Chapter One

Introduction to Forest Ecology

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1.1
INTRODUCTION TO THE BOREAL FOREST

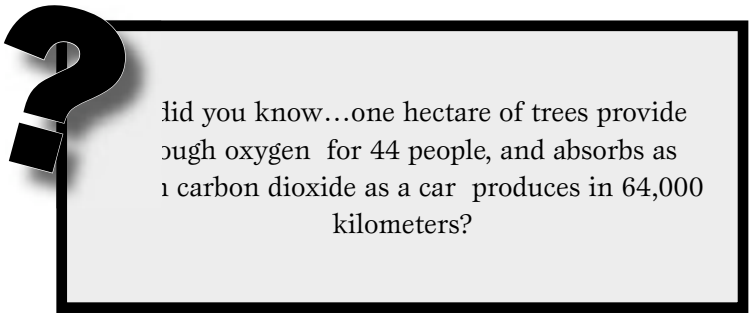
The Boreal Forest is Manitoba's largest biome, or ecological community. It covers about one-third of the province and stretches in a broad band across the central part of the province and down the east side of Lake Winnipeg. (figure 1a)

The climate is one of extremes, with very cold winters and deep snow cover for nearly half the year, and short cool summers. Adding to this contrast, the boreal forest is a patchwork of various ages of trees, from young seedlings to mature and even over-mature. Groups of trees, called **stands**, can be dense or sparse, and grow on dry ridges (jack pine) or wet bogs (black spruce). Stands of trees can be composed of **conifers** (pine, spruce) or cone-bearing trees, known as **softwoods**, or the **deciduous hardwoods** such as poplar or birch. Some stands may have both types intermingled.

Soils are generally poor and quite acidic and the growing season quite short, hence the lack of agriculture. Yet the boreal forest has been used for its other resources, such as timber for pulp and paper and lumber, which are Canada's leading export products.

The abundant natural resources of the boreal forest has contributed to the region's economic development. The Precambrian shield formations which lie beneath much of the boreal forest is rich in minerals such as nickel. The abundant fish and wildlife has created a growing ecotourism industry, and many people from around the world come here to hunt, fish, canoe, or just relax and enjoy the scenery.

The Manitoba Model Forest lies in the southeast corner of Manitoba, (figure 1a) and is essentially a research forest dedicated to the promotion of sustainable forest practices so that this magnificent ecosystem can provide for the needs of Manitobans today and into the future. By understanding the science of forest ecosystems, we can help ensure their survival.



Our forests have provided us with oxygen, wood products, and a healthy environment for generations. Forests are a renewable resource, which means that with proper management, they can continue to provide these things well into the future. In the following activity, you will examine the importance of the forest to Manitoba.

ACTIVITY 1
OVERVIEW OF MANITOBA FORESTS

Skill set: Reading and organizing data, making tables to compare data. Use the tables below as a source of information for the following questions.

1. How much forested land do we have in Canada? In Manitoba?
2. Who owns the forested land in Canada? In Manitoba?
3. How many people are employed in the forest industry in Canada? In Manitoba?
4. How much forested land is harvested every year in Canada? In Manitoba?
5. How much forest is destroyed each year by fire and insects in Canada? In Manitoba?
6. How much wood were we allowed to cut in 1999 in Manitoba? In Canada?
7. How much wood did we actually cut in 1999 in Manitoba? In Canada?
8. Compare the amount of forested land harvested in Manitoba with the amount burned and destroyed by insects. Do the same for Canada.
9. How much area does a hectare of land cover?
10. How much wood is in a cubic meter? Using a helper and 8 meter sticks, make a model of a cubic meter on the classroom floor.
11. List as many kinds of jobs as you can think of in the forest industry. (There are about 8800 people in Manitoba doing these right now to earn a living).

Population	1.2 million
Total area	65 million ha
Land area	54.8 million ha
Forest land	26.3 million ha
Provincial parks	3.4 million ha

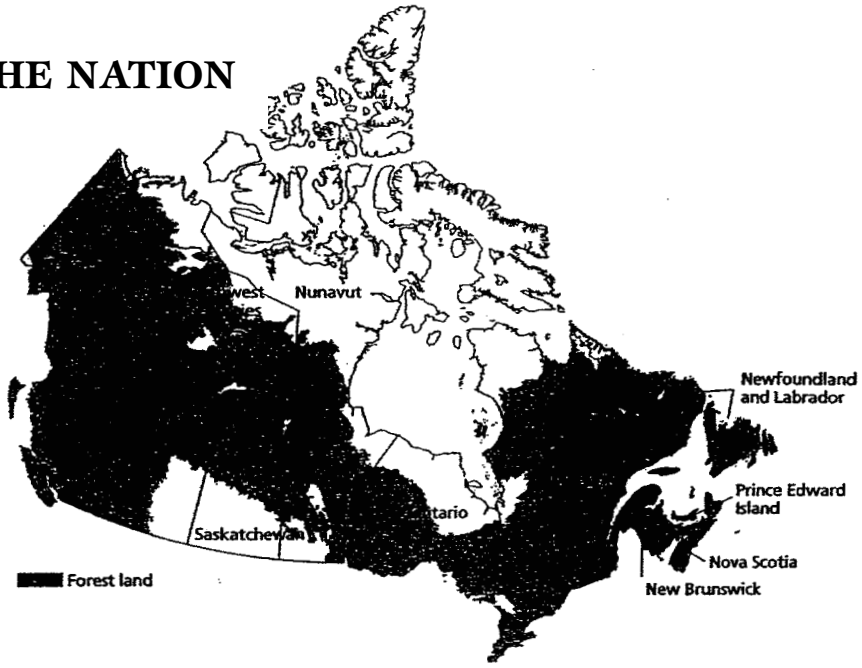
FOREST INDUSTRY

Value of exports (2002)	$615.4 million
Converted paper	4%
Newsprint	22%
Other paper and paperboard	14%
Other products	33%
Softwood lumber	14%
Waferboard	13%
Major export markets (2002)	
Other countries	1%
United States	99%
Balance of trade (2002)	$223.6 million
Value of shipments (2001)	not available
Logging (2001)	not available
Paper manufacturing (2001)	$549.1 million
Wood product manufacturing (2001)	$623 million
Number of establishments (2001)	not available
Logging (2001)	not available
Paper manufacturing (2001)	30
Wood product manufacturing (2001)	76
Direct jobs (2002)	7 300
Wages and salaries (2001)	not available
Logging (2001)	not available
Paper manufacturing (2001)	$104.5 million
Wood product manufacturing (2001)	$118.3 million
New investments (2002)	not available

FOREST RESOURCE

Ownership	
Federal	1%
Private	5%
Provincial	94%
Forest type	
Hardwood	21%
Mixedwood	20%
Softwood	59%
Annual allowable cut (2000)[a]	9.7 million m^3
Harvest (volume) Industrial roundwood (2000)[b]	2.2 million m^3
Harvest (area) Industrial roundwood (2000)	15 633 ha
Status of harvested Crown land (2001)[c]	
Stocked (95%)	308 000 ha
Understocked (5%)	15 000 ha
Area defoliated by insects (2001)[d]	not available
Area burned (2002)	81 174 ha

PROFILES ACROSS THE NATION



Canada

Population (2001)
31.1 million
Total area
997.0 million ha
Land area
921.5 million ha
Forest land
417.6 million ha
National parks
24.5 million ha
Provincial parks
32.3 million ha

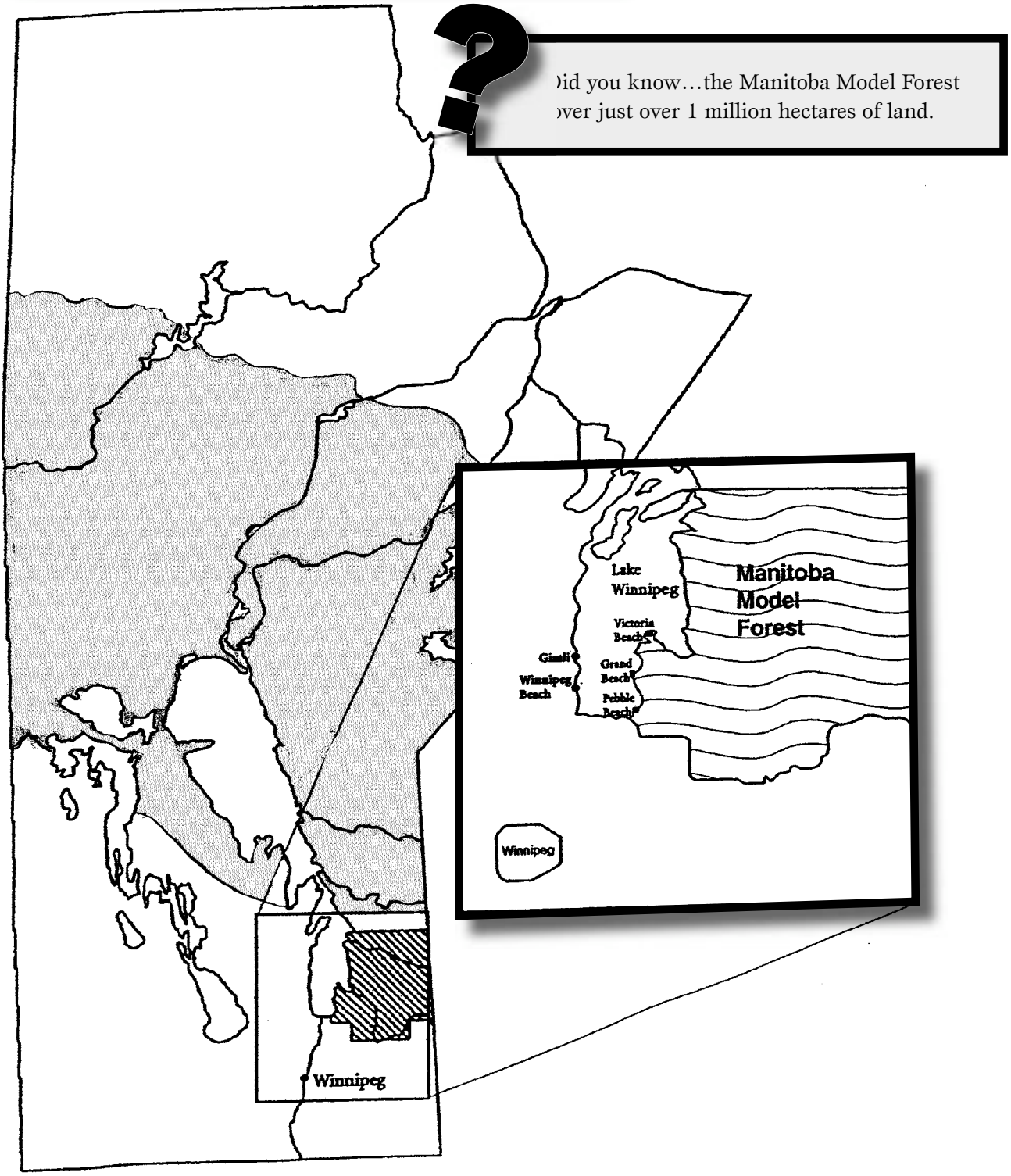
FOREST RESOURCE

Ownership	
Provincial	71%
Federal	23%
Private	6%
Forest type	
Softwood	67%
Mixedwood	18%
Hardwood	15%
Annual allowable cut (1999)[a]	225.3 million m^3
Harvest (volume) Industrial roundwood (1999)[b]	193.2 million m^3
Harvest (area) Industrial roundwood (1999)	1.03 million ha
Status of harvested Crown land (1999)[c]	
Stocked (88%)	14.5 million ha
Understocked (12%)	2.0 million ha
Area defoliated by insects (1999)[d]	6.3 million ha
Area burned (2001)[e]	629 836 ha

