How Greenhouses Work

Greenhouses create an artificial environment, sheltered from the ”outside” environment that may be too cold, too hot or too variable for the growing of plants. Greenhouses use their glass enclosures to trap solar radiation; the radiant heat enters through the glass or plastic covering and warms the air, soil and plants inside. This warm air rises and is replaced by cooler air that in turn is warmed up; this cycle raises the temperature quickly. The heat created by the solar radiation, plants and from the soil is “trapped” by the glass. Sometimes, the air inside can be overheated and has to be vented out. As you drive by a greenhouse, you may see the glass panels on top open to vent out the warm air vertically. Venting can also occur horizontally through side fans and vents. The venting also keeps the air in the greenhouse moving, allowing for a more even temperature throughout and cycling the carbon dioxide that plants need to grow. Most modern greenhouses have automated systems to regulate the temperatures inside.

The “heat” which is generated often comes from the sun. However, in really cold climates, heat is added to the air or to the soil.

In addition to the “heat component”, plants in greenhouses also require water. Many greenhouses use an automated irrigation system to keep the growing media moist and flowering plants supplied with needed water. Hydroponic systems, that don’t use soil to “hold” moisture, supply water directly to the roots on a more frequent basis.

Although a greenhouse may appear to be a simple structure, the key components of any human-made structure are present; in a greenhouse, these include ....

- a strong foundation,
- a sturdy frame to maintain the glass (or plastic) panels,
- flooring that varies from simple dirt to concrete, wood or stone,
- “glazing” - glass or other synthetic covering to allow in solar radiation and to help to provide insulation,
- a system for watering of the plants and flowers.

Appendix 6.2

The Martian Environment

The "red planet" – Mars does have an environment. However, it is a most unfriendly environment for humans. Due to its smaller size, the force of gravity is much less than that on Earth – about 1/3 the value. An object on Earth that weighed 100 kilos would weigh about 34 kilos on Mars. The limited gravity on Mars has resulted in an atmosphere that is very thin – about 100 times less dense that Earth's atmosphere. The thin atmosphere provides less protection from the ultraviolet (UV) radiation of the sun; in addition, there is nothing similar to Earth's ozone layer in the stratosphere which absorbs much of the UV radiation attempting to enter our atmosphere. These conditions make it very difficult for humans to live on Mars…and we haven't even considered any other factors other than the atmosphere!

The Composition of the Martian Environment	
Carbon Dioxide	95.32%
Nitrogen	2.7%
Argon	1.6%
Oxygen	0.13%

The thin atmosphere and its greater distance from the sun have resulted in much colder temperatures than here on Earth. The average temperature is -60oC with a range from

-125oC (at the poles in winter) to 20oC at the equator in summer. It is the DAILY range in temperature which is the biggest difference to the situation on Earth – usually in the area of 100 Celsius degrees!

As a result of the hostile environment on Mars, it is not possible for humans to survive without permanent residences … and greenhouses to provide sustenance.

The accompanying chart shows the changes in temperature on a typical day (called a "sol") on the surface of Mars.

SOL (day)	High Temperature (degrees Celsius)	Low Temperature (degrees Celsius)
1	-19	-71
2	-14	-74
3	-14	-70
4	-17	-75
5	-13	-73
6	-14	-73
7	-15	-75
8	-15	-76
9	-16	-75
10	-17	-76

Appendix 6.3

High and Low Temperature Charts – Earth and Mars

High and Low Temperatures (Earth)

(DAY)	HIGH TEMPERATURE (degrees Celsius)	LOW TEMPERATURE (degrees Celsius)	TEMPERATURE RANGE
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

High and Low Temperatures (surface of Mars)

SOL (DAY)	HIGH TEMPERATURE (degrees Celsius)	LOW TEMPERATURE (degrees Celsius)	TEMPERATURE RANGE
1	-19	-71	
2	-14	-74	
3	-14	-70	
4	-17	-75	
5	-13	-73	
6	-14	-73	
7	-15	-75	
8	-15	-76	
9	-16	-75	
10	-17	-76	

Life Support Systems

In human history, humans moved from a "hunting and gathering" nomadic life to become inhabitants of a fixed place with the cultivation of plants and the domestication of animals – the beginning of agriculture. The basics of life support – air and water – are provided by the Earth's ecosystem.

