FIRE as a fact of life

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INTRODUCTION

In New Zealand we **regard forest fire as a disaster**. But we forget that **fire in many areas is a natural fact of life**. And that many plants have become adapted to the effects of fire. In fact the continued existence and life cycle of some trees and shrubs is dependent on fire.

Fire is part of nature in countries such as Australia, Africa and America. The story of fire and of how plants have adapted to this event is the subject of this walk.

Australia is regarded as a fire adapted landscape, and we will include examples of trees from that country in our tour, and others as well.

Fire is an evolutionary factor - plants have clear adaptations to fire. We will explore some of these adaptations.

Fire frequency

Fire plays an important role in many ecosystems. For example on the East Coast of Australia the open forests and heaths have adapted to a variety of fire regimes. In the case of heaths, fire frequency may vary between 8 and 25 years and in open forest environments between 12 and 50 years on average. The wetter eucalypt forests in gully environments on the South Coast of New South Wales may have fire free intervals up to 150 years. In the wettest eucalypt forest types such as occur in Tasmania and Victoria and occasionally within the gully environments of the South Coast of N.S.W., fire free intervals of greater than 300 years may occur in which case a rainforest understorey often predominates.

Fire and Plant Responses

The evolutionary adaptation of eucalypts to fire

Most eucalypt species, for example, have adaptive traits ensuring their survival-even after very intense fires. Moreover, following the recovery of tree crowns, eucalypts may grow, for a number of years, more vigorously than they did before the fire. There are a number of hypotheses that may account for the **adaptation of eucalypts to fire** in these and other ways.

1. It is often said that eucalypts **evolved in a fire environment**; that is, such characteristics as **lignotubers**, epicormic shoots, and **thick bark** are taken to be direct adaptive responses to fire. This concept suggests an evolutionary interdependence between eucalypts and forest fires and presupposes that eucalypts may have evolved in the direction of large fuel loads and high flammability as a mechanism of attracting fire to itself, and through the response of regeneration to fire, ensuring its continuing existence.

2. Alternatively, eucalypts could have evolved in a **largely fire-free** environment as a nomad that is a species able to exploit disturbed and other specialised niches in rainforests, such as rock walls, riverbanks, earth slides and lava flows. The characteristics of the present-day eucalypts that enable them to regenerate and grow rapidly after fire may have developed in this way (i.e. they may not necessarily have been acquired through long adaptation to fire regimes in the distant past).

3. A third hypothesis is that **adaptation of some trees to fire may be seen primarily as a by-product of its evolutionary adaptation to declining soil fertility and a drying climate**. The outstanding capacity of eucalypts to respond to a number of environmental stresses could reflect, in turn, prior adaptation of its progenitor to more specialised and disturbed niches within the Gondwanan rainforests.

While it is possible that all three pathways played some role in their adaptation to fire, it remains **difficult to accept that some of their more significant growth attributes represent a direct evolutionary response to fire**. Both the lignotuber and the epicormic shoot have biological and ecological significance in no way connected with fire. The **lignotuberous habit** has been seen as a cardinal attribute contributing to **drought tolerance and occupancy of infertile sites**. New shoots that arise from reserve buds within the tree crown, and along the bole and branches of the tree after fire (epicormic shoots), can also be a response to other agencies which defoliate or weaken the tree, including insects and drought. Moreover, and perhaps most significantly, it is the epicormic shoot that maintains the eucalypt crown throughout the prolonged mature and over mature growth, and contributes to the dynamic use of a limited nutrient pool within the tree.

If, as seems likely, some of these growth attributes reflect **environmental adaptation to infertile soils**, then low levels of foliar and litter nutrients, and high flammability, might be linked in some way. Litter with low nutrient concentrations will affect flammability indirectly through its slow rate of decomposition and, hence, rapid accumulation of flame energy. It has also been suggested that there could be a more direct linkage between nutrient concentrations and flammability of biological materials. Sclerophyll-type tissue is seen as an evolutionary response to declining nutrients in the soil in an aging landscape when eucalypts were evolving. It also tends to have greater calorific value than plants growing in better environments. Flammability and adaptation to soils with low nutrient levels and other environmental stresses may be linked in this way, rather than in the sense that a high concentration of nutrients in the leaf will determine flammability directly by acting as a sort of flame retardant

- The degree to which soils are influenced by fire depends on fire **intensity** and **how much fuel** is consumed (duff).
- Fire is a major player at the landscape level and has an important role in **creating habitat diversity** in the forest.
- Fire induces change in ecosystem processes such as **energy flow and nutrient cycling**.

Many Australiana trees in particular produce significant quantities of oils in the leaves that **help to make the plant drought resistant**

FIRE RESISTANCE VS FIRE TOLERANCE (AVOIDANCE)

Any plant stress adaptation can be classified in terms of resistance, tolerance or a voidance to the stress.

Resistance involves the prevention of damage. A **drought resistant** plant might store water and have very effective mechanisms for conserving it like a cactus

Tolerance involves coping with damage brought on by stress. A **drought tolerant** plant may be killed by a drought except for subterranean buds.

Avoidance involves simply avoiding stressful periods altogether. A **drought avoiding** plant has a short phenology (typically annual) and germinates, grows, flowers and sets seeds (dormant seeds) in a few weeks when conditions are favourable.

Tour plants - underlined items fire strategies.

a. Ginkgo biloba

Reduced flammability: Some tissues produced by some hardwoods (poplars) are low in resin and oil, high in moisture. Presence of these species creates microclimate that is cooler and more humid than other forest types. Hardwood stands among stands of conifers create a break in continuity and flammable crown fuels. (The idea that this is actually a consequence evolutionary adaptation to fire is controversial. It may merely be a consequence the way these plants have been selected for other reasons.)

The **Ginkgo** is also thought to protect against fire and therefore it is still planted near temples. During the great fire after the earthquake in Tokyo in 1923 many Ginkgo trees survived while other trees died. A temple was saved because of the many Ginkgos that surrounded it. The bark and leaves are thought to secrete a sap that acts as a fire retardant. They have a high chemical content that increases flame resistance. Trees such as the eucalypts with a low chemical content have high flammability.

In Tokyo the Ginkgo tree is the symbol of Tokyo Metropolitan area and can be seen in many places.

This tree ahas also survived the ultimate of fire -the atomic bomb blast. Approximately 1 km from the centre of the Hiroshima bomb ground zero was a temple surrounded by ginkgo. One month after the blast it was the first plant to produce undeformed buds, and the tree now survives.

b. Silver Birch

Protected subterranean buds: **Lignotubers**

Aspen and other *Populus*, **birch**, nearly all-boreal shrubs, most boreal **perennial herbaceous species** have this adaptation. Heat penetration to the soil is relatively low, so many species have been selected for this adaptation. The structures are commonly **rhizomes, roots, root collar, or lignotubers**

Most Eucalypts have a specialised root system in the form of a 'lignotuber'. This is actually a swollen tap root which contains numerous dormant buds protected by the soil surface.

