer: because the jar is already full of something – air!]
3. What does it feel like when you first begin pushing your hand into the jar and how does the sensation change as you continue pushing? What property of air are you feeling on your hand? [Answer: you feel more and more pressure all over your hand; air pressure]
4. What happens when you try to pull the glove out of the jar? Why? [Answer: the sides of the glove get sucked in; air pressure in the jar is getting very low as you increase volume; this creates suction on the glove]
5. Why are you able to push the glove in or pull it out at all? Would you be able to do that if the jar were filled with water instead of air? Sand instead of air? [Answer: Yes, it's possible to push the glove in and pull it out. No because air is compressible; water is only minimally compressible (not noticeable), sand is not.]
6. Before moving to the next station, remove the glove from the jar.

STATION 3: How Do Changes in Temperature Affect Air?

Temperature changes are the primary drivers of air movement and weather in our atmosphere. See if you can explain how heating and cooling is affecting the air molecules in the balloons.

1. Place one bottle in a container of hot water, and the other in a container of ice water.
2. Place a balloon on the neck of each bottle.
3. Now take the bottle from the ice water and put it in hot water. What happens? Why? [Answer: balloon expands because the air in the bottle is heated and expands into the balloon]
4. Take the bottle that started out in the hot water and place it in the ice water. What happens to the balloon? Why? [Answer: balloon deflates because air in the bottle gets cooler and contracts]
5. Before moving to the next station, remove the bottles from the containers of water, and take off the balloons.

STATION 4: How Do Temperature, Volume, and Pressure Interact?

Properties of air are interrelated. When one property is changed, the others will change in predictiable ways.

1. Light the tea candles(s) and carefully use the tongs to place the candle(s) in the bottom of the jar.
2. Place the water balloon on top of the jar.
3. Watch the balloon carefully and notice what happens.
4. Describe what you observed about the balloon, if anything, while the candle(s) burned. [Answer: students may have seen the balloon jiggling a little bit as air escaped around it]
5. Describe what happened to the balloon after the candle(s) went out. [Answer: balloon was pushed into the jar, either partially or completely]
6. Use what you know about changes in air temperature and changes in air pressure to explain what you observed. [Answer: As the air in the jar heated up, it expanded and some escaped around the balloon. When the candles went out, the air in the jar cooled and the air pressure dropped. At that point, the air pressure on the outside of the jar and balloon was higher than the air pressure in the jar, with the result that the balloon was pushed into the jar.]

Teacher Tips

- Experiment the day before to come up with the right number of candles and the right size of water balloon to work with the jar you are using. This demo is particularly fun if the entire water balloon falls into the jar.
- You may wish to put all the materials in a plastic tray or dishpan in case the water balloon breaks while students are handling it.

– Mark Townley

STATION 5(A): What Happens When Water Vapor in the Air Condenses?

Air contains water vapor, which is the gaseous form of water. Cold air holds less water vapor than warm air.

1. Put about two inches of hot tap water in a jar.
2. Cover the mouth of the jar with a small plate.
3. Place the gallon bag of ice cubes on the plate.
4. You will need to wait a few minutes before finishing this demonstration – while you are waiting, do Part B of this station. When you're finished with Part B, continue with steps 6 and 7 below.
5. What do you see on the bottom of the plate? Why? [Answer: condensation will form on the bottom of the plate and drip off. Water vapor in the air condenses on the cold plate, because cold air holds less water vapor than warm air.]
6. Before moving to the next station, remove the plate from the jar. Take off the bag of ice and wipe off the bottom of the plate.

STATION 5(B): What Happens When Water Evaporates into the Air?

When water evaporates, heat is absorbed.