FOREST INDUSTRY

Value of exports (2001)	$44.1 billion
Other paper and paperboard	25%
Softwood lumber	25%
Newsprint	16%
Wood pulp	16%
Other products	14%
Waferboard	4%
Major export markets (2001)	
United States	81%
European Union	6%
Japan	6%
Other countries	5%
South and Central America	2%
Balance of trade (2001)	$34.4 billion
Contribution to GDP (2001)	$28.5 billion
Value of shipments (1999)	$73.6 billion
Exported	60%
Sold domestically	40%
Number of establishments (1999)	12 348
Logging (1999)	9 541
Wood product manufacturing (1999)	2 144
Paper manufacturing (1999)	663
Direct jobs (2001)	352 800
Wages and salaries (1999)	$12.3 billion
New investments (2001)	$3.1 billion

Fig. 1a: Manitoba Model Forest Map



1.2
FOREST VALUES

Everyone has their own idea about what the forest means to them. To some, it is a source of recreation and rejuvenation. To others, it means a steady job. Still others might value it for the beauty it gives to the landscape. From the list below, check off those which you value the most. Can you pick your favorite three and explain why they are important to you?

ECOLOGICAL
- Capture solar energy and create oxygen
- Moderate local and regional climate
- Store water and slows runoff
- Develop soil and makes it more fertile
- Stores and recycles nutrients
- Provides habitat for birds, mammals, other life forms
- Add to the planet's biodiversity
- Act as carbon reservoirs
- Absorb greenhouse gases

ECONOMIC
- One of Canada's main industries
- Employs more than 800,000 Canadians
- Supports other natural resource industries such as trapping, fishing, guiding

WOOD PRODUCTS
- More than 5,000 products made from wood; more than just lumber
- Pulp used in manufacture of paper
- Maple syrup, nuts, berries, mushrooms important food items
- Firewood
- Wood by-products produce items such as turpentine, rayon, adhesives, nature crafts
- Christmas trees and wreaths

CULTURAL AND SPIRITUAL
- Source of inspiration for artists, poets, etc.
- Plays a significant spiritual role for Aboriginal peoples
- Provides link to our historic past

RECREATIONAL
- Hiking, camping, skiing, photography, bird watching, canoeing, etc.
- Recreational fishing and hunting
- Ecotourism

Trees and forests play an important role in the lives of many aboriginal communities. As part of forest management planning, efforts are now made to identify and protect special spiritual and cultural places within the forest. Within the Manitoba Model Forest for example, community elders have been assisting with identification of these areas, and then they are given special protection by means of a "buffer zone" in which no harvesting shall take place.

Sometimes when resource users place different values on the forest, conflicts may arise. For example, many residents within the Manitoba Model Forest earn income from their community trapline. Conflict can arise when timber harvesting begins in area where fur harvesting is also taking place. Usually, a solution to the problem can be found when the local trapper's association negotiates with the timber company regarding where and when the harvest shall take place.

In Activity 2, which follows, you will explore the multiple values that relate to the forest, and go through an exercise which tries to identify "Who Wants What From the Forest".

ACTIVITY 2
"WHO WANTS WHAT FROM THE FOREST"

INSTRUCTIONS: Explain what each forest user wants or needs from the forest.

HUNTER

FISH

MOOSE

COTTAGE OWNER

LOGGER

ARTIST

TREE PLANTER

TOUR OPERATOR

NATURALIST

LOGGING COMPANY MANAGER

WOODPECKER

NATIVE ELDER

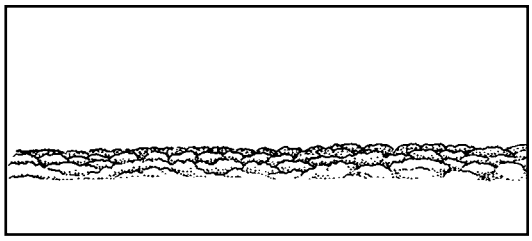
WOLF

1.3
BIOMES OF MANITOBA

A biome is a major regional ecosystem (ecoregion) made up of a distinctive type of vegetation and its associated animal life (i.e grasslands, tundra, etc.). Manitoba is subdivided into four biomes, each with its distinct plants and animals which reflect the regional climate and soils in the area. They are:

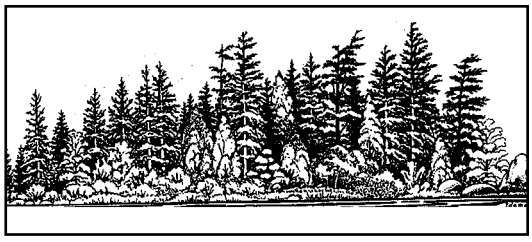
1. TUNDRA

- Poorly drained
- Saturated soils
- Permafrost
- Short growing season
- Example – Churchill



2. BOREAL FOREST

- Long cold winters
- Deep snow
- Thin acidic soils
- Short cool summers
- Example – Thompson, Flin Flon, Lynn Lake

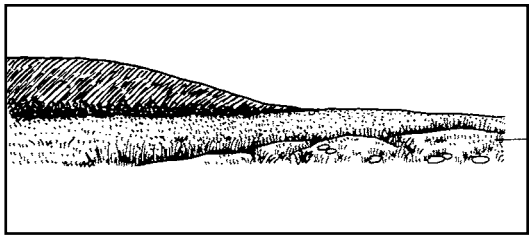


3. TEMPERATE DECIDUOUS FOREST

- Deciduous and coniferous trees
- Variable soil conditions, grey to black
- Moist summers, variable snow cover in winter
- Examples – Dauphin, Swan River

4. GRASSLAND

- Warm dry summers
- Fertile soils
- Few trees, mostly along creeks or river valleys
- Cold dry winters
- Examples – Melita, Virden, Deloraine



Because the Boreal Forest is the largest biome in our province, we will be focusing on it in this unit. However, each biome has its unique challenges to its sustainability. For example, oil and gas exploration in the tundra may harm the soil and vegetation, or poor farming practices may harm the soils of the grassland and contribute to erosion and excessive runoff of pesticides into rivers. As a citizen, your awareness of the issues will help you make choices that contribute to the sustainability of ecosystems and the health of the planet. By reducing consumption, reusing things, and recycling, we can minimize our use of natural resources.

ACTIVITY 3
YOUR HOME BIOME

DIRECTIONS: The four main biomes or ecoregions of Manitoba are shown on the map below. Which one do you live in? Place an "X" on the map indicating where you live. How far and in which direction would you need to drive to get to the next closest biome. Remember, a biome is a "biological home".

1.4
WHAT IS AN ECOSYSTEM?

An ecosystem is a complex system of living organisms (plants, animals, fungi, bacteria) called the **biotic** environment, and their **abiotic** environment (air, water, soil, and nutrients). They work together, creating a flow of energy and a cycling of matter, that leads to the creation of biomass, such as larger plants, or more animals in the ecosystem. An ecosystem can be a certain place as well. It can be a marsh or swamp, a lake, or a stand of trees. All the ecosystems in the world make up the biosphere. In a certain way, an ecosystem is a bit like a complex steam engine. The engine uses heat (energy) which dissipates constantly and is replenished constantly, and uses materials (molecules) which are recycled over and over again. There are millions of moving parts in this engine (organisms) and many types of parts (species) and even different categories of parts (herbivores and carnivores). Together, this engine, or ecosystem,.driven by solar energy, will continue to function as long as the parts are intact. In another analogy, an individual is like a whirlpool, sucking up nutrients and energy all its life, only to return all of its matter (molecules) back to the ecosystem when it dies.

The sun is the source of energy that drives all ecosystems. Plants, called **producers**, convert the solar energy of the sun into a usable substance called **glucose**, which is consumed by animals, called consumers.. (see figure 1b). For example, when a fox eats a mouse that ate grass, the energy moved along the food chain until less and less was available. Less energy means fewer organisms at the top of the energy pyramid. In other words, there will always be fewer mice than blades of grass to sustain them, and fewer foxes than mice. What would happen if the energy pyramid was upside down, and there were more foxes than blades of grass?

Producers , or plants, are also called **autotrophs** (organisms that can create their own energy) A second group of life form, the animals, are called **heterotrophs**. So the willow, a plant, captures solar energy, converts it to glucose, cellulose, and other plant products, which get eaten by animals, such as moose, who convert the plant nutrients into animal biomass, such as muscles, bones, and even antlers. We feed hay and grain to our domesticated herbivores (cattle, sheep, hogs, poultry) to produce meat, milk and eggs, and the food chain goes on. The food web is perhaps a more fitting name since it is composed of a series of overlapping and interrelated food chains. (see figure 1e) In the food web, any animals that eats plants is called a **herbivore**, such as a rabbit. Any animal that eats meat is called a **carnivore**, such a wolf. There are also **omnivores**, which eat either plants or animals, such as the black bear or raccoon.

In any ecosystem, the term population includes groups of individuals of any one kind of organisms, such as the population of black bears in the boreal forest. The term **community** includes all the populations of a given area, such as the members of the marsh community (i.e. snails, minnows, frogs, herons, bitterns, and waterfowl.) A **niche** is the particular role played by an organism (i.e. the fungi are decomposers). An ecosystem can be **terrestrial** (on land), **aquatic** (in fresh water) or **marine** (in oceans). In this unit we will continue our focus on forest ecosystems.

All ecosystems change with the passage of time. The biodiversity of an ecosystem can either increase or decrease with time, reflected by an increase or decrease in the number of species. For example, an **extinct** species is no longer found on any ecosystem on earth, such as the Wooly Mammoth or

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Passenger Pigeon. An **extirpated** species is no longer found in all of its former range, but confined to a small fraction of it, such as the Grizzly Bear. An **endangered** species faces serious risks to its survival due to various factors such as habitat loss and pesticide use, such as the Burrowing Owl. A **threatened** species will face serious problems in the future is conditions within the ecosystem do not improve, such as the Eastern Cougar. A **vulnerable** status means that the species could face an uncertain future if faced with competition from **exotic** (foreign) species, or such things as habitat loss or climate change, such as the Polar Bear, which is vulnerable to resource development in the tundra ecosystem.