Most soils are poor conductors of heat and provide adequate protection to lignotubers. As with epicorm ic buds, lignotuber buds respond when the upper parts of the tree are damaged by fire. Lignotubers are most common in 'mallees' or smaller, multi-stemmed Eucalypts

The importance of the Leaf

Leaves are a vital part of any living plant and **significant in the growth and survival** of any genus. Leaves are also something that is easily destroyed by fire. Plants have **developed four different ways of producing leaves**: shoots from naked buds, shoots from accessory buds, shoots from dormant buds and shoots from lignotubers and root swellings

A Leaf Buds

1 Shoots From Naked Buds

On the axil of every eucalypt leaf a bud develops on a fairly thin stalk as the leaf unfolds from its parental growing tip. Typically there is only one naked bud in a leaf axil, but there have been up to three observed. These naked buds are capable of rapid development as soon as the parent leaf unfolds, but all of the buds do not develop immediately due to inhibiting hormones called auxins. Buds near the apex of major branches develop concurrently with their parent shoot and will produce new leaves until conditions are unfavourable for growth. There appears to be no limit to the number of leaves that can be produced from the growing tip of a eucalypt, for in the axil of each new leaf is another bud to carry on the growth process. Because of this rapid growth a large crown can be built up very quickly. In most parts of Australia these naked buds can only develop for a few weeks early in the growing season because insects soon appear that tend to eat the tender new shoots and naked buds. These insects cause branches, which tend to be short and leaves that are imperfect, but since the growth rate is slowed the wood is of a higher quality. After a severe slash burn soils will become richer and insects will be driven off for a short time. This maximized growing potential and trees such as the flooded gum (E. grandis) can grow over 40 feet in height a mere two years from planting date (over 100 feet in seven years)

2 Shoots From Accessory Buds

There is a meristematic region at the base of the naked buds, which can sometimes be recognised as a growing tip. These meristematic regions are inhibited from developing as long as the naked buds and stem leaves are undisturbed. If the naked buds and stem leaves are destroyed in any way the inhibition is removed. One or more "accessory growing tips" can appear in some or all of the leaf axils, and in one or two weeks the original naked buds will have been replaced. Once formed the accessory axillary shoots will have the same growth potential as the naked buds. If these new shoots are destroyed further shoots will develop and the entire process can be repeated several times in one growing season. The accessory meristematic tissue is very resistant to drought, fire, frost and insect, and can only be killed if the parent shoot is completely destroyed.

3 Shoots From Proventitious (Dormant) Buds

Tissue in the leaf axil that can produce accessory buds lies between the stalk of the naked bud and the base of the leaf petiole. When the parent leaf falls off this tissue is not occluded by stem diameter growth. A small shaft of tissue with bud-producing properties grows radially outwards from the old leaf axil. Normally this doesn't happen because of the inhibition caused by younger growing leaves, but if the upper leaves and younger shoots are lost the inhibition is removed. This kind of development is frequently seen following fires. On the trunk and branches of any given tree there is at least one (up to three) shaft for every leaf that developed, equalling approximately 100 shafts per vertical foot. This quality is wonderful for persistence and permits mature trees to maintain their crowns.

4 Shoots From protected subterranean buds - Lignotubers and Root Swellings

Buried buds may be present in vertical stems or rhizomatous roots and are characteristic of dicotyledons and coniferous trees and shrubs. Plants with reserve buds protected by soil will normally survive fires that destroy the aerial parts of the plant. The amount of heat partitioned to the soil from fire is low, being of the order of 5% - 10% of the total released by the fire. In addition, the soil is a very effective insulator so that high temperatures are confined to shallow depths of soil.

Where the aerial parts of the plant are destroyed by fire, regeneration may take place from a single buried vertical stem; that is, the plant cannot spread in this way. Where regeneration is from roots or horizontal rhizomes, the chances of spread and multiplication of the plant are enhanced, at least immediately after a fire. Plants with root buds include *Acacia dealbata*, and with rhizomes, *Leucopogon suaveolens* and a few eucalypts from northern Australia.

Many species of the Australian flora will recover from severe fire by the response of buds in the stem below or just at ground level. Eucalypts with their **lignotuberous** habit belongs to this group. The actual lignotuber is most apparent at the seedling stage and young sapling stage and, usually, will be incorporated in the stem as it develops. In the case of the multi-stemmed mallees, the mature stage is characterised by a massive buried lignotuber.

The **lignotuberous habit has been described as a response to a range of environmental stresses, of which fire is but one**. Ecologically it is most significant on **drier or otherwise environmentally harsh** sites. Here it may take many years, or a succession of favourable seasons, for a newly established lignotuberous seedling to reach that stage where it is capable of growing vigorously through sapling and pole stages. Thus the presence of a more or less permanent **lignotuber pool** may be vital to the recovery of woodland or lower quality forest following a major perturbation. Alternatively, the non-lignotuberous eucalypts are mainly those which are restricted to sites with good moisture relationships (*E. regnans* - alpine ash, *E. delegatensis* - mountain ash, *E. fastigata* - brown barrel, *E. grandis* - flooded gum, ***E. pilularis* - blackbutt**), or in the case of the southern provenances of *E. camaldulensis* (river red gum), a species able to thrust a vigorous tap root through saturated soil following flooding.

Lignotubers are swellings in the axils of the cotyledons, which form on a seedling. As the seedling ages these swelling fuse and increase in size forming a bulbous mass which is called a lignotuber. Lignotubers tend to fold down the stem and envelop the upper part of the root. As they increase in age and size they bury themselves in the soil until the greater part if not all of the lignotuber is below the surface of the ground. The soil makes a wonderful insulator and fires rarely damage the lignotubers. Lignotubers are modified stem structures arising from the accessory merismatic tissue in the leaf axils, which contain food and numerous potential dormant bud strands. Lignotubers are capable of producing leaving shoots in profusion. Any second shoots that are produced in this manner will be stronger than the first shoots and will in turn strengthen the reserves in the lignotubers and roots which will in turn strengthen again if a third set of shoots need to develop. If the upper part of the lignotuber is killed by fire shoots will form lower down and push their way up through the soil The native cherry tree (*Exocarus cupressiformis*) is very fire sensitive, and the whole tree will readily die in a hot fire. Lignotuberous shoots are produced from below ground level within a few weeks after the fire "Mallee" vegetation is characterised by a very large lignotuber, which may be larger in size than a human being. *The **largest recorded lignotuber** was measured from a mallee tree (E. gummifera) that measured ten meters across and carried 301 living stems. Mallee roots can live to be over 200 years old and even the most catastrophic fires cannot kill these lignotubers!*

Species that do not develop lignotubers form carrot-like swellings near the junction of roots and shoots. These swellings are not as persistent as the lignotubers and the new buds that they can produce are sensitive to fire

5. Shoots From protected aerial buds - Epicormic buds will be discussed later under Sequoya

B Annual vs. Periodic Shoots

Most of the trees that we are familiar with go through a process called "**the unfolding of the annual shoot**." The resting buds of these trees contain the complete annual shoot in an embryo form. All the organs that will be produced on the stem are represented by primordial that can be recognised and identified. These buds develop into stems one growing season after they appear, thus they have a year of rest and are referred to as "resting buds".