1. Read the temperature on both thermometers.
2. Take a small piece of wet gauze and wrap it around the bulb of one of the thermometers, securing it with a rubber band.
3. Wrap dry gauze around the other thermometer, to serve as the control.
4. Direct a fan at the thermometers and turn it on. You can either hold the thermometers in front of the fan, or leave the thermometers on the table and direct the fan toward them. Make sure each thermometer is the same distance from the fan.
5. Record the temperature on the thermometers every thirty seconds. What happens? Why? [Answer: The temperature on the "dry bulb" thermometer does not change, whereas the one on the "wet bulb" thermometer decreases. That's because the water evaporating off the wet gauze removes heat from the surface of the thermometer bulb. This is called the latent heat of evaporation.]
6. Why do we feel cooler when a fan blows on us? [Answer: because our sweat is evaporating.]
7. Before moving to the next station, turn off the fan and remove the gauze from the thermometers.
8. Don't forget to finish Part A of this station!

Teacher Tips

- If you have a sling psychrometer, you can use that at Station 5 and you will not need a fan. Simply have the students compare the wet bulb and dry bulb temperatures on the sling psychrometer rather than comparing the temperature of the thermometer with dry gauze to the thermometer with wet gauze.
- If your class is already familiar with relative humidity, supply them with a chart and have them figure out what the relative humidity is in the classroom using the wet and dry bulb temperatures.

– Mark Townley

Part B: Video (Part II) and Layers of the Atmosphere Worksheet

Show Part II of the video, What Is Air? Students should complete the video worksheet as they watch.

VIDEO – PART II WORKSHEET ANSWER KEY

1. Name some of the processes that take place in the hydrologic cycle. [Answer: evaporation, condensation, precipitation, transpiration, freezing, thawing]
2. Water vapor is more likely to condense into clouds where the air temperature is... [Answer: lower]
3. Label the lower two layers of the atmosphere on the diagram on the left. [Answer: troposphere (next to Earth), stratosphere (above troposphere)]
4. Name the lower layer of the atmosphere and connect the temperature with the correct location. [Answer: troposphere, higher temperatures -> lower in layer, lower temperatures -> higher in layer]
5. What are the three major factors that cause air to move around so much in the lower layer of the atmosphere? [Answer: the air is warmer at the bottom, air is a fluid, hot air rises]
6. Name the second layer of the atmosphere and connect the temperature with the correct location. [Answer: stratosphere, higher temperatures -> higher in layer, lower temperatures -> lower in layer]
7. The ozone layer in the second layer of the atmosphere [Answer: absorbs] solar radiation.
8. In which layer of the atmosphere is ozone a good thing and which is it a danger to our health? Ozone is a good thing in the [Answer: stratosphere]. Ozone is bad for us in the [Answer: troposphere].
9. In which layer(s) of the atmosphere will you find 99.9% of the atmospheric mass? [Answer: troposphere and stratosphere]
10. In which layer of the atmosphere will you find most of the clouds, weather and pollution? [Answer: troposphere]

After the video, have students do the Layers of the Atmosphere worksheet in class or as homework.

Layers of the Atmosphere Worksheet

Scientists have divided our atmosphere into different layers: troposphere, stratosphere, mesosphere, and thermosphere.

The lowest layer is the troposphere. In the troposphere, temperatures decrease as you go up. Much of the heat in the troposphere comes from the sun's heat radiating back from the Earth's surface, so the parts of the troposphere closest to the Earth get the warmest. Because the troposphere is coolest at the top and because hot air rises, there is always a lot of air movement and mixing going on and that means weather!

The height of the troposphere varies from 6-20 kilometers in altitude (4-12 miles), depending on location, season, and weather conditions.

The next layer up is the stratosphere. Weather rarely reaches into the stratosphere, with the exception of the tops of thunderstorms. Temperatures increase with altitude in the stratosphere, which makes the air in the stratosphere relatively stable.

The next layer up is the mesosphere. Temperatures decrease with altitude in the mesosphere.

The next layer up is the thermosphere. Temperatures increase with altitude in the thermosphere.

Thinner layers of relatively consistent temperatures form the boundaries between the four layers. The boundary at the top of the troposphere is called the tropopause. The boundary at the top of the stratosphere is called the stratopause. The boundary at the top of the mesosphere is called the mesopause.

