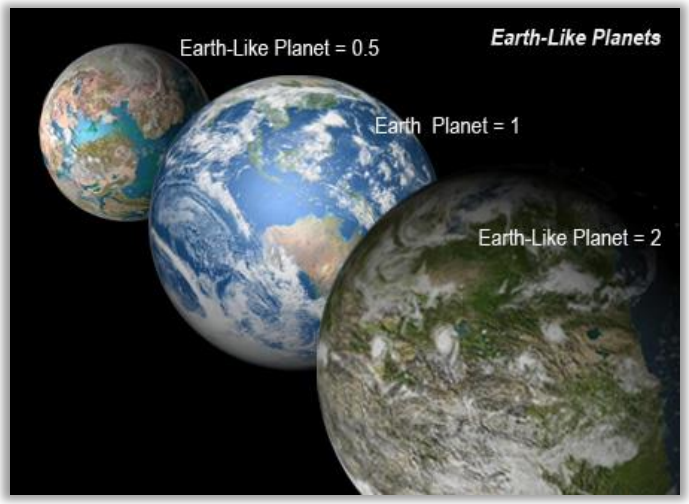
Student Sheet 1

CRITICAL THINKING ACTIVITY: INTERPRETING THE GOLDILOCKS EFFECT (1)

The Goldilocks Effect is derived from a children's story "The Three Bears" in which a little girl named Goldilocks finds a house owned by three bears. Each bear has their own preference of food and beds. After testing all three examples of both items, Goldilocks determines that one of them is always too much in one extreme (too hot or too large), one is too much in the opposite extreme (too cold or too small), and one is "just right".

Small planets, including Earth are much more likely to become incubators of life. Astronomers refer to these insignificant little worlds as **terrestrial planets** because they have heavy-metal cores surrounded by a rocky mantle. Terrestrial planets tend to stick close to their host stars, which means they have smaller orbits and much shorter years. Terrestrial or Earth-like planets are also more likely to lie in the ***Goldilocks zone.*** Also called the ***habitable zone*** or ***life zone***, the Goldilocks region is an area of space in which a planet is just the right distance from its home star so that its surface is neither too hot nor too cold. Earth, of course, fills that bill, while Venus roasts and Mars exists as a frozen world. In between, the conditions are just right so that liquid water remains on the surface of the planet without freezing or evaporating out into space.

Student Sheet 2



The ability to support life of Venus, Earth, and Mars would intrigue Goldilocks, but the actual story of these planets is somewhat more complicated than three bowls of porridge. Four billion years ago leftover water-rich comets and mineral-rich asteroids were still assaulting the planetary surfaces. Some planets had moved inward from where they had formed, others were pushed up to larger orbits and some had unstable orbits and crashed into the Sun or Jupiter. Others were ejected from the solar system altogether. In the end, the few that remained had orbits that were "just right" to survive billions of years.

Without greenhouse gases, what would happen to the Earth? It's interesting to look at Earth's two closest planets to see what is happening in their atmospheres. Greenhouse gases are invisible molecules in the atmosphere. They let sunlight energy into the atmosphere, but they are able to trap it so it can't get back out. In the Earth's atmosphere, there are several important greenhouse gases. Our neighboring planets either have too much greenhouse gases or not enough. Mars and Venus have very similar types of GHGs in their atmospheres, but they are different in the density of gas.

- **Venus** has an extremely dense atmosphere, which together with the concentration of CO_2 (96.5% of the atmosphere) is responsible for a "runaway" greenhouse effect and a very high surface temperature.

- **Mars** has almost no atmosphere; the amount of CO_2 (95% of the atmosphere) although similar to that of Venus, is not sufficient to supply a warming effect and the surface temperatures of Mars are very low.

Student Sheet 3

Earth settled into an orbit with an average distance of 93 million from the Sun. Almost 70% of Earth's surface is covered by liquid water its average temperature is about 50° F. At normal atmospheric pressures, water freezes at 32 °F and boils at 212 °F, so Earth is in a good position for most of Earth's water to remain in a liquid state. Water moves from the oceans to the atmosphere through ***evaporation***, then to the land through ***precipitation***, and back to the oceans through the flow of rivers and streams. This movement of water is called the ***hydrologic cycle.*** It maintains a steady amount of water vapor in the atmosphere.