The accessory and proventitious bud-producing tissues in eucalypt trees do not need a resting period before they develop. Axillary buds below destroyed tips can take over the lead without marked pause. If the growing tip dies the leadership of the shoot will be taken over by one of the upper leaf axils and the original lead branch (or what is left of it) can turn into a side branch. In eucalypts, the number of leaves that can develop is indefinite and naked buds can expand simultaneously with the mother shoot. Surprisingly, the life of any individual leaf is only around eighteen months even though the trees are considered evergreen.

C Controlling Bud Development

The buds of any plant would grow continuously (under ideal conditions) if it were not for inhibiting factors, which restrict their general development. Hormones called "auxins" or "growth substances" are produced by the apices of leaves and growing tips and are then transported towards the roots. Auxins also tend to move towards the shady side of any plant making the plant bend towards the sun and essentially grow in a vertically straight manner.

c. Melaleucas (Paperbarks)

Myrtaceae The myrtles

The *Myrtaceae* (myrtle) family in Australia includes *Eucalyptus*, paperbarks (*Melaleuca* species), bottlebrushes (*Callistemo*n species), tea trees (*Leptospermum* species), and lilly pilly trees (*Acmena* species). The Myrtaceae dominate the Australian vegetation, with around 1700 species.

In NZ, the Myrtaceae family includes **manuka** (*Leptospermum*), **kanuka** (*Kunzea*), **pohutukawa** and **rata** (*Metrosideros*), *Eugenia*, *Lophomyrtus*, and *Neomyrtus,* with a total of about 18 species for the family. ***Myrtle Way*** *is presumably named that for the pohutukawas (and eucalyptus) planted in the vicinity.*

In general it is not the 4-5 petals of the flower that make the ornamental members of the family the beautiful plants that they are, but the innumerable stamens with their long coloured filaments, for example, the flowers of pohutukawa and rata. Many members of the family are valuable herbs and medicinal plants.

1. Most members of the Myrtaceae produce a **lot of small seeds in woody capsules.** The seeds have small food reserves, and are easily dispersed by wind. The large numbers of seeds increase the chance of some reaching suitable places to germinate. The woody capsule protects the seeds from heat and dehydration.

2. Most members of the Myrtaceae have **thick, stiff, leathery leaves.** It helps the leaves to resist wilting.

3. Members of the Myrtaceae have **oil glands in their leaves**. If you hold a leaf up to the light you can see the glands, eg *Callistemon.* Its leaves smell slightly of lemon. The **myrtaceous oils are usually quite unpalatable**, and protect the plants from grazing animals like kangaroos, and from insect attack.

4. The oils are quite flammable **and are found among the fire-promoting plants. The plants benefit from fire to sustain themselves against competition from invading plants. The ash provides nutrients for the germinating seedlings.Woody seed capsules**

Melaleuca's have woody fruits (follicles) that open in heat are a common strategy of trees and shrubs of Australia. Some require heat to open them, while others open by drying after plant is killed by fire. In both cases seed is released after a fire when conditions for re-establishment are best.

The smaller seed capsules are not as efficient at retaining seed, and seed-fall may occur every few years whether a fire is present or not.

The Melaleuca's are a successful species. Its adaptations to fire include a thick bark, epicormic spouting and seritinous seed capsules. Its success in adapting to fire has resulted in it becoming a problem plant. Introduced into Florida around 1900, it has become a seriously invasive plant, adopting a Southern Florida fire adapted habitat.

As a first measure the area was burnt. However this resulted in a massive release of seed – where plants occurred without fire, fire resulted in the number of seedlings increasing 10 times. Flowers sprout on the current seasons growth, each inflorescence bearing a cluster of 30-40 serotinous capsules, each containing 250 seeds. Fire was the main factor giving rise to seed release, but freezing temperatures, herbicides, natural pruning due to shading, and radial growth of the branches can also trigger this. A single tree can produce over 20 million seeds.

Control of this species involves working around the natural growth pattern of the plant. On unburned sites, trees are cut down and the stumps are treated with a herbicide. Felling triggers seed release immediately, but limits wind dispersal of seeds. Subsequently the site is burnt after the released seeds have germinated but before they have grown to a size where they can survive fire. Many will survive, and the process may have to be repeated.

In infested areas burnt by wildfire, mature trees are treated with herbicide before they flower and set seed again. As soon as there is sufficient fuel, the site is burnt again (in 2-3 years) which should kill many of the seedlings. Surviving saplings have to be hand treated with herbicide.

EFFECTS OF FIRE ON GERMINATION:

1 Heat stimulated germination occurs in chaparral shrubs, Jack Pine, and Lodgepole Pine.

Chaparral species often have thick hard seed coats that are cracked by heat allowing water penetration. In some cases sunlight is enough-but in others, temperatures associated with breaking physical dormancy (cracking seed coats) is best achieved by fire. After fire, shade is removed that would otherwise inhibit seedling success. Chaparral species thus replace themselves after fire.

Germination in **pine** is **enhanced by short term exposure to heat** as in a cone opened by a fire. The mechanism by which pines have more successful germination after being exposed to heat is unknown-but is probably a physiological mechanism rather than physical. Mechanically opened pine cones are by no means dormant and the effect of heat is only a minor enhancement.

2 Removal of duff (environmental stimulation): Most plants do not germinate well in organic matter. Removal of duff by fire is not so much an adaptation as an environmental change brought on by fire. (Could be considered with effects on soil below) Primarily two mechanisms are involved in permitting germination after removal of duff by fire.

a. Removal of duff brings seeds into **intimate contact with soil** and allows the seed to absorb water-not possible with seeds in organic matter.

b. Fire assists in the r**emoval of the alleopathic germination inhibitors**, which are very common in decaying organic material.

3 Rapid early growth: *Pinus palustris* (longleaf pine) has a terminal bud close to the ground for approximately 5 years after germination. It remains surrounded by long leaves with high moisture status. Thus the bud is protected by leaves and its position. It is fire susceptible for 1 to 2 years, but more resistant after 3 years. At about 5 years, internodes lengthen and it increases in height very rapidly and gets above typical flame height for this environment. As it gets taller it rapidly develops fire resistant bark, a required characteristic for trees growing in this environment.