1. Graph the data in the following table using the graph paper provided. After you have plotted the data, connect the points with a line.
2. Label the following zones on your graph:

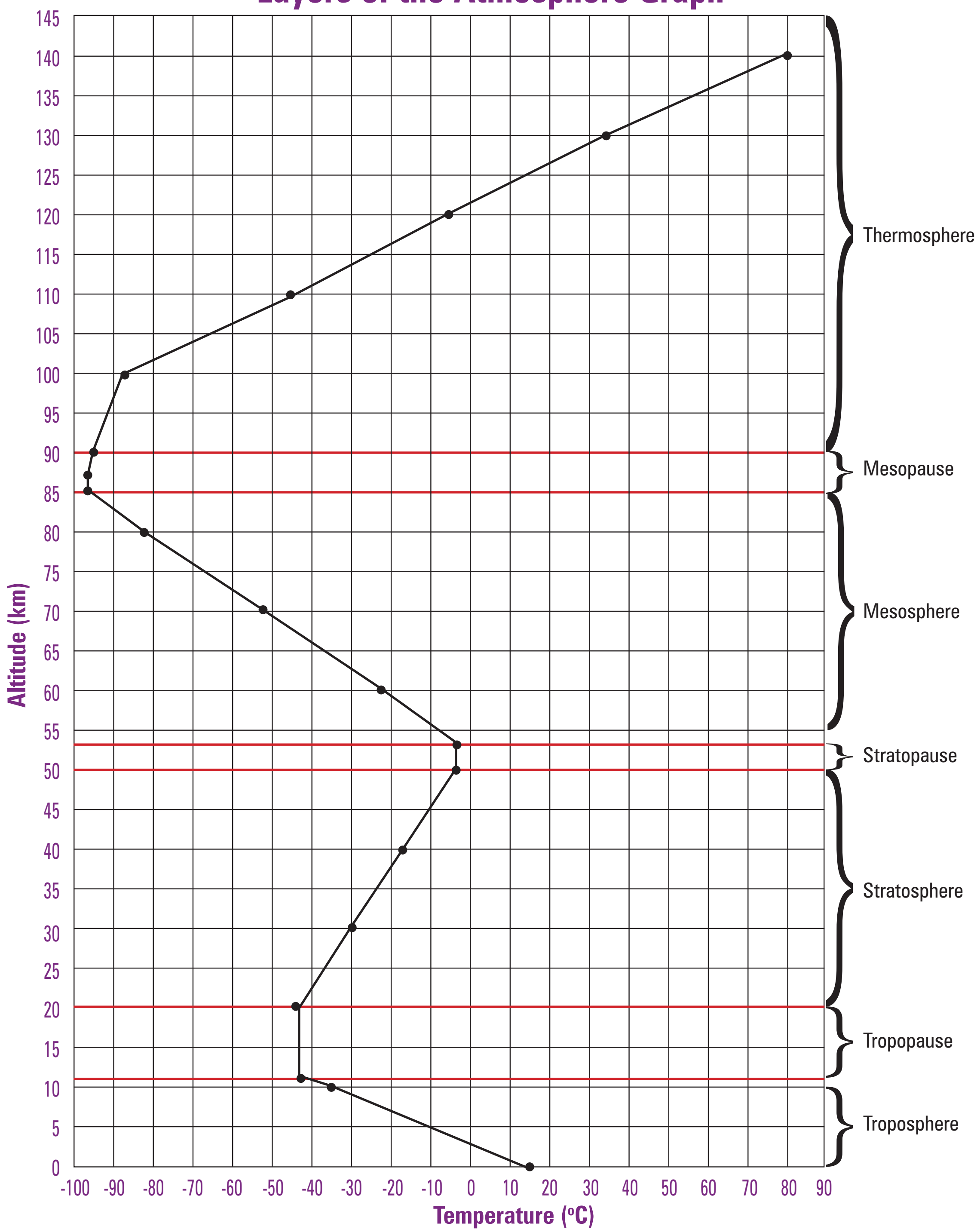
Altitude in kilometers (km)	Temperature in degrees C
0	15
10	-35
12	-43
20	-43
30	-30
40	-16
50	-4
53	-4
60	-23
70	-52
80	-82
85	-97
87	-97
90	-95
100	-87
110	-45
120	-2
130	38
140	80

- Troposphere
- Tropopause
- Stratosphere
- Stratopause
- Mesosphere
- Mesopause
- Thermosphere

3. Why does virtually all weather happen in the troposphere? [Answer: because its temperature gradient makes it unstable – warm air is constantly rising and cold air is constantly sinking so there is a lot of movement and mixing.]