In the past ...

However, humans have learned to "modify" small portions of the Earth's biosphere with the creation of GREENHOUSES. It is speculated that the earliest greenhouses may have been developed in ancient Rome, nearly 2000 years ago ... to grow vegetables year-round for the demanding Roman emperors! At this point, glass had not been invented, so small sheets of the mineral mica were used.

In the 13th century, greenhouses were built in Italy to grow the exotic plants that explorers brought back from the tropical areas that they visited.

In the 17th century, the first greenhouses made with glass emerged in Europe to propagate tropical plants in the colder environment of the area. Later, greenhouses for people evolved (called solariums), to provide warmer environments for human habitation.
Greenhouses may have been developed in the Far East in the 15th century, in both China and Korea. In Korea, greenhouses were used to grow mandarins using an active soil heating system.

The concept of greenhouses also appeared in Netherlands and then England in the 17th century. Today, the Netherlands has many of the largest greenhouses in the world, some of them so vast that they are able to produce millions of vegetables and flowers every year.

The botanist Charles Lucien Bonaparte may have built the first practical modern greenhouse in Leiden, Holland during the 1800s to grow medicinal tropical plants. In France, greenhouses were used to grow both oranges and pineapples, plants that could not withstand the harsh climate of northern Europe without some form of modification.

An elaborate greenhouse was built to accompany the Palace of Versailles just outside of Paris in the 17th Century; it was 150 metres by 13 metres and exceeded 14 metres in height.

At the same time, in the United Kingdom, elaborate greenhouses were established including several in Key Gardens and The Crystal Palace.

In the 20th century, the geodesic dome was added to the many types of greenhouses including the Eden Project In southwest England, and the Climatron in the Missouri Botanical Gardens in St. Louis.

The availability of polyethylene (the most common form of plastic) as a replacement for glass was one of the main developmental features of the late 20th century. The early versions of polyethylene did not stand up to the UV rays of the sun very well; however, their durability was increased with the development of effective UV-inhibitors in the 1970's and 1980's.

In recent years, greenhouses with two or more connected bays have been developed; they use a common wall or a row of support posts. Most of the greenhouses in Southern Ontario are in this form.

In the future ...