4 **Smoke effects** Recent research has shown that smoke releases a chemical that stimulates germination of

many plants, especially when associated with ground disturbance. Artificial 'smoking' of seeds is now used in nurseries to facilitate germination of some species otherwise thought to be difficult to strike.

d. *Eucaylptus pilularis* Black Butt

Eucalyptus is a large genus of some 600 species and many horticultural cultivars.

They are one of the world's most planted trees, especially in the drier areas, and they are tolerant of poor soils. They grow rapidly, and even young trees provide dry leaves, bark and twigs for fuel in countries where other forms of fuel are scarce. However in India there are complaints that extensive planting of eucalypts creates an environment hostile to other plants and animals.

Many produce **volatile turpines** or oils which are valuable, but which also encourage fires and thus are a benefit and danger to man. This is in distinct contrast to the gingko that produces fire inhibitors.

Nutrient Scavenging and Hoarding

The eucalypts tend to develop **extensive, deep root systems**. Once absorbed, eucalypts carefully retain and recycle nutrients. Seedlings develop lignotubers to store nutrients and ensure that when conditions are right for growth the tree will have adequate reserves of the nutrients it needs. Like wise, eucalypts store nutrients selectively within their bole. **Eucalypts can acquire nutrients far in excess of their immediate needs, and store that surplus for years.**

A eucalypt crown is dynamic: old branches become senescent and die back, while new branches immediately spring forth from epicormic shoots lodged under the bark. This "pulsating" action continually reshapes the crown for maximum efficiency, including the reabsorption of precious nutrients before the branch becomes vulnerable to breakage and loss.

As an evergreen, the eucalypt retains its leaves, shedding them as infrequently as possible, tenaciously hoarding their precious supply of nutrients. When leaves do fall, they are drained of vital nutrients to the fullest extent possible before deposition. Once on the ground, lechates from the crown quickly return residual nutrients to the tree through the soil . A large proportion of the litter consists of woody material (twigs, bark, capsules). Much of this material is largely resistant to decomposition and when incorporated into the soil organic matter may adversely affect the soil microflora and processes of nutrient cycling, to the point where decomposition degenerates to stagnation and the available nutrient pool becomes largely locked up in the surface litter. Under these conditions there may be insufficient nutrients to maintain all ecosystem components beyond the short-term rapid growth phase, and the shrubby understorey may decline until such time as a fire event releases these nutrients and stimulates new growth.

The development of soil improving (nitrogen-fixing) understorey, such as *Acacia*, following periodic fire may contribute nitrogen to the ecosystem, accelerating the rate at which the eucalypt litter decomposes (releasing additional nutrients), stimulating a more diverse, active and healthy microflora, and, through this, more vigorous tree growth

The Tough, the Opportunistic

The eucalypt has prevailed over the Australian continent to an extent unrivalled by any other genus anywhere else in the world. *Eucalyptus* is generally considered less as a genus and more as an alliance composed of three suballiances, ten subgenera, and over six hundred species. The flexibility of the genus is extraordinary. Hybrids are common within subgenera, juvenile habits persist into adulthood, and phantom species (hybrid populations that occur in the presence of only one parent) have been identified. Most people agree the eucalypt is a true symbol of Australia. But few people appreciate the extent to which the prevalence of *Eucalyptus* has transformed the Australian landscape.

The eucalypt became a **supreme opportunist**, ready to seize disturbed and open sites. They **could capture nutrients released by fire far in excess of their immediate needs and store them for future use**. Bark was thick, tough and it shed as it burned. If branches were seared off, new ones could sprout from epicormic buds hidden safely beneath the bark. If the bole burned, new trunks could spring from the lignotuber. Fire helped **purge hostile microbes from the soil**, encouraged better percolation of water and opened areas to sunlight allowing the eucalypt seedlings to out compete more shade tolerant rivals. For most eucalypts, fire was not a destroyer but a liberator.

Impoverished soils are characteristic of Australia and were something to which most members of the Gondwanic rainforest had to adapt. *Eucalyptus*, however, elevated nutrient scavenging and hoarding to an art form.

Eucalyptus was successful at persevering through dry seasons and periodic drought; but so were the other scleromorphs. Eucalypts, in fact, tend to occupy the relatively better sites - shunning the driest, the worst waterlogged, and the most nutrient-degraded. In none of these attributes was there anything to account for its extraordinary supremacy within the scleroforest. What made the eucalypt special was its extraordinary opportunism, a relationship reinforced by fire. Eucalypts accepted wretched soil and tolerated drought, but they thrived amid fire.

The resistance of Australian plants to the effects of fire and drought, are the result of long periods of selection, migration, redistribution and extinction through geological time.

The Role of Bark As a rule, bark does not conduct heat very well, making it an important **insulator** to protect the tree from heat caused by fires. Some types of bark are resistant to fire making them favourable for forest trees while others are dangerous in fire and easily killed by it. Small fires can thin the bark on trees while larger fires can completely defoliate a tree.

Some trees rely on bark **thickness** to resist fire. As a protective measure, **pale barked** gums have been shown to reflect considerable amounts of radiation in a fire. The darker barks on the other hand, although efficient at absorbing heat are usually too dry to conduct it satisfactorily and thereby help prevent damage.

The bark of many eucalypts will also **thicken** when **damaged** by fire making it more resistant to heat in the future. If the trunk can't recover between fires the tree will die. Fire resistant bark of Ponderosa Pine, Douglas-Fir, Western Larch, Redwood and giant sequoia can survive surprisingly severe ground fires by virtue of thick insulating bark that is a **poor conductor of heat**. The vascular cambium of all species is sensitive and when damaged results in fire scars.

When a **fire defoliates** a tree **epicormic** branches develop which are then shed as the upper crown of the tree regains its dominance.

Bark is as diverse as the tree that it grows on. Some smooth eucalypts shed their bark in small plates or patches. Other smooth eucalypts shed their bark in long strips which can be a serious hazard in fires as a burning strip of bark can fly through the air and carry fire a considerable distance. Some species, such as *E. viminalis* produce massive amounts of bark. A heavy accumulation of bark gathers around the bases of these trees, which are **approximately 50 tons of dry weight fuel per acre (225 toms per ha)**. Stringybarks develop a loose spongy tissue that has a tendency to flare up and break away in fire. Flames can also rapidly run up the outer bark because it is so readily flammable. Mealy barks (like *E. angophoroides*) develop a rich flora, which changes the surface structure of the bark. This bark is not fire dangerous and the soft surface actually cushions any blows that the tree may encounter. The fibrous bark of Red Stringybark (*Eucalyptus macrorhyncha*) readily ignites while the underlying bark is protected from the heat and the flames. The Eucalyptus *E. rossii* will shed its bark in massive quantities during a fire. This provides an excellent groundcover that protects young plants from erosion, and the damaged stems soon produce epicormic shoots.