Fig. 1b: A Food Web in the Forest

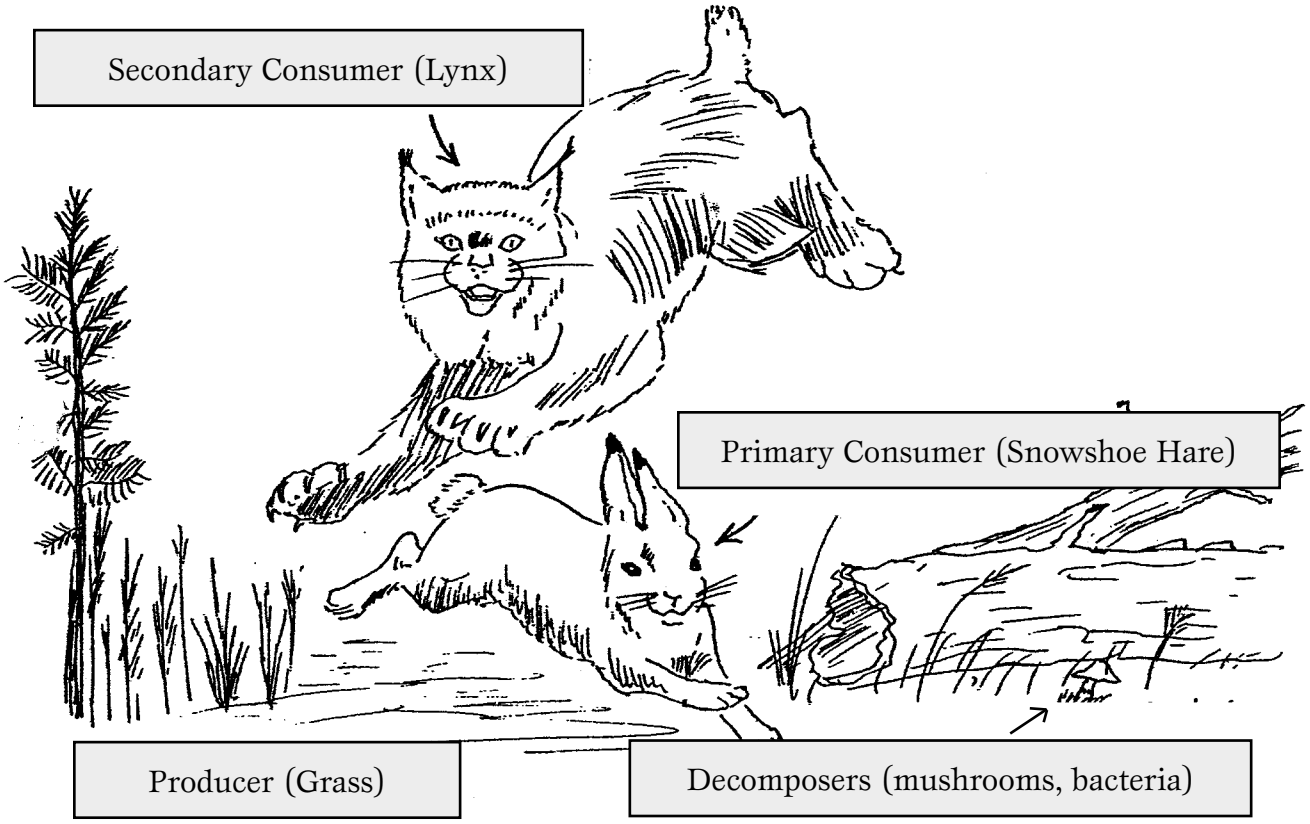
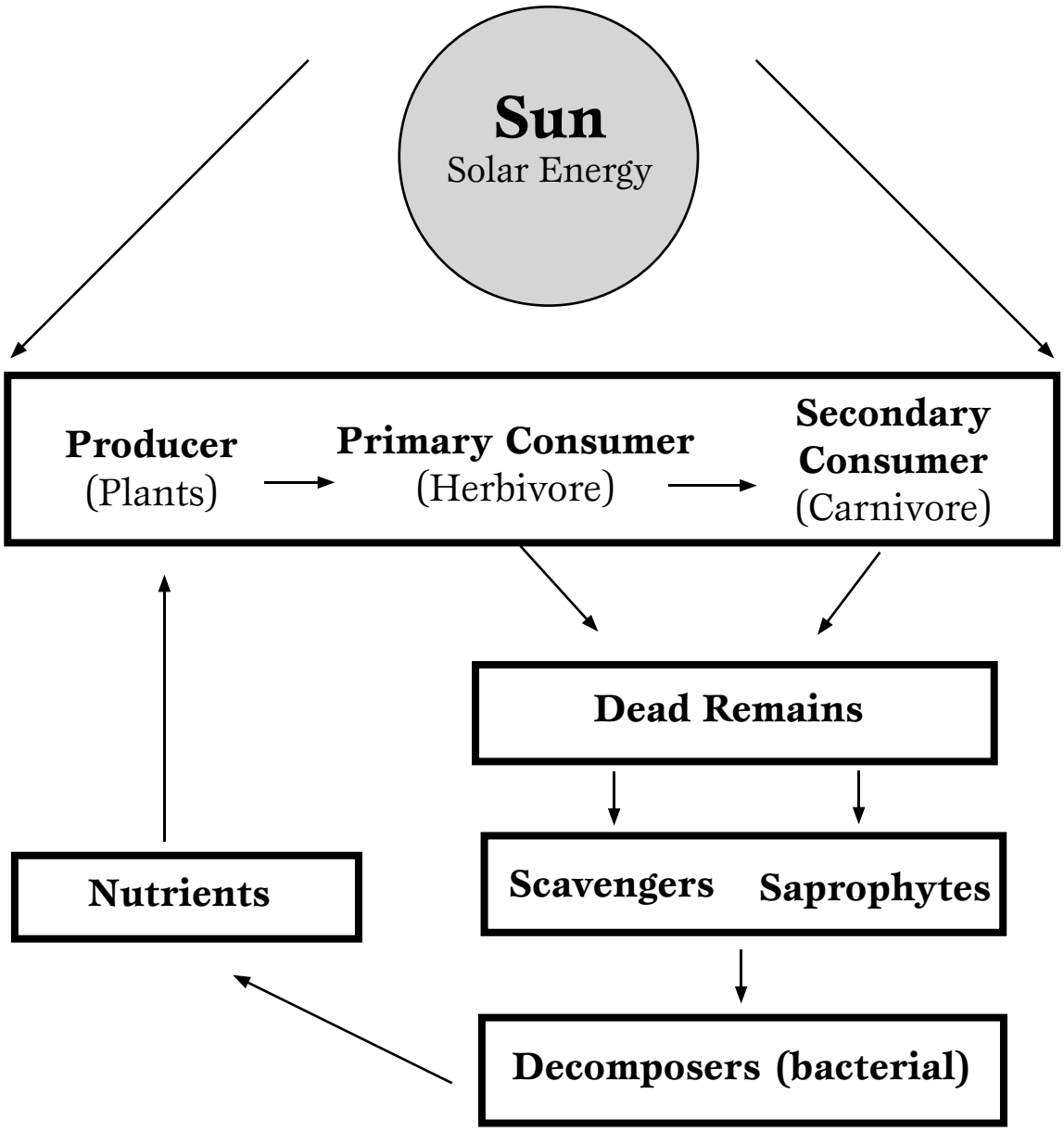


Fig. 1c: Forest Ecosystem Structure



1.5
ECOLOGY OF FORESTS AND FOREST BIODIVERSITY

Forests with many different species of animals and plants, and with many types of interrelationships between them have a high level of biodiversity. Think of an ecosystem as a house that you have built. Step by step you made a foundation for the house to rest on, then carefully put up the walls, the rafters, the roof, and installed your favorite doors and windows. The exterior paint was put on as a finishing touch. Now imagine taking the shingles off of the roof, or the eaves off. Removing one or two components will not destroy the house, but it will take away some of its strength and beauty. Take away too many components and the house will fall apart. In an ecosystem, nature's "house" is made of the seedlings, trees, deer, moose, eagles, flowers, mice and all other living things that interconnect. Remove too many of them, and the entire ecosystem can collapse.

When you think of biodiversity, think about the variety of houses and buildings in your neighborhood. There are many types of buildings, such as houses, apartment blocks, office buildings and other businesses. Some are made of brick, some of steel, and others have a wooden structure. There are multitudes of varying building styles, colors, shapes, etc. This diversity produces an interesting neighborhood. In a similar way, a healthy ecosystem has plenty of biodiversity. Just as your neighborhood's existence would be threatened if buildings began to disappear, so to with an ecosystem. The integrity of the ecosystem depends on a large variety of plants, animals, and other life forms.

Even if a life form is introduced from elsewhere in the world, it can adversely affect an ecosystem. For example, carp were introduced into North America from Asia in the early 20th century. What began as an experiment in fish farming quickly got out of hand. The carp escaped and now occupy most waterways in North America. They multiply in such large numbers that they can upset the ecology of a river or lake, and because they stir the water so much as they feed in large schools, they increase the sediment load in the water, causing harm to species that prefer clear water, such as trout. Similarly, there are plants that have invaded our ecosystems and have created serious problems. One example is the Purple Loosestrife plant, which grows so densely in wetland habitat that it can literally choke out other species such as bulrushes and cattails. When that happens, organisms that are used to the native species cannot obtain proper food or shelter, and must leave the area.

Biodiversity is an important characteristic in ecosystems because they are generally quite stable, and can handle disturbances. The size of a forest is not necessarily a measure of how diverse it is. The greatest biodiversity is usually found in stands of trees that are at different stages of age and development, known as an uneven aged stand. Groups of trees together (known as a stand) that are approximately the same age is called an **even aged stand.**

Forest succession is a state of constant change in the forest, and accounts for the reason that trees gradually replace or succeed each other. Animal populations change according to the successional stages that take place. For instance, young trees and shrubs which grow back in a harvested or burned site will provide excellent nutrition to animals such as moose and deer, but as the forest matures, these animals can no longer browse or feed on the tender shoots and twigs which soon get out of reach. Female moose (cows) often produce two calves per year on high quality feed compared to the usual one calf.