4. What causes the temperature gradient you see in the troposphere? [Answer: Most of the heat in the troposphere comes from heat radiating back from the surface of the Earth. Areas closer to the surface of the Earth are warmer than areas farther away.]

Layers of the Atmosphere Graph



WRAP UP AND ACTION

As a class make a list of ways that we notice or use or benefit from of the properties of air in our daily lives [Answer: Some examples include inflated tires, air pumps, balloons, air mattresses, the way plastic bottles contract on an air plane or up in the mountains and expand again when you come back down, all kinds of weather including air currents and wind].

Let the students know that for much of this curriculum, they will be learning about things that are invisible to the naked eye, yet have measurable qualities. Have a class discussion about the difference between "invisible" and "nothing." Just because you can't see something, does that mean nothing is there? What are some ways to demonstrate that something invisible really exists? What are the challenges of scientifically exploring things that are invisible?

ASSESSMENT

HAVE STUDENTS:

- Turn in their worksheets for grading.
- Explain in writing some of the properties of air and how these properties can be demonstrated.
- Come up with other ways of demonstrating some of the properties of air besides the activities the students did at each station. If you have time, try some of them out in class.
- Set up stations like you did for the activity, but with no titles or instructions. Have students demonstrate and explain the relevant concepts at each station.

EXTENSIONS

If you have time, allow students to experiment some more with the jars and gloves. See what happens if you fill the jar with water instead of air. Put the jar in a plastic dishpan first because water will force its way through the seal between the glove cuff and the jar and come spilling out everywhere. Ask the students to compare and contrast the experiment with water and with air. In what ways are water and air alike and different? [Answer: both are clear, both take up space, both flow (unlike solids); air is compressible while water is not, water is wet while air is not]

Another fun thing to do with the jars and gloves is to cut the finger off one glove and let students try the activities again. When air can move through the hole in the glove, there will be no difference in air pressure between the inside of the jar and the outside. (If you do this, you may want to use nitrile gloves, which are less expensive than dishwashing gloves.)

Your students may enjoy learning to use instruments to measure the properties of air, including barometers, psychrometers, thermometers, and anemometers. For instructions for making your own psychrometer, see http://science-edu.larc.nasa.gov/SCOOL/psychrometer.html.

For instructions for making your own barometer, see http://kids.earth.nasa.gov/archive/air_pressure/barometer.html.

Consider setting up weather stations around campus and teach students how to collect data at each site – temperature and relative humidity, precipitation, pressure, wind speed and direction, cloud cover. Have students work in groups to collect data each day for at least one week (longer if possible!) Have students record data in a weather log. Students can use the data collected each day to make predictions for the following day.

RESOURCES

Bottle-and-balloon activity:
http://www.wrh.noaa.gov/vef/kids/magicballoon.php

Graph of atmospheric layers from UCAR: http://www.windows.ucar.edu/tour/link=/earth/images/profile_jpg_image.html

For a thorough summary of information about the layers of the atmosphere, see http://www.shodor.org/metweb/session1/layers.html

Info about layers of the atmosphere from NOAA: http://www.srh.noaa.gov/jetstream//atmos/layers.htm

What is Air?

Student Page
Video Part I

WORKSHEET Page 1

1

List the four states of matter:

__________________ __________________

__________________ __________________

Mark an “X” through the one that is not relevant to understanding air.

2

Is air a solid, liquid or gas?

____

3

Water doesn’t fill the upside down glass because…

____

4

The crushed bottle weighs less than the one with air because…

____

5

At sea level, our atmosphere exerts a pressure of…

____

IT'S OUR AIR

What is Air?