The **bark catches fire readily**, and deciduous **bark streamers** and **lichen epiphytes** tend to carry fire into the canopy and to **disseminate fire ahead of the main front**. Other features of eucalyptus that promote fire spread include **heavy litter fall**, **flammable oils** in the foliage, and **open crowns bearing pendulous branches**, which encourages **maximum updraft**. Despite the presence of volatile oils that produce a hot fire, leaves of bluegum eucalyptus are classed as intermediate in their resistance to combustion, and juvenile leaves are highly resistant to flaming

e. Sequoia

(Bark comparison with adjoining eucalypt)

Protected aerial buds: Epicormic buds

Some **pines** ((*Pinus rigida* and ponderosa pine), **redwood**, and some eucalypts-can replace foliage and branches lost in a crown fire. ***Pinus canariensis***, from Teneriffe, growing below a volcano, is often subject to fires. It is one of the few pines that can regenerate from the trunk from epicormic buds and base after fire.

Protected buds lie beneath the bark and are stimulated by **loss of photosynthetic area**. Young individuals better able to regenerate crowns than old ones. It easy to understand how protected aerial buds would be adaptative to young trees growing in an area that has frequent ground fires. **Protected aerial buds** often co-occur with the adaptation of **fire resistant bark**.

Beneath the bark of many trees, including Eucalyptus species are specialised **'epicormic'** buds that lie dormant until the canopy of the tree is either removed or scorched by fire. The loss of leaves triggers a burst of growth from these buds (epicormic shoots) that provides an almost immediate leaf growth to sustain life and aid the recovery of the plant. Eucalyptus trunks clothed in fresh, green foliage are a common sight after a bushfire

Where a plant has reserve buds along the bole and branches, it may respond very rapidly to the loss of its green crown by producing a massive number of new shoots, as in the case of eucalypts. If reserve buds are not present in a plant, it will probably be killed by a fire of sufficient intensity to scorch the complete crown

Trees and shrubs with reserve stem buds will depend upon the **insulating properties of bark** for any resistance they may have to fire. Measures of thermal diffusivity or insulating capacity suggest that **all eucalypt barks have generally good insulating properties**, although there may be some differences between them. Stringybark and gumbark species of the same thickness generally have similar insulating characteristics, a feature not readily appreciated. The resistance to fire will be influenced not only by the thickness of the bark at the time of the fire, but also by the amount of bark lost during or soon after the fire. An appreciable amount of fibrous bark may be lost where the outer bark is burned during a fire. Alternatively, a gumbark species may lose thickness after a fire as a result of the abscission of the outer layer of the bark, the extent of the loss being a function of the duration and temperature of the fire.

Young eucalypt stems, for example, survive damaging fire in two main ways - by **epicormic shoots developing along the stem** and branches, and by shoots developing from **epicormic buds protected from lethal temperatures by soil surrounding the base of the stem.**

Cones take 2 years to mature. In its native habitat the cones are retained on the tree with viable seed for up to 30 years. The cones open after the heat of a forest fire

f. Pinus radiata

Most species are **fire adapted**; the recurrence of fire permits the pines to maintain a dominant role in forest successions. Fire may kill the tree, but the seeds are protected in the cones. Over subsequent months the cones will open and there can be a prodigious seed fall onto ground that the fire has left in a state securing the maximum seed germination. Their quick growth allows re-establishment before other competitive plants can become established

<u>Increased flammability</u>:

Most seed adaptations (germination or dispersal) are coupled with the adaptation of **increased flammability of foliage**. Flammability of chaparral spp. **increases over time through deposition of flammable leaf litter impregnated with volatile oil**. (**Oils in the leaves help to make the plant drought resistant**) Architecture of chaparral plants and communities also leads to ease of fire spread. There is frequently a high dead-live ratio.

Architecture of **pine** and black spruce stands can also lead to rapid fire spread-and of course, conifers are very flammable.

Pitch pine (*Pinus rigida*), redwood, and ponderosa pine, and some eucalypts-can replace foliage and branches lost in a crown fire. Protected buds lie beneath the bark and are stimulated by loss of photosynthetic area. Young individuals better able to regenerate crowns than old ones. It easy to understand how protected aerial buds would be adaptative to young trees growing in an area that has frequent ground fires. Protected aerial buds often co-occur with the adaptation of fire resistant bark.

<u>Seed dispersal</u>:

1 **<u>Serotinous cones</u>** nearly always occur in jack pine. Populations of Lodgepole Pine that occur in fire prone areas have serotinous cones, but populations that occur in areas where fire is infrequent have open cones. Many populations of black spruce, which is usually found in fire prone areas, have semi-serotinous cones, meaning that <u>some cone scales open and release seed, while others remain closed until exposed to heat</u>. The resin that holds scales of jack pine closed melts at 60ºC. The thick woody scales spring open and the seeds are shed in the days following the fire. Seeds remain viable in cones exposed to 200ºC for 10 minutes and 370ºC for 1 minute. Crown fires are of short enough duration and the seeds are protected enough within the cones to remain viable. Seeds in this aerial "seed bank" retain viability for many years, but do not have the long viability of seed from species that specialize forming soil seed banks. .

Seeds of eucalyptus were protected for about 4 minutes from a lethal rise in temperature when capsules were subjected to a heat of 826 degrees Fahrenheit (440 deg C). Following all types of fire, an **accelerated seed shed** occurs, even where crowns are only subjected to heat scorch.

<u>Storage of seeds in fire-safe environments by serotiny</u> (eg. **<u>Common Sugarbush - *Protea repens*</u>**) and myrmecochory (eg. **<u>The Pincushion - *Leucospermum cordifolium*</u>**). In Africa, these fire survival strategies are largely confined to the Cape Floral Kingdom where many species have no other fire survival mechanism. Plants may take from 3 to 15 years to flower for the first time. Therefore, these species are susceptible to fires that occur at intervals shorter than those needed to produce seeds. In contrast to the previous strategy, adult plants may also survive fires by:

<u>2 Growing in a fire safe environment</u>

A mature closed ***Nothofagus* forest is remarkably fire-resistant**. These forests create a microclimate, which is cool, moist and almost free of understorey due to its high level of foliage cover. Even when these mini forests are located in the middle of a larger more flammable forest, the fires will often stop at the edge of a *Nothofagus* forest and not do any serious damage to the trees there. If damage does occur, these trees do have methods of springing back. *Nothofagus cunninghamii* can regrow from the basal burl as well as by the seed from undamaged stands. At least two generations of fire produced coppice shoots may be produced from one epidermic burl, which suggests that regeneration may be able to occur several times after a fire

g. Douglas Fir

Rhizomes and underground rootstocks

Rhizomes are horizontal underground stems that obviously enjoy the benefit of some protection from fires burning overhead. Plants such as the common Spiny-headed Mat Rush (*Lomandra longifolia*) may be destroyed by fire, but are afterwards able to send up new shoots from their rhizomes

The **Douglas Fir** can respond to damage and fire by the **natural grafting** of roots from adjoining trees underground. In this way damaged trees can revive and survive

FIRE AND ECOSYSTEM PROCESSES

1 ENERGY FLOW

Decomposition is speeded up after a fire-warm moist conditions enhance decomposers. Inputs to the forest floor may increase temporarily as dead leaves and branches fall, but ultimately inputs go to almost zero before litter fall from regeneration rises again. As the site becomes shaded, decomposition slows, and the leaf layers begin to rebuild.