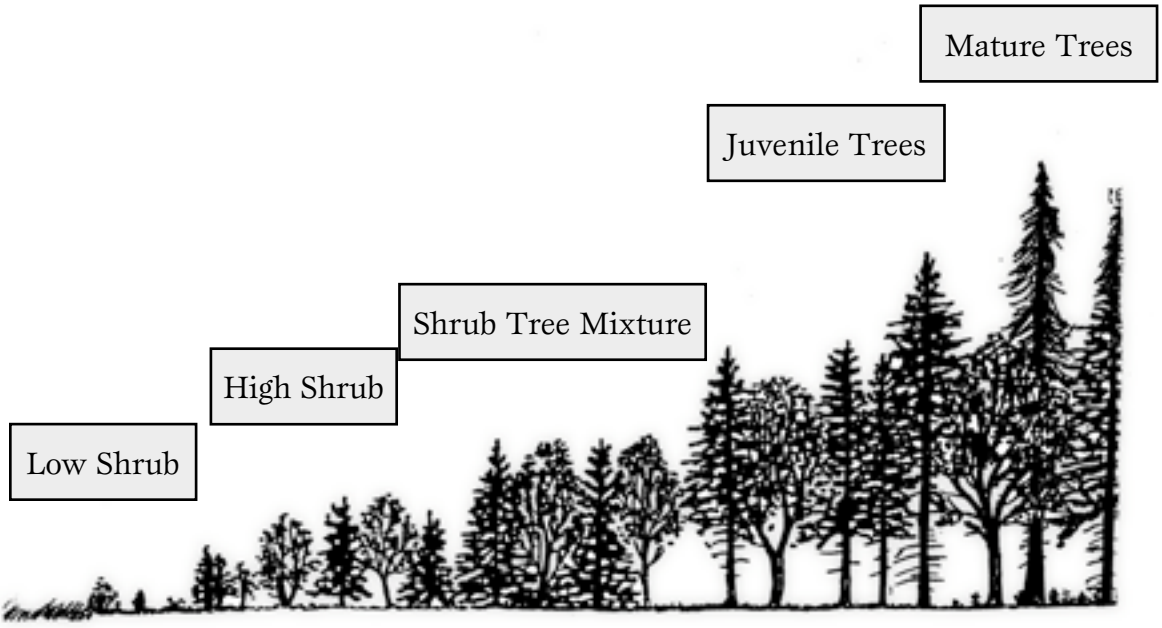
Lets imagine that an area in the forest has been cleared due to fire or harvest, and follow the successional stages that take place. The first to appear are the grasses and other small plants such as fireweed. These are known as **pioneer** species. They are gradually replaced by low shrubs such as blueberry, raspberry, and wild rose. Over time higher shrubs such as alder and pincherry replace the lower shrubs. As more time passes the sun loving (or **shade intolerant**) poplar or birch will begin to take over. A poplar stand will never flourish in the shadow of other trees. Later on, under the shade of the poplars, **shade tolerant** trees such as the spruce will begin to grow. This last stage of succession is called a **climax community**. It will continue to grow to maturity as the poplars, lifespan of 60-70 years, begin to die, decay, and fall to the ground, only to rot into the soil and provide nutrients to the remaining spruce trees. After another disturbance, either fire or harvesting, the cycle begins again. (see figure 2j)

Although not every forest of forest stand follows this exact formula, every stand reveals glimpses about its past, and the forces that shaped its very existence, such as fire, or a field or meadow no longer being farmed causing seedlings to germinate there from nearby seed producing trees. Even animals can influence the success or failure of a growing forest. Heavy browsing by deer can destroy many seedlings of Red Pine, or Cedar. Animal populations also change with the advancing age of the forest. For example, the Pileated Woodpecker lives mainly in forests of advanced age where the many dead trees (snags) provide a place to nest in, and many insects to eat.

A stand of trees in the forest will increase in height and diameter. This increase in biomass is due to the new wood added each year in the form of a growth ring. (see figure 1h). Gradually the tree will mature, and as time continues, it will become overmature. The growth rings by this time have become smaller and smaller, and the tree slowly begins shedding mass (i.e. dropping limbs and branches from the top down as they die). The tree may become attacked by insects and fungi, which further weakens the tree's structure. At this point the tree is said to be **decadent**. Eventually the tree will die. It may remain standing for years, providing a home for insects, birds, and even bats, raccoons, and other mammals. Or, it may snap off in a windstorm and become deadfall. Once on the ground, bacteria and fungi will consume it, and recycle its tissues back into the soil, providing nutrients for other seedlings or young trees.

Ideally, if trees are to be harvested then, it makes sense to harvest them at the point where growth has stopped, but the tree has not yet begun to die. In a sense, it is like picking the vegetables in your garden when they are large, mature, and ripe, not small, green, and immature. By harvesting in the mature stage, foresters are getting the most wood fibre per hectare, and setting the successional stage for a new forest to begin.

Fig. 1d: Successional Stages in a Manitoba Forest



The diagram below shows successional changes resulting in a closure of the clearing and growth of a new forest

ACTIVITY 4:
INVESTIGATING THE ECOLOGY OF A ROTTING LOG

Background information: An ecosystem can be as small as a tiny pond, or even as small as log rotting on the forest floor. In this activity you will explore and identify life forms found in this common microecosytem.

Materials: hand lens or magnifying glass
Plastic zip-lock bags
Tweezers
Small jars with screw caps
Flat blade screwdriver or similar tool for digging/prying

Procedure: Place log on large sheet of paper. Observe and sketch log noting evidence of insects or other animal life, i.e. burrowing holes, tunnels, etc. Examine outer bark for fungi, moss, lichens, etc. Using your digging tool, remove small sections of bark at a time, looking for centipedes, ants, beetles, insect larvae, etc. Capture these in the bags or jars for identification later.

Roll the log over and examine the bottom.. Compare the moisture levels on the top of the log as compared to the bottom. Look for evidence of white or yellow threadlike strands called **hyphae**, which make up the body of fungi. These hyphae secrete enzymes which digest the cellulose in wood, further speeding the decomposition of trees on the forest floor.

Application questions:

1. Account for the different moisture levels on the top and bottom of the log.
2. Compare other abiotic factors between the top and bottom of the log, such as wind, sunlight, and temperature. Try to relate these factors to the kinds of life forms found there.
3. Use a diagram to explain the food web on the rotting log. (Hint: who are the producers? The herbivores? The carnivores? The decomposers?)
4. What ultimately happens to the biomass of a large fallen tree? How is this beneficial to the forest ecosystem?

1.6
PLANT AND ANIMAL RELATIONSHIPS

In the forest as in all biomes, each day brings new interactions between plants and animals. These relationships can be one of several types. In a predator-prey relationship, a carnivore (or omnivore) hunts, kills, and eats another animal, usually (but not necessarily always) a herbivore. The population of prey is kept at a healthy level, since large number of rabbits or mice, for example, could over browse their habitat, and exceed their carrying capacity, or the ability of the ecosystem to support them. A farmer, for example might be able to graze four cows on a two hectare pasture, but definitely not forty. The number of predators usually follows increases or decreases in the number of prey, rising and falling in a rather cyclical pattern. (see Fig. 2p).

In **competition**, two or more individuals compete for food, shelter, or habitat. **Interspecific competition** occurs between members of different species, for example, rabbits and deer competing for tender young shoots and seedlings in a woodlot. **Intraspecific competition** occurs between members of the same species, such as two moose competing for the same mate. Competition has an adaptive advantage since it creates conditions necessary for "survival of the fittest". In a forest, trees will compete for sunlight, nutrients, and soil moisture. The tree that wins the struggle is said to be a "dominant" stem, and will have a larger "crown" or amount of foliage to capture sunlight, and will have more biomass. It will also be slightly taller than surrounding trees, and usually has a straighter trunk. It has superior genetics, and often its seeds or cones are collected for seedling production, and is sometimes referred to as a "plus" tree. This dominant tree may have several "co-dominant" trees nearby, since the sight conditions are usually quite similar. Shorter, inferior trees will grow in the shadow of these larger trees, and since they lose the battle for survival, will often die, fall over, and return their nutrients to the forest floor (see Fig. 2k)

In a relationship called **commensalism**, two species are associated together, yet only one benefit from the relationship. The other species is not helped or harmed. An example of this would be moss growing on the lower trunk of a tree. It benefits by securing moisture from the moist lower bark, especially on the north side's microclimate, which is cooler. The tree itself receives no benefit from the presence of the moss.

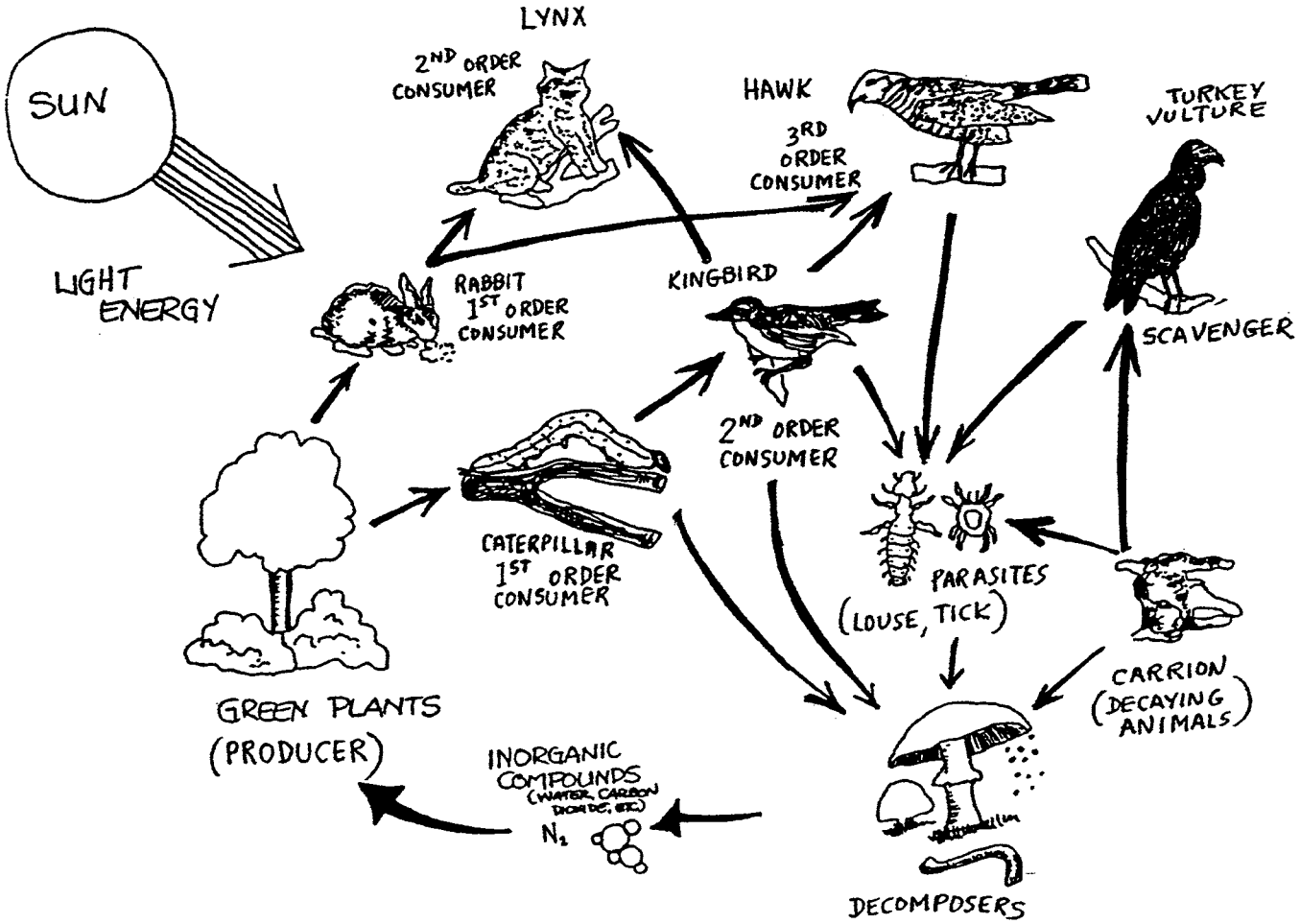
An interesting form of a relationship called **mutualism** exists in forests, in which both species benefit. It is so important that a forest can never reach its peak of health and productivity without it. Yet, it can never be seen! Researchers have identified a soil fungus called **mycorrhyzae** which is found deep in the root zone of forests. The fungi are delicately intertwined around the rootlets and even the tiniest root hairs of trees. They exist by absorbing small quantities of sugars that the tree sends down to the roots for storage, and they in turn enhance the root's ability to absorb minerals, water and other nutrients from the soil, mainly by increasing the surface area for absorbtion.