Venus falls right in the center of the Sun's habitable zone. It is covered completely by a thick layer of clouds and has the highest reflectivity of any planet in the solar system. There is no apparent reason why Venus could not have been a comfortable place. But it happens to suffer from a ***"runaway" greenhouse effect***. Scientists believe that on Venus, the intense solar heating kept oceans from forming, or kept them from staying around if they did form. The resulting lack of rainfall and failure of plant life to evolve kept the carbon dioxide in the atmosphere rather than joining it with the rocks as on Earth. Basically, Venus has an environmental disaster for an atmosphere. Venus' thick atmosphere of carbon dioxide traps nearly one hundred percent of the small quantities of radiation that reaches its surface. At 900° F Venus is the hottest planet in the solar system, yet it orbits at nearly twice Mercury's distance from the Sun.

Mars is the fourth planet from the sun. In a lot of ways, Mars looks a lot like Earth, but instead of blue oceans and green land, Mars is has a constant red tint. A mineral called iron oxide that is very common on the planet's surface causes this color. The diameter of Mars is 6,800 km across. This is 53% the diameter of Earth. The mass of Mars is only 10% the mass of Earth. Because of the small diameter and low mass, the gravity of Mars is only 38% the gravity of Earth. Mars has ice caps at its North and South Poles, much like Earth. In addition, both ice caps are made mostly of frozen water. Mars

does not have a protective layer of atmosphere like Earth, so it cannot store heat from the Sun. It lost its greenhouse effect, if it ever had one, when its atmosphere escaped into space. As a result, the temperature on Mars regularly drops to -125 °F in winter and only rises to 23 °F in summer.

An imaginary visitor from another star, approaching our solar system from outside, could easily analyze the compositions of the atmospheres of the nine planets, using the same techniques that scientists use to study the atmospheres of Mars and Venus from a distance. This visitor would notice very quickly that Earth was the odd one of the terrestrial planets. Our planet has an imbalanced atmosphere, rich in oxygen; Mars and Venus have stable carbon dioxide atmospheres. However, they are totally without life as far as we know.

Student Sheet 5

DATA TABLE #1:

Temperature and Pressure Comparison	VENUS	EARTH	MARS
Surface Pressure Relative to Earth			
Major Greenhouse Gases			
Estimated Temperature if No Greenhouse Gases (°C)			
Actual Temperature (°C)			
Temperature Change Due to Greenhouse Gases			

DATA TABLE #2

Atmospheric Concentrations of Greenhouse Gases (%)	**VENUS**	**EARTH**	**MARS**
Carbon Dioxide (CO_2)			
Nitrogen (N_2)			
Oxygen (O_2)			
Argon (Ar)			
Methane (CH_4)			

Student Sheet 6

PART 1: ANALYSIS/COMPREHENSION:

1. Write a brief explanation of how the term " Goldilocks effect" came to be applied to the temperature variations seen in these three planets.
2. What is the main factor when determining atmospheric temperature of a planet?
3. What factors will trap energy in a planet's atmospheric system?
4. What will reflect incoming solar radiation back into space?
5. What is the most variable component of the Earth's atmosphere that is most likely the main reason that Earth does not experience huge temperature variations between day and night?
6. If the temperature of a planet is to remain constant, the energy in must _____ the energy out.
7. Compare and contrast the atmosphere of Earth with the atmosphere's of Venus and Mars. Draw picture, create a Venn diagram, or just write a description.
8. Explain how Earth's atmosphere allows life to exist.
9. What must happen to Mars' atmosphere for life to be possible there?
10. Explain why Venus is too hot and Mars is too cold.
11. Describe the concept of a "habitable zone."
12. Why is it so much colder on Mars than on Venus, even though they have similar amounts of carbon dioxide?

PART 2: IN CONCLUSION!

1. In what ways do you think the planet where your extraterrestrial creature lives might be different from Earth?

2.Compare your extraterrestrial creature with others in the class. Could they all survive on the same planet? Why or why not?

Student Sheet 7

PHYSICAL FEATURE RECORD SHEET

ADAPTATION	ADAPTATION OF ORGANISM
1. Kind of skin	
2.Number of openings for waste removal	
3.Long or other shapes	
4.Segments	
5. Appendages	
6. Hard inside parts	
7. Hard outside parts	
8. Size	
9. Feeding cells	
10.Moving around	
11.Sensing vibrations	
12.Chemical senses	
13. Number of eyes	
14. Eating	
15.Plant/Meat eater	
16. Predator/Prey	
17.Defensive structures	
18.Poison as a defense	
19.Defensive behaviors	
20. Reproduction	
21.Sexual/asexual reproduction	
22. Mating practices	
23.Offspring	