Primary production often goes to zero or near zero immediately after a fire but rises very quickly beginning in the following growing season. Within a few years primary production rises well above the level of primary production of a mature forest. Young faster growing shrubs are replaced by slow growing trees.

Secondary productivity follows a similar pattern - animals are attracted to the lush young growth of a recent burn. Eventually secondary productivity declines to very low levels as conifers replace hardwoods.

2 NUTRIENT CYCLING

Measuring the amounts of nutrients in ecosystems is difficult and expensive. Our knowledge of the impact of fire on ecosystem nutrients is far from complete. Probably all of the attempts to measure nutrient dynamics before and after fire to access the losses due to have serious flaws. There are difficulties in every level of measurement, but the most difficult is to measure the amounts lost as fly ash and volatilised. One of the best estimates ,and a conservative one at that, is that 39% N, 11% Ca, 15% Mg, 35% K, 83% Na were lost after a fire.

Extreme situations of nutrient loss some of which have been caused by fire (referred to as fire barrens) are heath lands. Such areas are too nutrient poor to support ordinary tree growth and are dominated by ericaceous shrubs (low nutrient stress tolerators). Heath lands produced by fire, sometimes hundreds of years ago, are known from Canada, U.S. and Europe.

h. Banksia Protea Wattle (Acacia)

The genus ***Acacia*** belongs to the family Mimosaceae. There are some 1500 species of *Acacia* found throughout the world and close to 1000 of these are to be found in Australia. Commonly known as Wattle, *Acacia* is the largest genus of vascular plants in Australia. Australia's national floral emblem is *Acacia pycnantha*, the Golden Wattle. Wattle Day is celebrated on the 1st of September each year. *Acacia* is to be found in Australia, Africa, Madagascar, throughout the Asia - Pacific region and in the Americas.

Distribution Within Australia Acacia occupies vast areas of the continent and is to be found in a wide range of differing habitats from coastal to sub-alpine regions and from high rainfall to arid inland areas. They are particularly prevalent in the arid and semi-arid and the dry sub-tropical regions of the country.

Banksia is a genus of about 75 species in the *Protea* family (Proteaceae).

All species occur in Australia with one (*B.dentata*) extending to islands to Australia's north.

Banksias can be found in most environments; the tropics, sub-alpine areas, the coast and desert areas. The most diversity in the genus occurs in the south of Western Australia where over 80% of the species occur.

A Hard seeds in the soil

Leguminous shrubs e.g. **Acacia** (Wattles) and the many members of the Fabiaceae (Pea flowers) family are usually destroyed by fire but regenerate from the huge number of seeds stored in the soil or leaf litter. Most legumes produce seeds with a hard coating that is impermeable to water and will therefore not germinate until cracked open by fire. These species are usually the first plants to regenerate after a fire

One of the notable responses of some plant communities to fire is the way, in which seed that has accumulated in soil, often over very long periods, will germinate, sometimes in remarkable quantities. This applies mainly to small trees and shrubs with hard-coated seeds. It does not apply to eucalypt seed that will remain viable only a short time in soil, probably no more than 6-12 months. Germination of soil-stored seed may also follow mechanical disturbance of soil, for example, tractor-working during logging, although the germination response may be more sporadic and stocking density much less spectacular.

Species with hard seed coats show a lack of imbibition, swelling and softening of the seed when exposed to water. The seed may germinate quickly only when the seed coat is softened, cracked or removed. High temperatures following fire may lead to cracking of the seed coat, and this may also occur as a response to high soil temperatures during summer and daily temperature fluctuations. Softening of seed may also be induced in nature by scarification in stream beds or passage through the gut of animals, particularly birds.

Hard seededness is a common property among leguminous plants (Fabiaceae, sub-families Faboideae and Mimosoideae), but is also found in a wide variety of plants including species of Anacardiaceae, Asteraceae, Malvaceae, Poaceae and **Proteaceae**. Occasional fires may make a positive contribution to the forest ecosystem through the germination of leguminous and other species with soil improving potential. That contribution is enhanced through the highly durable nature of the seed of many of these species, and their long-term survival in soil.

Where an over mature, mixed eucalypt-rainforest community is felled and the debris burned, massive ***Acacia*** regrowth may develop very rapidly from soil-stored seed. This seed may have accumulated in the soil following an earlier fire, which had established the community in the first place. Seed of woody species other than *Acacia* may not survive in the soil more than 100 years. Seed of some non-woody species may also remain viable after being stored in soil for a long time; for example, grass, herb, rush and sedge seeds may germinate in soil from a *Nothofagus* forest, even though these taxa were not present at the time of soil sampling.

The environmental conditions needed to release seed from the hard seeded condition will vary with species. Within the sub-tropical forest, *Dodonaea*, ***Acacia*** and *Kennedia* species all require heat to stimulate germination, although the response will vary with the soil temperature, the duration of high temperature, and the depth at which the seed is buried. This also means that for each species there is a critical temperature and depth at which seed may be killed. For example, *Acacia* seeds are more readily destroyed in the soil by high temperatures than are *Dodonaea* and *Kennedia* seeds. Thus, it may be possible to manipulate the development of **fireweeds**, as regards species and abundance, by paying attention to the way slash is distributed, the intensity of the burn, and the judicious use of tractors in preparing for a slash-disposal burn.

B Release of seed stored on the plant

There are many Australian forest species with **woody fruits** that **release seed in response to fire**, although with the possible exception of some Banksia species, fire may not be an absolute prerequisite for seed release. Accelerated dehiscence of fruits at time of fire has been noted for members of the families Myrtaceae (including the **eucalypts**), Casuarinaceae, **Proteaceae** and **Cupressaceae**.