Parasites can affect a tree, and can spread to affect an entire stand of trees. One example is pine blister rust, in which parasitic spores invade the needles of coniferous trees, causing them to turn orange. When this happens, they lose their ability to photosynthesize, and the tree may eventually die. Other parasites, such as aphids, suck the juices out of leaves, causing a loss of vigor in the tree or shrub.

Whether it's a plant or an animal that dies in an ecosystem, one of nature's clean up crew is there to take care of it. **Scavengers** generally clean up the remains of dead animals, such as winter killed deer. Ravens, magpies, and other birds will feed on animal carcasses, as will mammals such as bears, fox, and coyotes. **Saprophytes**, mainly fungi and bacteria, will assist in the decomposition of fallen trees, leaves, branches, and other biomass that ultimately ends up on the forest floor. They assist in the breakdown of this organic material, and return the nutrients to the soil. They are the ecosystem's recycling crew. The combined efforts of the bacterial and fungal action create a moist black organic substance called humus, which will eventually become the very soil that the forest emerges from. It provides a moist nutrient rich layer in which seeds can germinate and become seedlings.

As in every ecosystem, every day brings a struggle for survival of the fittest. It is a case of "eat, or be eaten". When energy in an ecosystem passes from one organism to the next in a straight line fashion, it is called a **food chain**. (example: grass --- mouse---fox). In reality because of the complex way that energy is passed between a multitude of species, it is probably better known as a **food web**.(figure 1e).

Fig. 1e: A Forest Food Web



ACTIVITY 5
LET US SPRAY
A CASE STUDY OF THE SPRUCE BUDWORM

BACKGROUND INFORMATION: The Spruce Budworm is a destructive forest pest found in the Manitoba Model Forest, as well as other forested ecosystems of Manitoba. It has been responsible for killing or slowing down growth of the forest, causing serious economic losses. In 2000, over 113,000 km2 of forest was affected.

The adults are dull grey moths with brown spots. These moths fly around in July and August and lay eggs on the underside of needles near the crown (top) of the tree. The eggs lie dormant until the spring, when they become active. The larvae which emerge from the eggs begin to feed on the new growth of buds which begin to grow in the spring. When half grown, the larvae form a small nest which they construct out of silk on the tips of twigs. By the end of June, feeding is complete, at which time they will then form a pupa. The pupa will metamorphose into an adult, emerge in July to lay eggs, and the whole cycle is repeated. The needles of the trees turn brown. Heavy feeding can cause stunted growth, and after several seasons, the tree may die.

CASE STUDY: There are several ways to control the Spruce Budworm, such as chemical insecticides, biological controls(bacillus thuringiens or Bt), or biosynthetic hormones. Manitoba used to use Bt but since 1997 has switched to a biosynthetic molting hormone that makes the budworm begin metamorphosis, but not complete it. The hormone will act only on the larvae of the spruce budworm. Chemical pesticides have not been used since 1981 in Manitoba, partly out of concern that it may lead to bioaccumulation, or the accumulation of toxins in individual organisms. **Biomagnification** is the bioaccumulation occurring through several levels of a food chain.

Students should research the following to gain a better understanding of the issue:

1. How can living things become resistant to something that it supposed to kill them? Find out by exploring how pesticide resistance happens.
2. Certain countries continue to use harmful pesticides like DDT. Find out why DDT is so harmful. Why should Canadians be concerned about DDT use in other countries.
3. Find out why the biosynthetic molting hormone will not act on other species of insects such as butterflies. (hint: find out what a receptor site is on a cell membrane and the answer will become clear)
4. Produce a poster showing the complete life cycle of the spruce budworm, including a sketch of the eggs, larvae, pupa and adult.
5. Explore the various occupations of people that would be affected by a decision to halt all pesticide use. Try and estimate in dollars the loss of 113,000 km2 of spruce forest. Which occupations would be most affected?

1.7
NATURAL VS. ARTIFICIAL ECOSYSTEMS

Humans have been converting natural ecosystems to artificial ones ever since the days of early agriculture. Early civilizations advanced in culture, the arts, and even mathematics and astronomy once they settled down and met their need for food by growing it, rather than hunting and gathering. Most land conversion from a natural ecosystem to an artificial one involves clearing the land and either cultivating it for crops, or for grazing animals such as sheep and cattle. Most of Eastern North America was cleared of its natural forest cover and converted to agriculture in the last 200 years. Railway development in Canada's early history led to enormous amounts or wood harvested for railway ties, bridges and trestles, not to mention the wood lost to fires on the right of way due to the sparks sent out of the engine smokestack,. After World War 2, increased demand for lumber, and other forest products such as paper, led to increased harvesting of the forest. Scientific forest management was being introduced in response to this, and gave rise to plantation forestry, especially in the United States.

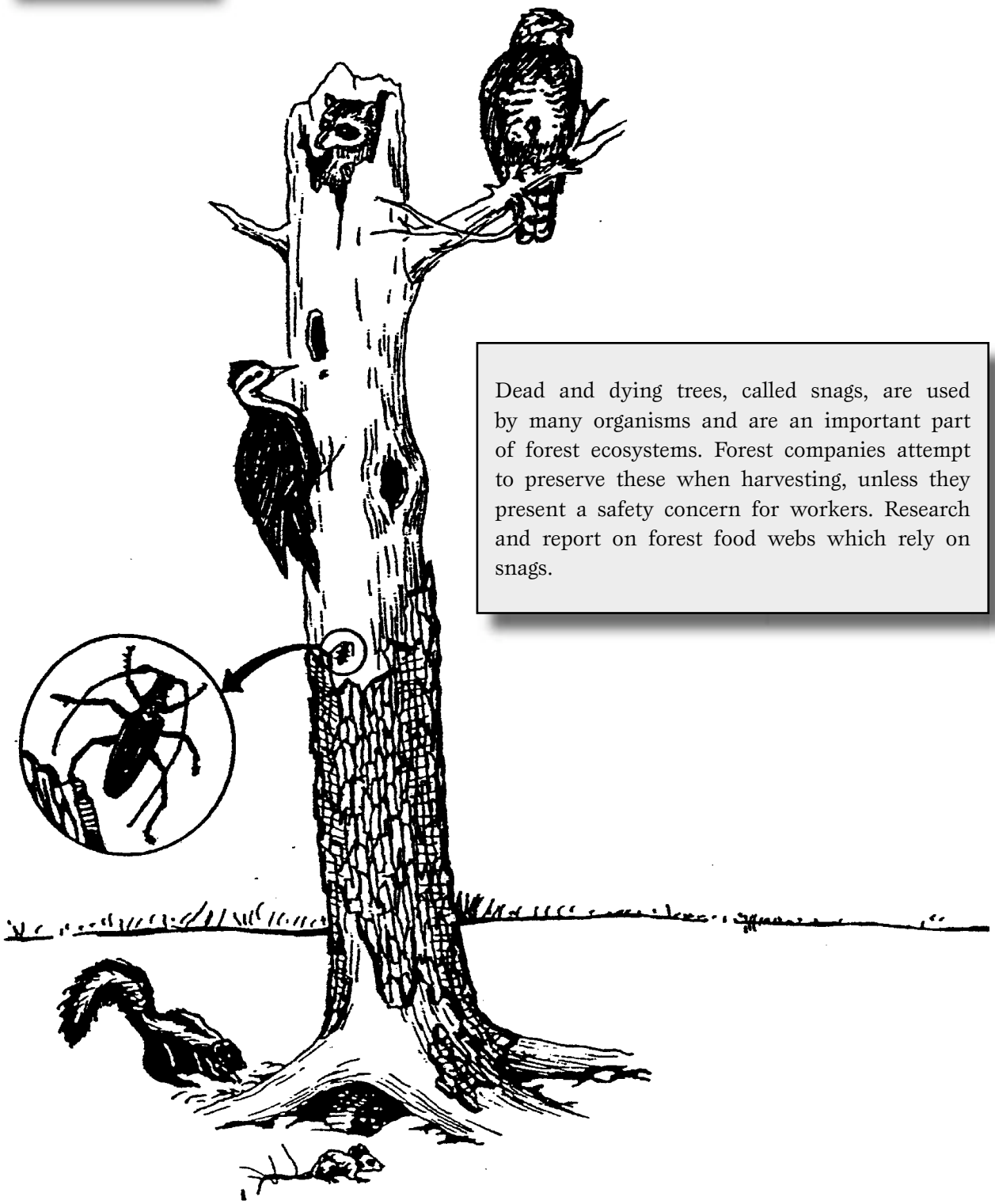
There are several differences between a natural forest and a plantation:

1. Natural forests show a great deal of biodiversity since they are home for many plant and animal species. Plantation forests on the other hand are generally a monoculture, generally of one species of tree for industrial use, and perhaps a few other species of plants and animals. Because it is a monoculture, insects or disease can spread very quickly unless costly measures are taken to control them. In a natural forest, a healthy balance of species usually means that insects are controlled by natural means such as predator-prey interaction. There are very few plantation style forests in Canada.

   In the Manitoba Model Forest, all sites harvested are regenerated either by natural means, or by humans, who plant hundreds of thousands of seedlings. The average size cut block is about 40 acres (15 hectares). The new forest will be a mix of softwoods (spruce or pines which are preferred by the local mill) and hardwood species, which invade the bright sunny opening, since they are a pioneer species. Plantation style forestry does not suit Manitoba for two reasons. First of all, the topography of the Canadian Shield is very rocky and swampy so it is difficult to establish a plantation in the first place. Secondly, because of the high cost of managing a plantation, forests products would cost far too much to produce. It can cost $400 per hectare just to "thin" a plantation, and many years would pass before the investment would yield results.