Student Page
Video Part I

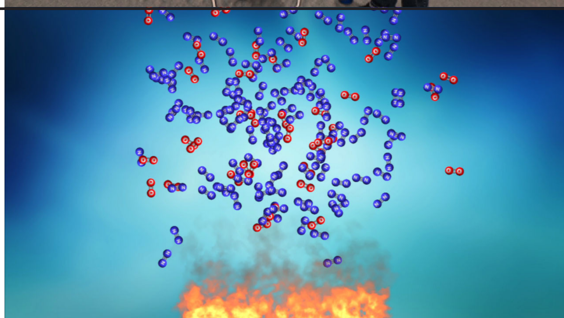
WORKSHEET Page 2

6

What keeps everything on the surface of the Earth from being crushed by the pressure of the atmosphere?

____

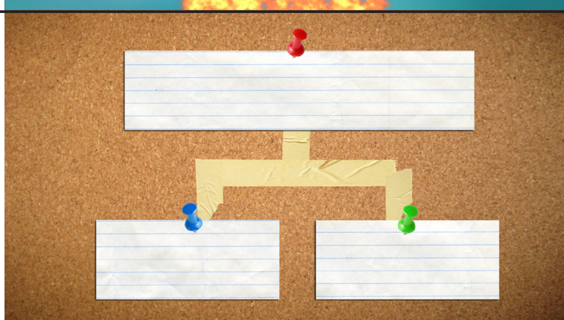
7



When air is heated, it...

____

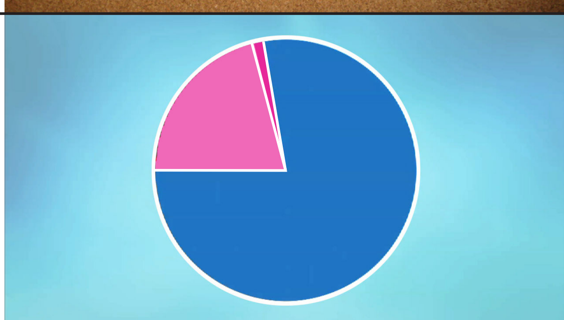
8



Write in the following words in the correct places on the flow chart to the left.

Liquids Gasses Fluids

9

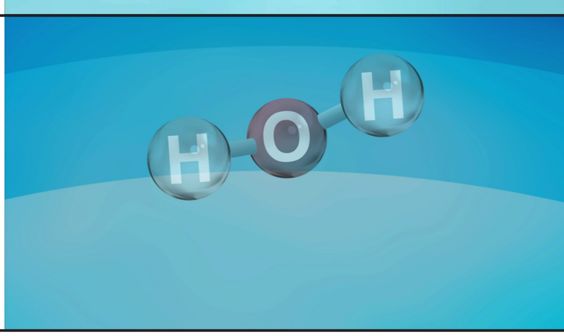


Write in the names of the 3 major gases in our atmosphere and draw a line to the wedge on the pie chart that shows the percentage for each one.

________________ ________________

____

10



What is the name of the invisible, gaseous form of water in the air?

____

WORKSHEET

Station 1: What Are the Components of Air?

About 99% of air is made up of three major gases. Air contains other gases in very small quantities and water in both gas (water vapor) and liquid (droplets of water in clouds and fog) forms. Air also contains solids and other liquids. Solids in air include pollen, dust, and soot. Other liquids in the air include certain pollutants.