There are a number of forest taxa in which dehiscence of the fruit and release of seed will occur only after prolonged desiccation or death of the supporting branch, or direct contact of the fruit with flame. The woody follicles of some ***Hakea*** (Proteaceae) species open upon desiccation of the parent branch, and this normally occurs upon the death of the plant. Alternatively, dry, woody fruits of ***Banksia*** *ornata* may not open unless they have been in direct contact with flames. Other **Banksia species showing fire-dependent dehiscence** are *B. ericifolia, B. serratifolia* and *B. asplenifolia* on the coastal heath lands of New South Wales.

The seed of the eucalypt is normally released from its woody capsule at the end of a seasonally dry period (e.g. late summer to early autumn in southern Australia). Depending on weather conditions, the release of seed may be sporadic over an extended period, or a large part of the seed crop may be cast in a relatively short period. **A fire that scorches the crown of a eucalypt but does not burn the capsules may trigger a near total release of seed** from a mature capsule crop soon after the fire, sometimes leading to `**wheatfield'** regeneration.

C Woody seed capsules

Woody fruits (follicles) that open in heat are a common strategy of trees and shrubs of Australia. Some require heat to open them, while others open by drying after plant is killed by fire. In both cases seed is released after a fire when conditions for reestablishment are best.

Shrub species such as **Banksias** and **Hakeas** have the capacity to regenerate from rootstocks as 'sprouters' but also store their seed for many years in thick, woody capsules. A hot fire will often kill the adult plant but also assist in the release of the seeds from the capsules. The capsules are desiccated by the heat and in shrinking release the seeds into an ash bed favourable to germination. Species such as **hakeas, banksias, some acacias and many eucalypts regenerate from seed**. **The heat of the fire facilitates the release of seed.** The set of circumstances created by fire is ideal for some types of plants. The **open canopy allows more light to reach the ground, and the 'ash-bed effect' provides many nutrients for initial germination.**

Fire and Banksias

Of the plants that have developed in relation to fire, the Banksia stands out as being both dramatic and familiar. Its often charcoal cones present an intriguing variety of forms and an invitation to the most staid of imaginations. Consequently, a brief look at the adaptive responses of that genus would seem appropriate.

Existing bushes of *Banksia ericifolia* are killed outright by fire, recovery of the species depending on the accelerated seed shed a fire induces.

Studies on *B. ericifolia* have shown that **the post-fire emergence of seedlings is affected by both seasonality and fire intensity**. It has been found that seeds are released earlier and quicker from cones exposed to high fire temperature than from those exposed to a low fire temperature. Follicles were usually incompletely opened during the fire, maximum opening normally occurring only after a subsequent drying out of the cones on the killed bushes. Disturbance created by wind or heavy rain shakes the seeds free, thus bringing about variation between seeds in their time of release. Should fire be followed by periods of good rainfall a very large proportion of seed will germinate. New plants mature and produce seed again after 5 - 6 years. A second fire passing through within 5 years would therefore result in the species being lost to the area.

Banksia serrata - burnt cones

Of the banksias occurring in the Hawkesbury/Blue Mountains area *B. ericifolia, B. penicillata and B. cunninghamii* are the only ones to be killed outright by fire. Other species *(B. marginata, B. oblongifolia. B. paludosa, B.robur* and *B .spinulosa* var. *collina* regenerate from lignotubers. a woody swelling at the base of the stem which contains buds and food reserves.

Fire tolerant species such *as B. aemula. B. integrifolia* and *B. serrata* regenerate from both lignotubers and epicormic shoots located along the trunk. The trunk is usually protected by bark 1-3 cm thick. Fire sensitive arborescent species and the narrow stems of lignotuberous species on the other hand have a bark less than 5 mm thick which is unable to protect the stems against fire.

Fire-induced flowering

Not related to this group, but another fire response.
The Grass Trees (Xanthorrhoea spp.) often produce a large flowering stalk immediately after a fire in order continue their regenerative processes as soon as possible.

Conclusion

Conditions Favourable for Regeneration

As a forest stand **ages, natural mortality rates increase**.

The **mass on the forest floor is reduced** and the **lignified material in the soil organic matter increases**. Under these conditions the edaphic environment becomes increasingly unfavourable for the **understorey shrub component**.

Germination is typically poor unless the seed is buried in the mineral soil. Paradoxically, a **fire** can produce the **ideal circumstances for germination**. Seed rains down from the canopy overwhelming the predators that normally feed on it. The ash bed accepts and buries the seed, encasing it in an environment full of available nutrients and temporarily purged of antagonistic micro-organisms.

Fire temporarily **sweeps away competition**. It **sterilises the soil** of microflora and microfauna, most of which resided in the combustible litter. It may burn away or cripple other woody species, permitting greater access to site resources.

Fire **mobilises vital trace elements** such as Molybdenum, and volatilises lechates in the litter that often contain inhibitory chemicals.

The high temperatures may increase the rate of **mineralisation of soil nitrogen and phosphorus** and can add a considerable mass of inorganic material to the soil, creating **new pools of nutrients available for plant use**.

A moderate to severe fire will restructure the canopy to allow **greater penetration of sunlight** and **restrict toxic leaching from rain drip**.

Most of these processes are collectively known as the "**Ashbed Effect**". The processes are multiple and complex, but the results can be dramatic and outstanding. A forest may appear decimated and the soil parched following a fire. Within days, new life is evident as flowers emerge from the ashes and epicormic buds spring forth from the charred boles of the trees.

EFFECTS OF FIRE ON GERMINATION (refer to pine section if not covered there)

EFFECTS OF FIRE ON SOIL

1 PHYSICAL CHANGES

Organic matter on the site is reduced by fire. Sometimes the amount of reduction is negligible as in a very light surface fire. Sometimes litter and duff is completely oxidized down to the mineral soil in a very severe fire. Organic matter incorporated into mineral soil is not normally oxidized, but if it is, or even heated, soil structure may be damaged (see below). Usually the immediate effects of fire are to reduce the organic matter to an extent somewhere in between these extremes. In the months that follow the fire the remaining organic matter will be reduced further caused by optimal conditions for decay organisms.

Temperature is frequently **limiting to organisms living in the soil** and this is especially true of boreal forests where low soil temperatures can limit tree growth. In these situations fire causes a dramatic shift in soil environmental conditions. Fire kills the trees allowing light penetration to the soil surface. The blackened soil surface heats readily. If the thickness of the duff is much thinner there will be effective heat penetration into the mineral soil, warming up the site for many years.

The other aspect to temperature is the **immediate impact of heat transfer into the soil**. Surface temperatures within the fuel bed have been recorded as high as 1100^{O}C, but are often lower (350-900^{O}C**). Duff is a remarkable insulator** and the highest soil temperature achieved at a depth of 5-10 cm after passage of a flame front was only 100^{O}C in one study. In another study temperatures as high of 300^{O}C was reached 5-8 cm below the surface at the organic mineral interface.