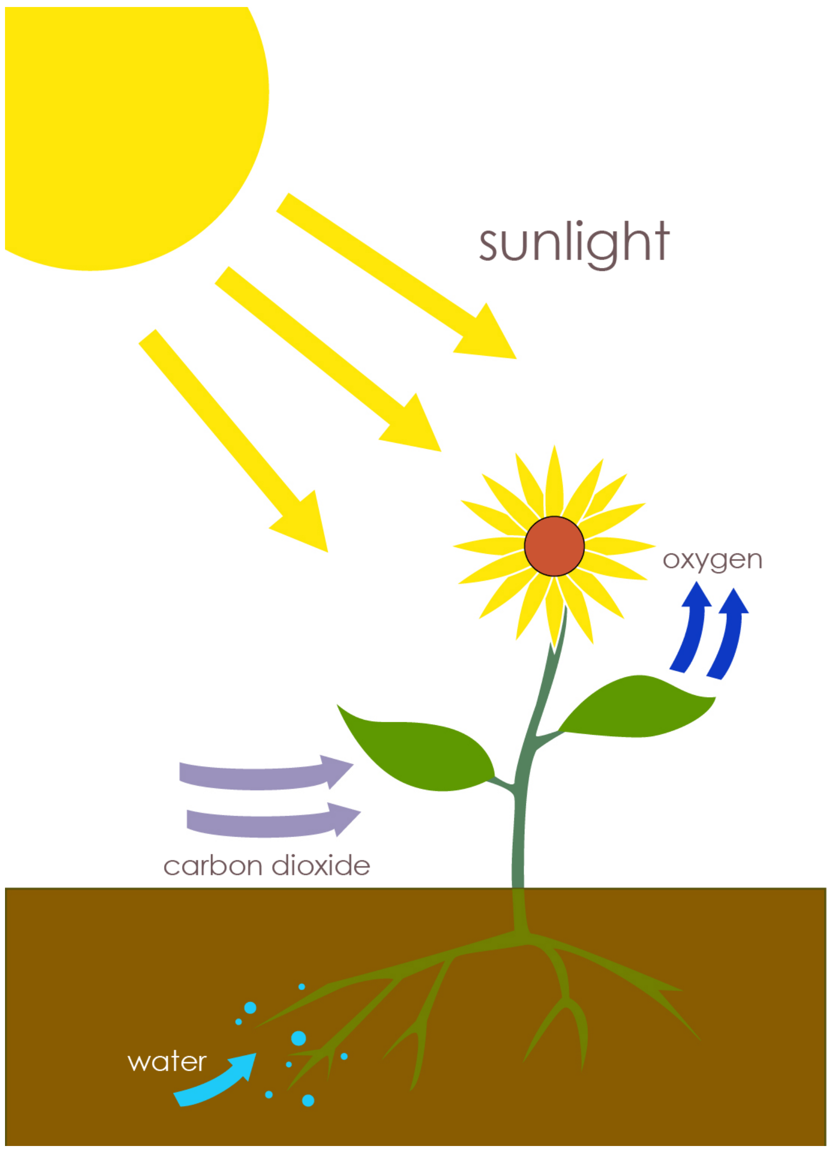
Because of the lack of a suitable biosphere on either the Moon or Mars, the habitants of these new environments will have to create their own! This will be a CLOSED life support system that includes plants and microorganism – a greenhouse on Mars. A greenhouse isolates plants from the adverse conditions of the Martian environment.

Photosynthesis

Photosynthesis is a big word … but the meaning of the word is simple. The first part (photo) comes from the Greek word meaning "light"; the second part (synthesis) simply means "putting together". Light from the sun puts things together. Photosynthesis is how plants "eat" using carbon dioxide from the air, water, and light from the sun. These are absorbed by the plants and changed into oxygen and sugar; the sugar is used to help the plants grow, and the oxygen is "breathed out" into the atmosphere.

Every plant goes through the process of photosynthesis. Animals and humans do the exact opposite, taking IN oxygen and breathing OUT carbon dioxide.

Light + Water + Carbon Dioxide ➡ ➡ ➡ ➡ Oxygen + Sugar



Photosynthesis by At09kg

Earth's atmosphere contains less than 1% Carbon Dioxide (actually 0.038%) whereas the atmosphere on Mars is over 95% Carbon Dioxide. Not good for humans! But, plants could absorb some of this Carbon Dioxide.

The Martian Environment Compared to Earth's Environment

COMPONENT	MARS	EARTH
Atmosphere components	Carbon Dioxide – 95.3% Nitrogen – 2.7% Argon – 1.6% Oxygen – 13%	Nitrogen – 77% Oxygen – 21% Argon – 1%
Atmospheric Pressure	7.5 millibars (average)	1013 millibars (average)
Gravity	0.375 of Earth's gravity	2.65 times the gravity of Mars
Length of Day	24 hours 37 minutes	Just less than 24 hours
Length of a Year (one orbit of the sun)	687 Earth days	365.25 days
Tilt of the axis	25 degrees	23.45 degrees
Satellites (natural)	2 – Deimos and Phobos	1 - Moon
Distance from the Sun (average)	228 million km	150 million km
Radius (at the equator)	3400 km	6378 km
Relationship with the Sun	Thin atmosphere – high levels of radiation	Earth's atmosphere is similar to a greenhouse – blocking radiation and moderating temperatures
Surface Temperatures	Average -63°C Range -12°C to +20°C Daily range - 100 Celsius degrees	Average 14°C Range -88°C to +58°C Daily range – usually less than 30 Celsius degrees
Surface Material	No organic material – mostly silicon dioxide, iron oxide and "rocks" similar to those on Earth; no permanent surface water	Varies with region – soil contains both organic and inorganic materials.
Largest Volcano	Olympus Mons – 26 km high and 602 km in diameter	Mauna Loa (Hawaii) – 10 km high and 121 kilometres in diameter
Deepest Canyon	Valles Marineris – 7 km deep and 3000 km long; as much as 600 km across	Grand Canyon – 1.8 km deep and 800 km long; as much as 30 km across
Surface Material	No organic material – mostly silicon dioxide, iron oxide and "rocks" similar to those on Earth; no permanent surface water	Varies with region – soil contains both organic and inorganic materials.