Table: Volume of the Most Abundant Gases in Our Atmosphere

Gas	Volume in Parts Per Million (ppm)	Percent	Atomic Symbol	Bond
Nitrogen	780,840 ppm	78.0840%	N_2	triple
Oxygen	209,460 ppm		O_2	double
Argon	9,340 ppm		Ar	none
Carbon dioxide	400 ppm*		CO_2	double
Neon	18.18 ppm		Ne	none
Helium	5.24 ppm		He	none
Methane	1.79 ppm		CH_4	single
Krypton	1.14 ppm		Kr	none
Water vapor	0 - 40,000 ppm		H_2O	single

Source: American Meteorological Society
**levels change both seasonally and over time*

1. Study the table titled "Volume of the Most Abundant Gases in Our Atmosphere." Using the information in the column labeled "Volume in parts per million (ppm)," fill in the column labeled "Percent." The first one has been done for you.
2. Which are the three most abundant gases? What percentage of the atmosphere does each make up?
3. The container filled with beads represents the proportions of the three major gases in the atmosphere. Which color corresponds to each of the three gases?
4. Use the molecule set to make models of nitrogen and oxygen.
5. Make models of at least two of the gases shown in the table that exist in much smaller quantities in our atmosphere.
6. Draw pictures of nitrogen, oxygen, and argon molecules, labeling the atoms.
7. Before moving to the next station, take apart the molecule models you made.

IT'S OUR AIR

What is Air?

Student Page
Station 2

WORKSHEET

Station 2: Can We Feel Air Pressure?

Air may look like nothing but it does take up space – in other words, it has volume. Air also exerts pressure.

1. Drape the glove into the jar, fingers down, and fold the cuff over the mouth of the jar. (If using a plastic bag instead of a glove, drape the bag into the jar, then use a rubber band to secure it to the rim of the jar, forming an air tight seal.)
2. Place your hand in the glove and attempt to push it in farther or pull it out. You will be able to push it in or pull it out a small amount, but after that your hand will meet serious resistance. Why?
3. What does it feel like when you first begin pushing your hand into the jar and how does the sensation change as you continue pushing? What property of air are you feeling on your hand?
4. What happens when you try to pull the glove out of the jar? Why?
5. Why are you able to push the glove in or pull it out at all? Would you be able to do that if the jar were filled with water instead of air? Sand instead of air?
6. Before moving to the next station, remove the glove from the jar.

WORKSHEET

Station 3: How Do Changes in Temperature Affect Air?

Temperature changes are the primary drivers of air movement and weather in our atmosphere. See if you can explain how heating and cooling is affecting the air molecules in the balloons.

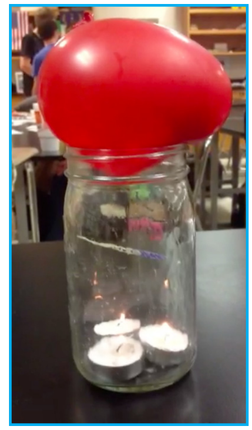
1. Place one bottle in a container of hot water, and the other in a container of ice water.
2. Place a balloon on the neck of each bottle.
3. Now take the bottle from the ice water and put it in hot water. What happens? Why?

4. Take the bottle that started out in the hot water and place it in the ice water. What happens to the balloon? Why?

5. Before moving to the next station, remove the bottles from the containers of water, and take off the balloons.

WORKSHEET

Station 4: How Do Temperature, Volume, and Pressure Interact?



Properties of air are interrelated. When one property is changed, the others will change in predictable ways.

1. Light the tea candles(s) and carefully use the tongs to place the candle(s) in the bottom of the jar.
2. Place the water balloon on top of the jar.
3. Watch the balloon carefully and notice what happens.
4. Describe what you observed about the balloon, if anything, while the candle(s) burned.

5. Describe what happened to the balloon after the candle(s) went out.

6. Use what you know about changes in air temperature and changes in air pressure to explain what you observed.

WORKSHEET

Station 5(A): What Happens When Water Vapor in the Air Condenses?

Air contains water vapor, which is the gaseous form of water. Cold air holds less water vapor than warm air.

1. Put about two inches of hot tap water in a jar.
2. Cover the mouth of the jar with a small plate.
3. Place the gallon bag of ice cubes on the plate.
4. You will need to wait a few minutes before finishing this demonstration – while you are waiting, do Part B of this station. When you're finished with Part B, continue with steps 6 and 7 below.
5. What do you see on the bottom of the plate? Why?

6. Before moving to the next station, remove the plate from the jar. Take off the bag of ice and wipe off the bottom of the plate.