Moisture: **Fire reduces transpiration** and interception in proportion to reduction of the canopy, leading to a rise in soil moisture-in many situations. However, in light soils it may have the opposite effect. Most moisture on sandy soils is held by the duff. When this is gone, as it often is when sandy sites burn, the water holding capacity is lower and evaporative losses are increased. Infiltration rates may change by several mechanisms:

-**mineral soil structure may be lost** through the oxidation of colloidal material in mineral soil

-**macropores can be plugged** with ash

-**formation of a charred crust which is water repelled**

-**formation of water repellent layers in the soil.** Pyrolysates can be driven downward by the fire and condense on mineral soil particles. The most volatile compounds are driven farther into the soil. These materials are hydrophobic and create a hydrophobic layer in the soil. Hydrophobicity of the soil not only reduces infiltration-it reduces loss by evaporation from the deeper layers.

2 CHEMICAL CHANGES

pH: **Many anions (anions of N, P, Cl) are lost as a consequence of fire**. Cations (of Ca, K, Mg) tend to be left behind in the ash as soluble oxides. These oxides are rapidly changed to carbonates that tend to neutralize acidity in the soil, raising the pH. The effect persists for a few decades (recall overhead).

Nutrients: During a fire, **oxidation changes the availability of some nutrients**. N is lost above 300^{O}C. S, P, and B are lost as gasses too. K may be lost above 500^{O}C. Any nutrient can be carried away in fly ash in the convection column. The more intense the fire the more nutrients are likely to be lost from the site. Nutrients left behind usually become more soluble and susceptible the leaching. One might expect that these losses mean that nutrients are in poor supply. In fact the nutrient losses mainly come from nutrients tied up in organic compounds and would have been unavailable to plants anyway. The immediate effects of the fire are to release nutrients-and the subsequent increase in decay does this as well and make nutrients more available for early rapid plant growth.

3 BIOLOGICAL CHANGES:

Bushfires can have biological, chemical and physical effects on soils. The occurrence and/or extent of these effects are dependent on the fire's intensity and the resulting temperature of the soil. Generally, only the top few centimetres are affected as they are subjected to the highest temperatures.

Low **intensity fires cause biological effects** such as **sterilisation** (or death of living tissue) within the soil. **Higher soil temperatures** (greater than 100ºC) may **alter soil chemical structure**, changing the amounts and availability of nutrients such as nitrogen and phosphorus. These soil changes, combined with **ash** from the fire, may cause an ***'ash-bed effect'***, increasing the fertility of the soil. However, these nutrients are relatively soluble, and may be rapidly washed from the site by rain.

Fire may cause changes in the **permeability of the soil** (or its ability to absorb moisture) and so may also alter soil structure. The removal of vegetation during a fire exposes the soil to wind and water. These two factors make soils very susceptible to erosion, and consequently, heavy rainfall immediately after a fire may cause massive erosion or mudslides.

Fire can affect **stream water quality** and may also influence the amount of water produced by a forest (that is, the levels of stream water). Erosion may cause soil, ash and nutrients to be transported into streams. This increases the sediment load and the turbidity of the water. The quantity of water produced by an area that has been burnt may initially increase, as there is little vegetation, and subsequently little water usage or entrapment. Sometime later, however, high water use by regenerating vegetation can reduce water yield from a catchment.

The impact of fire on **bacteria and fungi is variable. They are killed** very easily by fire but recolonise at the time of the first rain-through transport or germination of spores that survived the fire.

The increased N status of a site after a fire is sometimes partly attributed to N-fixation by certain free-living bacteria. There is little evidence to support this, but after the initial flush of soluble N declines in a few years, symbiotic N-fixation sometimes becomes important.

Successional changes in soil: In boreal forests organic inputs to the ground accumulation layers occur at a faster rate than does decomposition. In warm, humid forests (tropics) the opposite is true-the potential rate of decomposition far exceeds inputs. A visiting tropical forest ecologist once remarked that boreal forests must literally have duff that is metres thick. Fire does not allow tremendous build up of duff like this tropical ecologist envisioned-because periodic fire reduce organic matter on the forest floor. If we had no fires for a few hundred years we might get a situation where nutrients are mostly tied up in duff. (RE: Peat bogs are nutrient poor areas that have massive accumulations of organic material.)

Many insects and spiders are also killed, especially in a high intensity fire that destroys the bark and litter layer in which they live. Flying insects have a higher chance of survival, as they can move away from the fire and then back again after it has passed.

FIRE IN THE LANDSCAPE

DIVERSITY

Fire and other disturbance **creates a patch mosaic** that **contributes to biological diversity**. Animals and plants that require an early or late successional habitat will not become locally extinct. Species like the ruffled grouse, which require the whole spectrum of successional situations will fare well. Diversity at the landscape level is also called -diversity. In boreal forests there is rather low species diversity (-diversity), but -diversity is higher than some other types of forest, meaning that there is some compensation for low -diversity. Because of the habitat mosaic created by fire, greater numbers of species can co-exist in the landscape.

This age of reproductive maturity differs between species found in typical vegetation in this region may vary from two years (*Acacia sp.*) up to fifteen years (*Banksia serrata*). This means that ***all the species*** in a patch of bush burnt this year will begin to regenerate almost immediately - but what will happen if a similar fire occurs in three years time? Those species that have matured quickly will again be able to respond and regenerate, but those still reproductively immature will not. So although the bush will grow back, there will be a number of species missing. As ecologists put it, the vegetation community will move from ***complexity*** (many species of plants) to ***simplicity*** (fewer species of plants). Therefore both the frequency of fires - whether wildfire or for hazard reduction - and the lifecycle of plants need to be considered by the managers of bushland areas

2. FIRE REGIME

Fire regime is the pattern of fire in time and space that gives rise to the pattern of vegetation change. Fire regime gives vegetation its particular character. A change in fire regime changes the vegetation. When we instituted fire suppression six decades ago, we began a gradual shift in the fire regime, changing not only the fire but the fuel complex. The mix and pattern of vegetation, the distribution and abundance of animals and the very character of the landscape.

fire regime - the kind of fire activity or pattern of fires that generally characterize an area. Important components include fire cycle or fire interval, fire season, and the frequency, type and intensity of fires.

fire cycle - the number of years required to burn over an area equal to the entire area of interest.

fire interval - the average number of years between the occurrence of fires at a given point.

fire frequency - the average number of fires that occur per unit time at a given point.

There is a lot of discussion about the "natural fire regime" and how we can mimic it with harvest practice.

3 SUCCESSION

Vital attributes model includes autecological characteristics that account for mode of persistence (by seed dispersal, seed bank, serotinous cones, vegetative regrowth), establishment (tolerant, intolerant, intermediate tolerance, dependent). By knowing these characters, one can predict the trajectory of succession and the composition at any point in time. Knowing these characters is the hard part.