2. Natural forests provide other benefits such as recreational camping, hiking, bird watching, etc., while an artificial ecosystem such as a plantation generally does not, however both forests produce oxygen and wood fibre, and protect the land from erosion.
3. Plantations can be managed to produce a maximum amount of wood fibre per hectare of land, since herbicides, thinning, and tree spacing can be carefully controlled. These plantations often thrive on land not well suited for crop production, and help conserve the soil in the region. Also, plantation forestry can supply industry with wood, thereby taking the harvesting pressure off the natural forest. Spacing trees 2.5 meters apart in all directions will produce 1600 trees per hectare, giving higher yields than most natural forests ecosystems.
4. Plantations could help Canada meet the conditions of the Kyoto Accord, which recognizes the key role of trees in taking Carbon Dioxide, a key greenhouse gas, out of the atmosphere (Canada's Forest 2020 program).

Fig. 1f.



Dead and dying trees, called snags, are used by many organisms and are an important part of forest ecosystems. Forest companies attempt to preserve these when harvesting, unless they present a safety concern for workers. Research and report on forest food webs which rely on snags.

1.8
BASIC TREE BIOLOGY

In order to better understand the forest, it helps to understand the basic biology of an individual tree. A tree has three basic parts, each with its own function. The **roots** anchor the tree, and absorb water and nutrients. The **trunk** supports the crown, and conducts water and nutrients up and down from the crown to the roots, and from roots to the crown. The **crown** manufactures food in the individual leaves by photosynthesis.

During **photosynthesis**, chlorophyll (fig. 1g) – the green pigment found in leaves – captures the energy in sunlight and uses it to convert carbon dioxide and water vapour in the air into a simple sugar, called **glucose** or **fructose**, and gives off oxygen as a by-product. This reaction sustains all life on earth. The herbivores then feed directly on the plants, and the carnivores feed on them, and thus the entire food web on Planet Earth carries on. The foliage on the entire crown is oriented in such a way to capture the maximum amount of sunlight to produce a maximum amount of glucose, which will later be converted by enzyme action to cellulose, a large important molecule which makes up wood fibre.

When a tree comes out of a dormant state in the spring, only one row of cells under the bark, called **cambium**, begins to grow. This layer can grow in both directions – inward and outward. The outward growing cells form the inner bark phloem, which carries sap from the leaves down to the roots for storage. These cells eventually die and become the outer bark. Inward growing cells form the **xylem**, which carries water from the roots up to the leaves. Eventually these cells die and lose their water carrying ability and become **heartwood**, which provides strength to the trunk by acting as a rigid skeleton. The wood fibres in heartwood may be slightly different in color than sapwood, having been stained over the years by minerals in the ground water which the tree absorbed. The tremendous strength of wood is explained by the rigid cell walls of the heartwood and sapwood.

Looking at a tree trunk in cross section allows us to see the **growth rings**. (see fig. 1h) Each ring is made up of a light colored band of cells and a darker band. The lighter band of cells is called **springwood**, and is made when moisture conditions are ideal and the tree experiences a "growth spurt". Later in the summer when its is hotter and drier, and the days of summer are growing shorter, the **summerwood** is more dense and has smaller cells. Counting these rings will determine the age of a tree. The relative size of the rings reflect the kind of growing conditions the tree experienced that year. In a dry year for example, the growth rings will be spaced much closer together, indicating poor growth. The tree rings will also be tightly spaced toward the end of a tree's life span, indicating to foresters that little wood volume is being added, and that the tree is suitable for harvest.

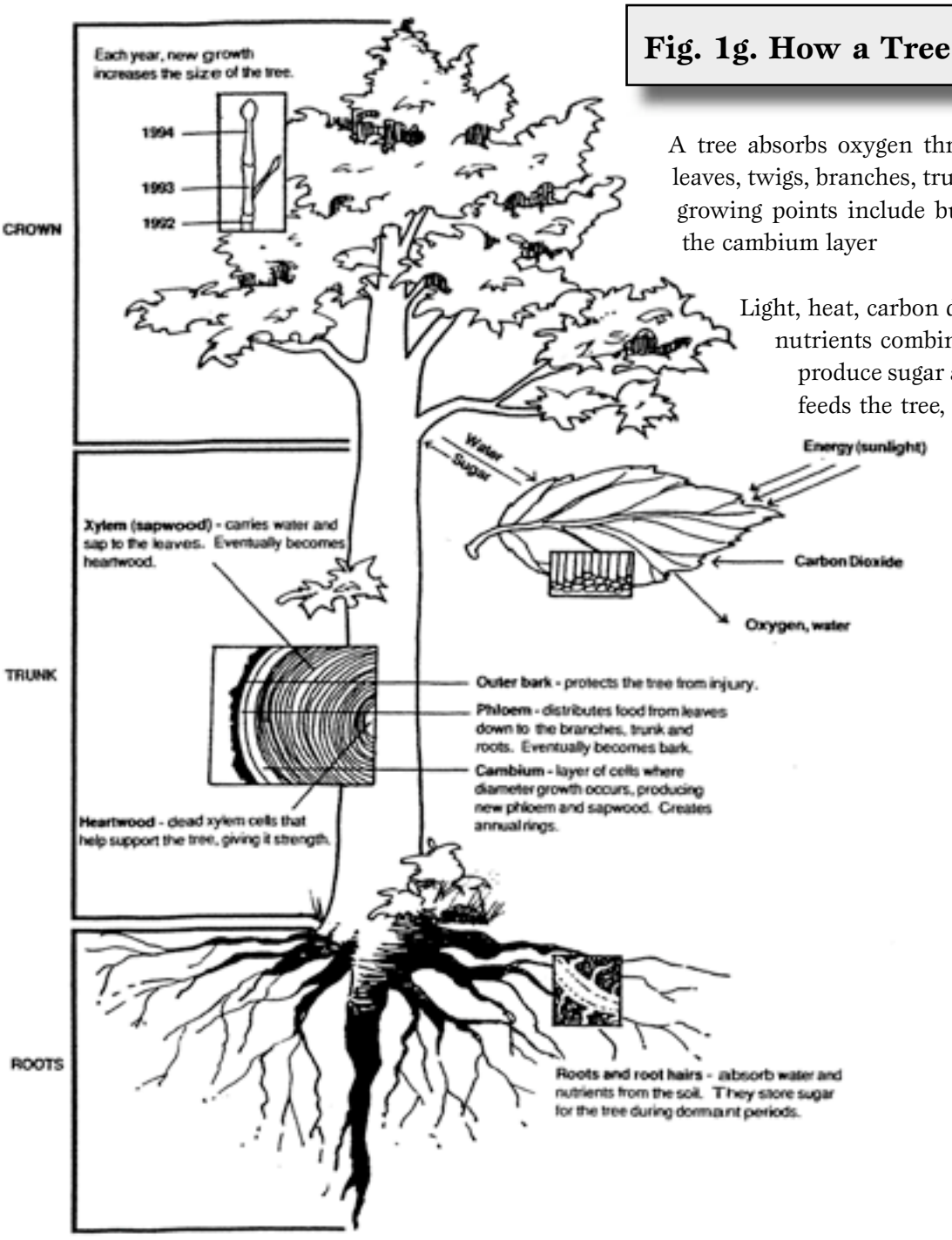
Generally speaking, there are two main groups of trees – the coniferous or softwoods, which have needles rather that leaves, and whose seeds develop in cones. These trees retain their needles all year (except for one species called larch or tamarack). The other group is the deciduous trees, or hardwoods who have broad leaves which are shed each year before winter to conserve moisture. The needles are an adaptation to the boreal forest since the they conserve water due to their shape and waxy coating. After all, the trees in the long boreal winter may go without water from freeze-up (November) until spring thaw (late April), Since the soil is frozen, the roots cannot absorb water. Occasionally, however,

during a mild spell, the needles may begin to photosynthesize, lose the water in their tissues, and turn brown as they die. This winterkill is sometimes called sunscald, and is the reason some homeowners cover their conifers with burlap in the fall, shielding them from the winter sun.

Fig. 1g. How a Tree Functions

A tree absorbs oxygen through pores in its leaves, twigs, branches, trunk and roots, The growing points include buds, root tips and the cambium layer

Light, heat, carbon dioxide, water and nutrients combine in the leaves to produce sugar and oxygen, Sugar feeds the tree, while oxygen and water are released to the atmosphere., Carbon is stored in the wood.



ACTIVITY 6
LAB: KING OF THE RINGS

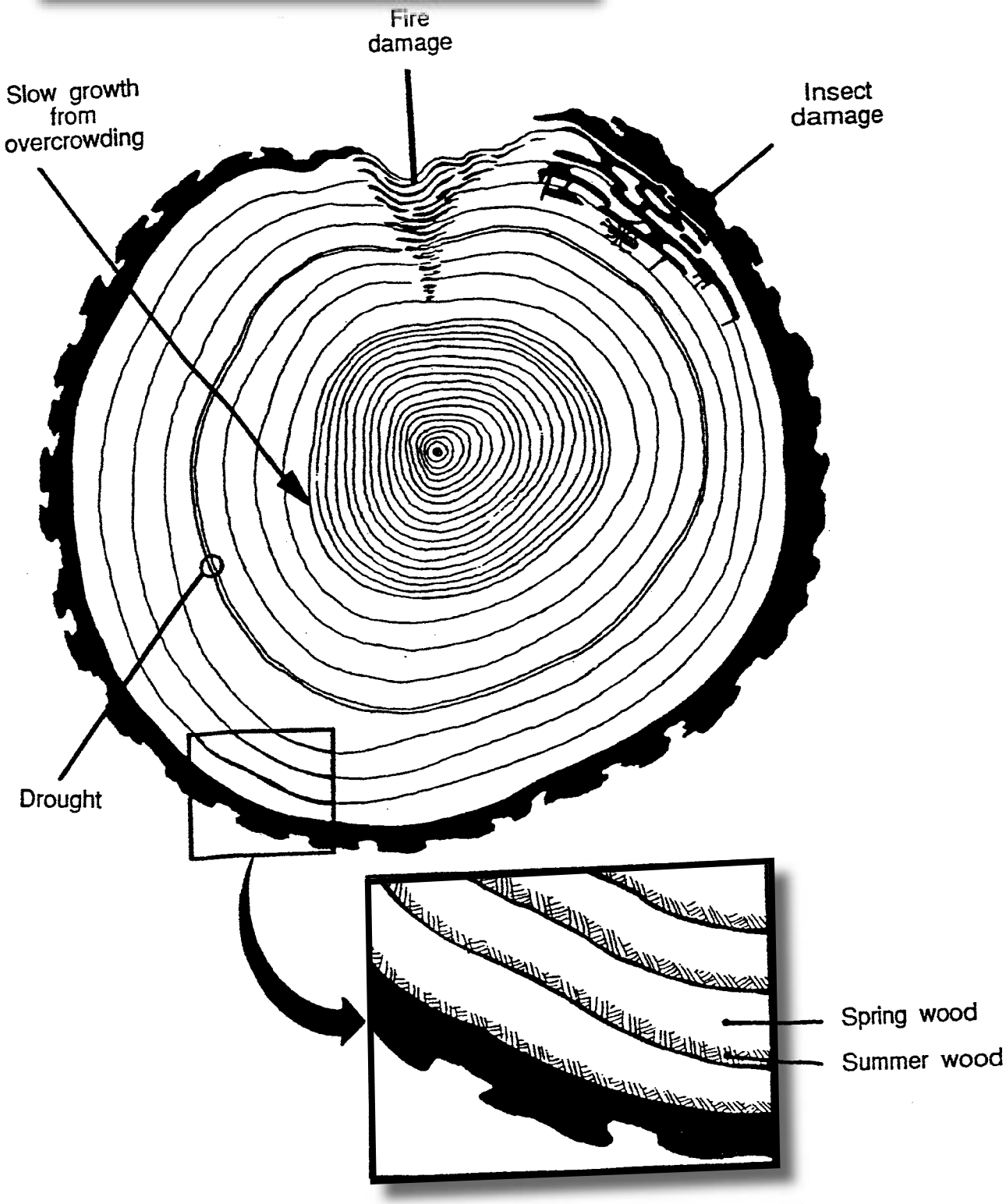
Background information: Each year that a tree grows, it increases in diameter by adding a new growth ring. This ring is made of a light colored springwood section, and a darker and narrower summerwood section. Together they equal one year of growth. The purpose of this lab is to study the variation in growth rings and relate this to factors which influence the size of the rings such as weather, disease, insects, fire, etc. Foresters will often age trees by the number and size of the growth rings, taking several samples from trees within the stand.