Station 5(B): What Happens When Water Evaporates into the Air?

When water evaporates, heat is absorbed.

1. Read the temperature on both thermometers.
2. Take a small piece of wet gauze and wrap it around the bulb of one of the thermometers, securing it with a rubber band.
3. Wrap dry gauze around the other thermometer, to serve as the control.
4. Direct a fan at the thermometers and turn it on. You can either hold the thermometers in front of the fan, or leave the thermometers on the table and direct the fan toward them. Make sure each thermometer is the same distance from the fan.
5. Record the temperature on the thermometers every thirty seconds. What happens? Why?

6. Why do we feel cooler when a fan blows on us?

7. Before moving to the next station, turn off the fan and remove the gauze from the thermometers.
8. Don't forget to finish Part A of this station!

IT'S OUR AIR

What is Air?

Student Page
Video Part II

WORKSHEET Page 1

1

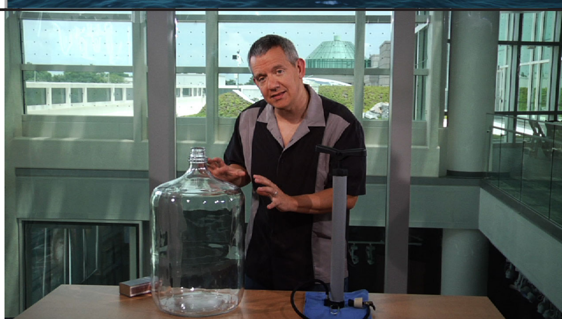
Name some of the processes that take place in the hydrologic cycle.

________________ ________________

________________ ________________

________________ ________________

2

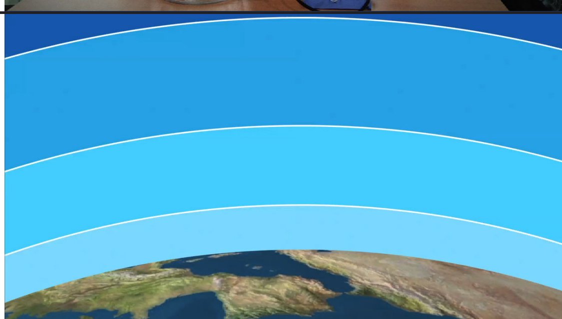


Water vapor is more likely to condense into clouds where the air temperature is...

______ higher.

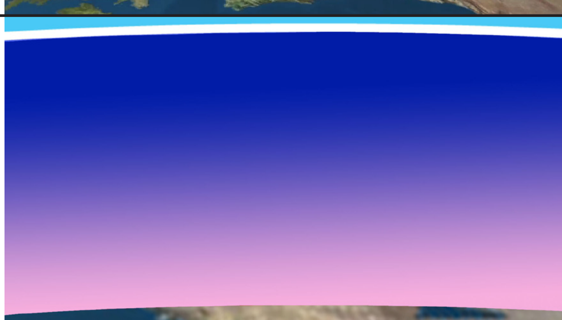
______ lower.

3



Label the lower two layers of the atmosphere on the diagram on the left.

4

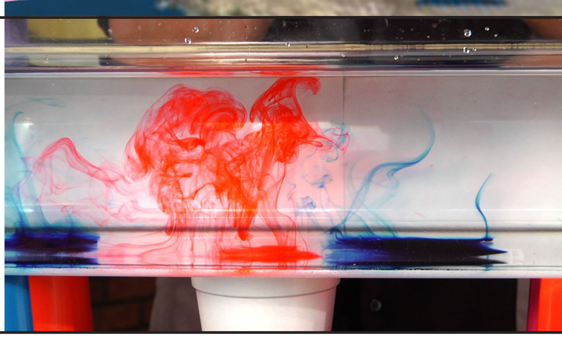


Name the lower layer of the atmosphere and connect the temperature with the correct location.

____

Higher Temperatures	Higher in the Layer
Lower Temperatures	Lower in the Layer

5



What are the three major factors that cause air to move around so much in the lower layer of the atmosphere?