Changes to the Environment Inside a Martian Greenhouse

COMPONENT	MARS	CHANGES
Atmosphere components	Carbon Dioxide – 95.3% Nitrogen – 2.7% Argon – 1.6% Oxygen – 13%	The amount of Carbon Dioxide would have to be reduced. Other changes :
Atmospheric Pressure	7.5 millibars (average)	
Gravity	0.375 of Earth's gravity	
Relationship with the Sun	Thin Atmosphere – high levels of radiation	
Surface Temperatures	Average -63°C	
Surface Temperatures	Range -12°C to +20°C	
Surface Temperatures	Daily range - 100 Celsius degrees	
Surface Material	No organic material – mostly silicon dioxide, iron oxide and "rocks" similar to those on Earth; no permanent surface water	

KWL Chart (Know...Want to Know...Learned)

KNOW	WANT TO KNOW	LEARNED
What do I already know about the environment of planet Mars and growing plants there?	What questions do I have about the environment of the planet Mars and growing plants there?	AFTER THE UNIT, what have I learned about the planet Mars and growing plants there?
The PickOntario website was useful to me because I learned		

Appendix 6.9

Rubric for Assessing a Diary on Establishing a Greenhouse on Mars

Indicator	Novice	Apprentice	User	Specialist
Indicates the problems associated with arriving on new planetary body	Is unaware of the large number of problems humans face when landing on a new planetary body	Provides a minimal number of problems to be solved when arriving	Provides an understanding of the complexities of living in space and arrival on Mars	In written material provides many examples of the problems to be solved as soon as the vehicle arrives
Shows knowledge of the Martian atmosphere	Misses the basic concepts of a different environment on planetary bodies such as Mars	Provides examples of problems related to the air and water components of the environment on Mars	Indicates understanding of the basic issues of the atmosphere and the surface conditions on Mars	Shows evidence of knowledge of the atmosphere, surface conditions and the effects of these on human survival on Mars
Is able to set priorities for tasks	Lacks the ability to identify what is most important about setting foot on a new planetary body	Indicates a basic understanding of the priorities that need to be tackled	Lists the priorities of tasks to be accomplished when settling into the new environment on Mars	Provides a sequential list of tasks and a rationale for dealing with the tasks in a logical manner

Appendix 6.10

Career Survey

For each of the following five questions, choose one of A, B, C, D, to indicate the topic that interests you most.

1. A. Selling a product (like flowers) or a service (like advertisements for the media).
   B. Studying living things and their structure (like genes)
   C. Working with plants and/or animals
   D. Learning about different topics and things

2. A. Marketing a product or a service
   B. Designing or building structures (like greenhouses), using engines or machinery
   C. Farming
   D. Working with or for government agencies

3. A. Using your creative skills in new situations
   B. Doing experiments
   C. Working outdoors
   D. Using social media to promote ideas and products

4. A. Developing your own business – being your own boss!
   B. Learning more about plants.
   C. Planting trees
   D. Using your knowledge and skills to improve the environment and contribute to dealing positively with climate change.

5. A. Being a manager – working with people to get a task completed
   B. Using your knowledge of science and the scientific method in different situations.
   C. Gardening
   D. Using your knowledge and skills to teach others.