Materials: hand lens or magnifying glass
Tree "cookie" or cross section about 1" thick (sanded both sides)
Millimeter ruler

Procedure: Hand out tree rings. Identify some of the unique characteristics and have students analyze the life of the tree.

1. How many rings does it have?
2. In what year did this tree begin growing?
3. Measure the diameter of each ring in millimeters.
4. Identify the species of tree. Is it a hardwood or softwood species?
5. Compare the tree rings with weather data available in the Environment Canada website.
6. Identify factors that could have impacted on the tree's growth. i.e. diseases, insect infestations, natural disasters, fires, or human-induced situations ie. Damage to bark from machinery
7. Calculate the area of the circle made by the final tree ring and the one from 10 years ago. How much did it grow in 10 years…(hint: what is the difference in area between the two?) formula for area of circle: 3.14 x (radius squared).

Fig 1h. Stories in Tree Rings

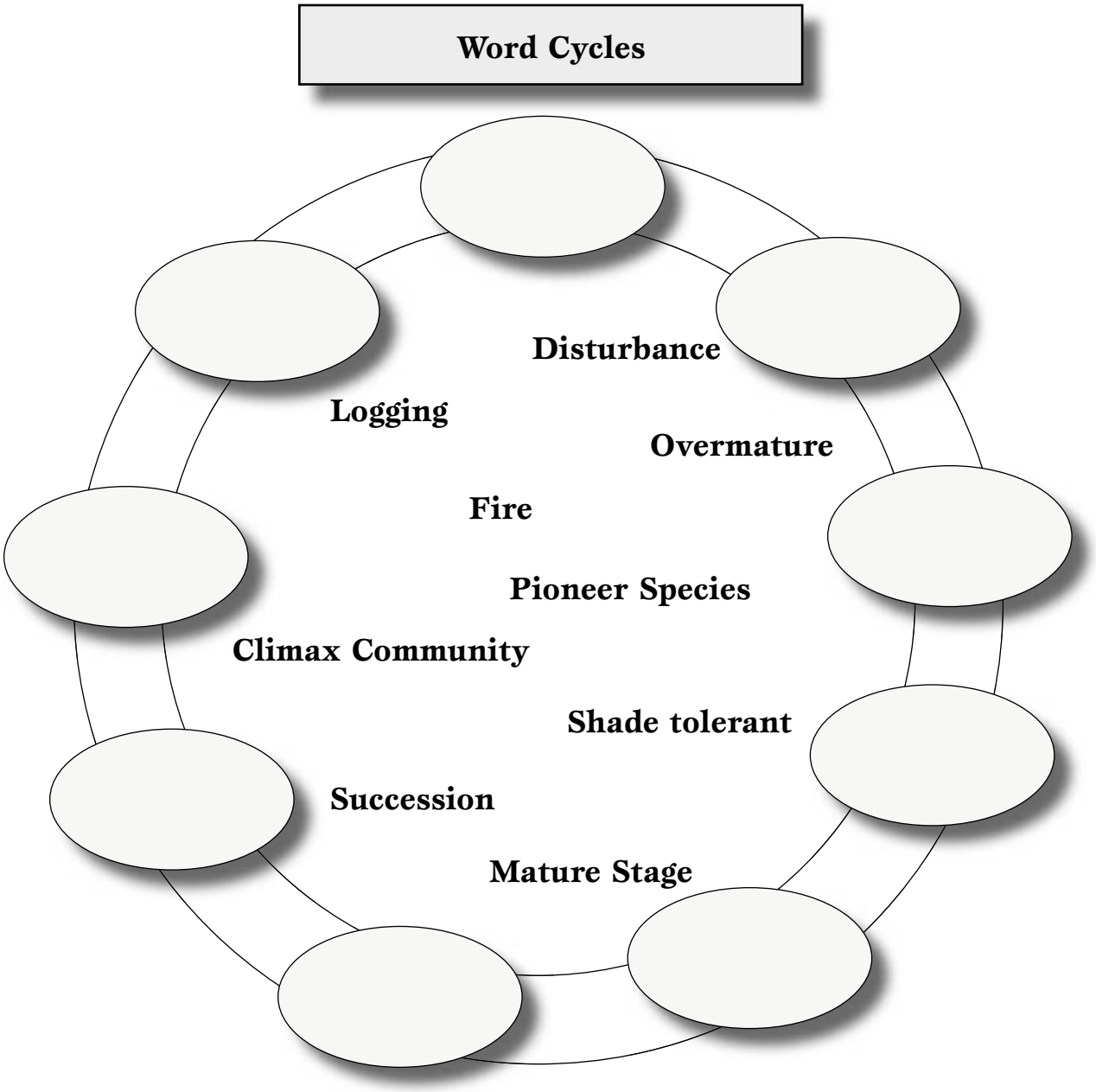


Chapter 1 Assignment

1. Why is it important that all parts of an ecosystem be considered when humans develop cottages, harvest trees, or build roads in the Boreal Forest?
2. How does a stand of trees in a forest become established?
3. List three things that can affect the health of the forest.
4. What is the difference between an autotroph and a heterotroph?
5. What kind of competition is there between rabbits and beavers competing for food in a stand of young willow trees?
6. What is humus? How does it form?
7. Sketch a cross section of a tree showing tree rings, heartwood, and sapwood.
8. Explain how a growth ring is formed.
9. List three main parts of a tree and explain their function.

Projects and Activities

1. Find a shoebox. Make a diorama of a scene in a Boreal Forest. Include as many species of plants and animals as you can. Have groups present 4 dioramas, one for each season.
2. Using old magazines, cut out pictures and arrange them in a collage to illustrate the different values that humans place on the forest, i.e recreation, employment, etc.
3. Adopt a tree in the school yard or local park. Identify its species. Sketch the tree and make a journal describing the subtle changes that take place week by week. What other organisms are using the tree (birds, insects, etc)?
4. Prepare a report on Forest Biodiversity. Begin by visiting BioBlitz @ www.biodiversityonline.ca/BioBlitz/intro.htm
5. Discuss how Canada is protecting its ecosystems. Begin with a visit to Parks Canada @ www.parkscanada.pch.gc.ca
6. Report on the various ways that the Canadian Model Forest Network is working to develop and promote sustainable forest practices. Visit them at www.modelforest.net



Directions

Read the list of words in the circle above. Select one word and place it in any oval. In the next oval place another word that is related to the first. They could be synonyms, antonyms, steps in a process, examples of something and so on. Be prepared to finish the statement "Word A is related to word B because ..." Write a note on the band in between the words to remind yourself of the relationship. Continue this process until you have placed all the words. Plan ahead; the last few words will be tricky to place.

Definition	Word or Concept	Diagram
	Overmature	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Decadent	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Endangered	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Vulnerable	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Climax Community	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Community	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Autotroph	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Heterotroph	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Biodiversity	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Growth Ring	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Threatened	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Extinct	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Extirpated	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Population	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Pioneer Species	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Tundra	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Boreal Forest	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Temperate Deciduous Forest	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Grassland	
	Synonym/Example	

Definition	Word or Concept	Diagram
	Ecosystem	
	Synonym/Example	

Key word or Concept.

Ecosystems

Write an explanation or definition in your own words. You will be paraphrasing.

Draw a figurative Representation.

List Facts (at least five).

Write down two questions about the concept.

Create an analogy

Concept Overview: Used by permision of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27.

Compare Relationship Frame

Compare and Contrast

Make the distinction between:
Biotic Enviroment and Abiotic Enviroment

Biotic Environment	Abiotic Environment

Write a summary statement:

Concept Overview: Used by permision of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27.

Compare Relationship Frame

Compare and Contrast

Make the distinction between:
Coniferous trees (softwoods) and deciduous trees (hardwoods)

Coniferous Tree	Deciduous Tree

Write a summary statement:

Concept Overview: Used by permision of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27.

Chapter 1 Answer Key

1. All parts of the ecosystem must be considered to prevent damage to any one component, whether it is soil, water, or wildlife. A healthy ecosystem depends upon the health of each of its components.

2. A stand of trees becomes established after a disturbance in the forest ecosystem, such as fire, logging, blowdown, or insect/disease infestations.

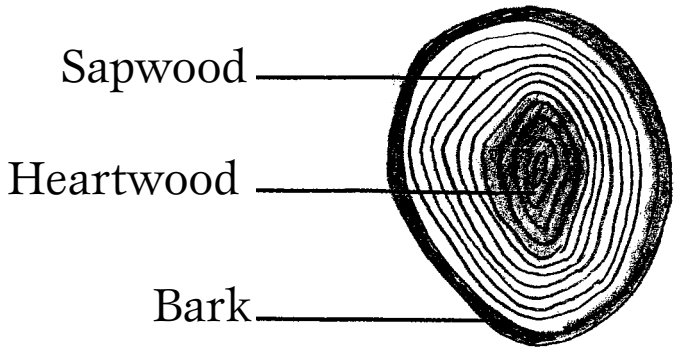
3. The health of the forest can be affected by:
   a. amount of light reaching the canopy
   b. nutrient levels in the soil
   c. amount of moisture received
   d. competition with other vegetation
   e. insects and disease

4. An autotroph produces its own food, such as plants undergoing photosynthesis. A heterotroph cannot produce its own food and relies on other organisms for its nutrients, such as a moose browsing on willows, or a fox eating mice.