____

____

____

IT'S OUR AIR

What is Air?

Student Page
Video Part II

WORKSHEET Page 2

6

Name the second layer of the atmosphere and connect the temperature with the correct location.

____

Higher Temperatures	Higher in the Layer
Lower Temperatures	Lower in the Layer

7

The ozone layer in the second layer of the atmosphere

____________________ solar radiation.

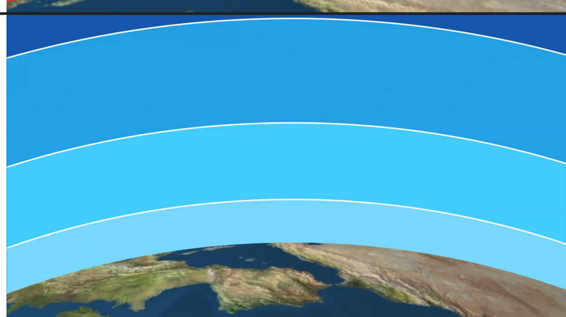
8

In which layer of the atmosphere is ozone a good thing and which is it a danger to our health?

Ozone is a good thing in the ____________________

Ozone is bad for us in the ____________________

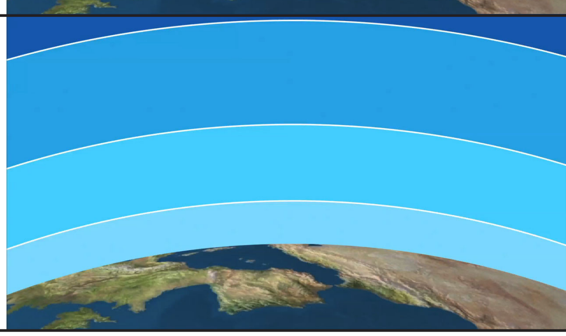
9



In which layer(s) of the atmosphere will you find 99.9% of the atmospheric mass?

____

10



In which layer of the atmosphere will you find most of the clouds, weather and pollution?

____

WORKSHEET

Layers of the Atmosphere

1. Read the following:

Scientists have divided our atmosphere into different layers: troposphere, stratosphere, mesosphere, and thermosphere.

The lowest layer is the troposphere. In the troposphere, temperatures decrease as you go up. Part of the sun's energy directly heats the Earth's surface. Another fraction is radiated back into the troposphere and absorbed in a process called the Greenhouse Effect. As a result, it's warmer closer to the earth. Because the troposphere is coolest at the top and because hot air rises, there is always a lot of air movement and mixing going on and that means weather! The height of the troposphere varies from 6 to 20 kilometers (4 to 12 miles) in altitude, depending on location, season, and weather conditions.

The next layer up is the stratosphere. Weather rarely reaches into the stratosphere, with the exception of the tops of thunderstorms. Temperatures increase with altitude in the stratosphere, which makes the air in the stratosphere relatively stable.

The next layer up is the mesosphere. Temperatures decrease with altitude in the mesosphere.

The next layer up is the thermosphere. Temperatures increase with altitude in the thermosphere.

Thinner layers of relatively consistent temperatures form the boundaries between the four layers. The boundary at the top of the troposphere is called the tropopause. The boundary at the top of the stratosphere is called the stratopause. The boundary at the top of the mesosphere is called the mesopause.

2. Graph the data in the following table using the graph paper provided. After you have plotted the data, connect the points with a line.
3. Label the following zones on your graph:

Altitude in kilometers (km)	Temperature in degrees C
0	15
10	-35
12	-43
20	-43
30	-30
40	-16
50	-4
53	-4
60	-23
70	-52
80	-82
85	-97
87	-97
90	-95
100	-87
110	-45
120	-2
130	38
140	80

- Troposphere
- Tropopause
- Stratosphere
- Stratopause
- Mesosphere
- Mesopause
- Thermosphere

4. Why does virtually all weather happen in the troposphere?

5. What causes the temperature gradient you see in the troposphere?

Layers of the Atmosphere Graph