5. Rabbits and beavers competing for willow is an example of interspecific competition.

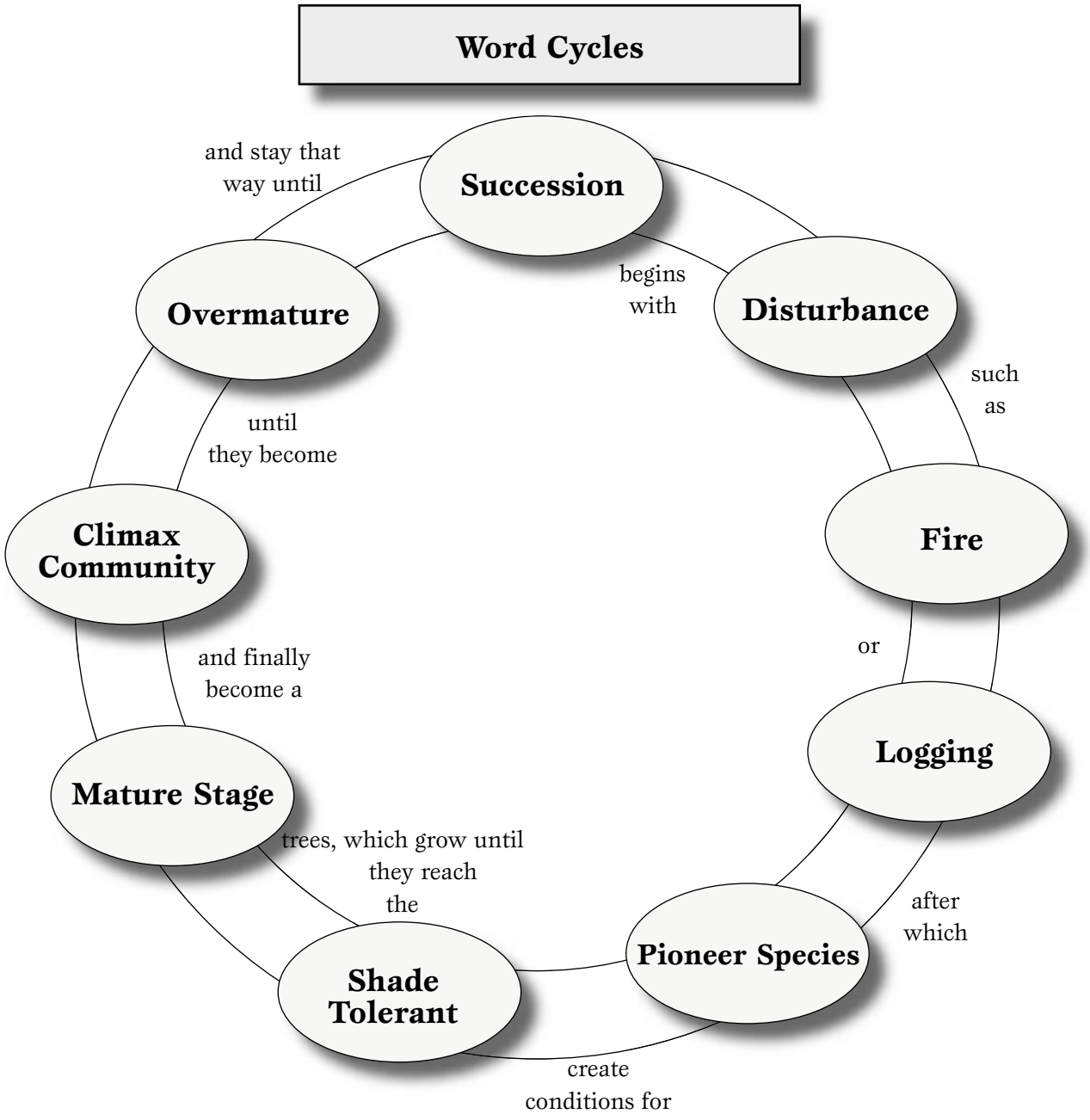
6. Humus is a major component of soil. It forms from decaying vegetation and other organic matter, and is an important source of nutrients for plant growth.

7.



8. A growth ring is formed from the cambium layer, and is made of large celled, rapidly growing springwood, and smaller celled, slower growing summerwood. Together, they make up one year's growth.

9. The three main parts of a tree are:
   a. crown: supports leaves, exposing them to the sun
   b. trunk (stem): conducts materials from crown to roots, supports crown
   c. roots: anchor the tree, absorb water and nutrients, stores energy, sometimes involved in reproduction (suckering)



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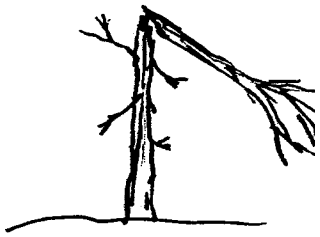
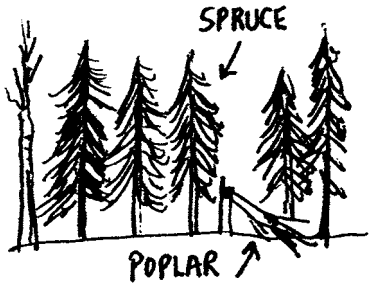
Definition	Word or Concept	Diagram
A tree or stand that has gone past the point of maturity	**Overmature** Synonym/Example	

Definition	Word or Concept	Diagram
Trees deteriorating due to age	**Decadent** Synonym/Example: decaying	

Definition	Word or Concept	Diagram
Species facing serious risk to its survival	**endangered** Synonym/Example	Whooping Crane Eastern Conger Atlantic codfish

Definition	Word or Concept	Diagram
Species could face an uncertain future	**vulnerable** Synonym/Example	Polar Bear

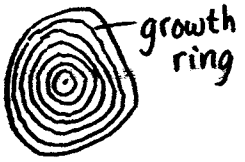
Definition	Word or Concept	Diagram
The stable, self replacing stage in plant succession that persists for long periods of time.	**Climax Community** Synonym/Example	

Definition	Word or Concept	Diagram
The living organisisms in a given community, such as plants, animals, fungi, bacteria	**Community** Synonym/Example	pond woodlot grassland forest lake river etc.

Definition	Word or Concept	Diagram
Any organism that can produce its own food, such as plants	**Autotroph** Synonym/Example photosythetic producer	

Definition	Word or Concept	Diagram
Any organism that depends on energy stored in another organism	**heterotroph** Synonym/Example consumer	deer fox wolf moose

Definition	Word or Concept	Diagram
A variety and abundance of different plants, animals, and micro organisms, and the biological process they preform	**Biodiversity** Synonym/Example	any stable community

Definition	Word or Concept	Diagram
amount of wood added to a tree during one growing season.	**Growth Ring** Synonym/Example annual ring	

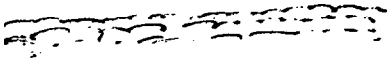
Definition	Word or Concept	Diagram
A species facing serious problems if conditions in the ecosystem do not improve.	**Threatened** Synonym/Example many examples on the Enviroment Canada Website	

Definition	Word or Concept	Diagram
A species no longer found on any ecosystem on earth.	**Extinct** Synonym/Example •Wooly Mammoth •Passenger Pigeon	

Definition	Word or Concept	Diagram
A species no longer found in a particular area, but not from its entire range	**Extirpated** Synonym/Example	Grizzyly bear Woodland Caribou

Definition	Word or Concept	Diagram
groups of individuals of any one kind of organism.	**Population** Synonym/Example Many examples on Enviroment Canada Website	

Definition	Word or Concept	Diagram
Species that are the first to appear after a disturbance in the ecosystem	**Pioneer Species** Synonym/Example	

Definition	Word or Concept	Diagram
An ecosystem found at high latitude, consisting of a short growing season, permafrost, and saturated soils	**Tundra** Synonym/Example	

Definition	Word or Concept	Diagram
An ecosystem in northern latitudes with long winters, short cool summers, thin soils and extensive coniferous forest.	**Boreal Forest** Synonym/Example	

Definition	Word or Concept	Diagram
An ecosystem at mid latitudes with mixedwoods forest, variable soil conditions and moist summers.	**Temperate Deciduous Forest** Synonym/Example ie. Swan River area	

Definition	Word or Concept	Diagram
An ecosystem with warm dry summers fertile soils, and few trees.	**Grassland** Synonym/Example Virden Neepawa area	

Definition	Word or Concept	Diagram
Complex system of living organisms (biotic) and non living components (abiotic).	**Ecosystem** Synonym/Example	

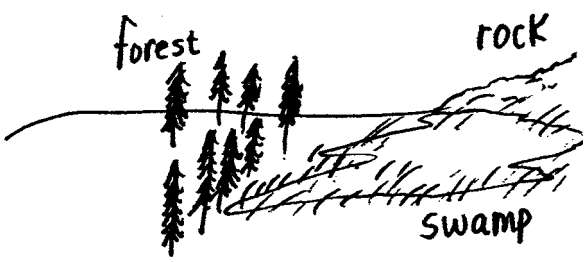
Key word or Concept.

Ecosystems

Write an explanation or definition in your own words. You will be paraphrasing.

An ecosystem is a complex system made of living parts (biotic) such as plants, animals and fungi. As well as non-living (abiotic) parts such as rock, air and water

Draw a figurative Representation.



List Facts (at least five).

- there is an ongoing flow of enery in an ecosystem.
- all ecosystems together form the biosphere.
- matter is recycled in an ecosystem.
- ecosystems run on solar energy which provides energy for the plants.
- consumers feed on plants

Write down two questions about the concept.

- Do ecosystems last forever ?
- What kinds of things effect an ecosystem ?

Create an analogy

An ecosystem is like a house, made of various parts such as a frame, a foundation and a roof etc. All parts of the system must be sound if the house is to provide living space.

Compare Relationship Frame

Compare and Contrast

Make the distinction between:
Biotic Enviroment and Abiotic Enviroment

Biotic Environment	Abiotic Environment
living Parts of an Ecosystem • *plants* • *animals* • *fungi* • *bacteria*	*non - living Parts of an Ecosystem* • *sunlight* • *air* • *water* • *soil* • *nutrients*

Write a summary statement:

A healthy, living ecosystem depends on the abiotic environment (sun, water, air) sustaining the biotic environment. (plant, animals, fungi, and bacteria).

Concept Overview: Used by permision of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27.

Compare Relationship Frame

Compare and Contrast

Make the distinction between:
Coniferous trees (softwoods) and deciduous trees (hardwoods)

Coniferous Tree	Deciduous Tree
• softwoods • needles • needles present all year except for tamarack • reproduces from seeds found in cones	• hardwoods • leaves • leaves shed in autumn • variety of seed types ie. oak (acorns) ash (samaras or winged seeds)

Write a summary statement:

Coniferous trees and deciduous trees differ in their appearance, the way they reproduce, and the harness of the cells which form their wood.

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