Plants Through Time

This walk was presented as A Themed Rostered Walk in July 2023. It was based on a Plant Evolution walk developed by Pam Cooke and modified by the Themed Rostered Walks group.

Theme:
Generally this walk is about plant evolution. Specifically, we want to:

- show visitors modern examples of plants that represent each major evolutionary stage;
- emphasise plants from the period when megafauna roamed Australia, to complement the current megafauna exhibition.

By the end of this walk we want visitors to understand the major evolutionary steps in the plant world using a calendar year to illustrate the time scale for these steps.

Introduction

Featured amongst the plants in the ANBG at the moment is a series of replicas of some of the megafauna, the large animals that roamed the Australian continent between 2.5 million and about 12,000 years ago.

Today, we are going to look at the life story of plants on earth and see where both the dinosaurs and the megafauna fit into this developmental chain.

The chain extends back over 3,000 million years, rather a long time to imagine. Let's condense that period into a calendar year, a concept that we can understand and fit the main evolutionary steps in the development of plants into those 12 months.

The approximate timescale is:
1 day = 8.2 million years
1 hour = 340,000 years
1 minute = 5,700 years

Alternatives for Wheelchairs

Instead of going down into the rainforest for stop 2, walk up the side of the rainforest, past the bollard where there are some mosses, but unfortunately no liverworts, on the stone wall on the rain forest verge.

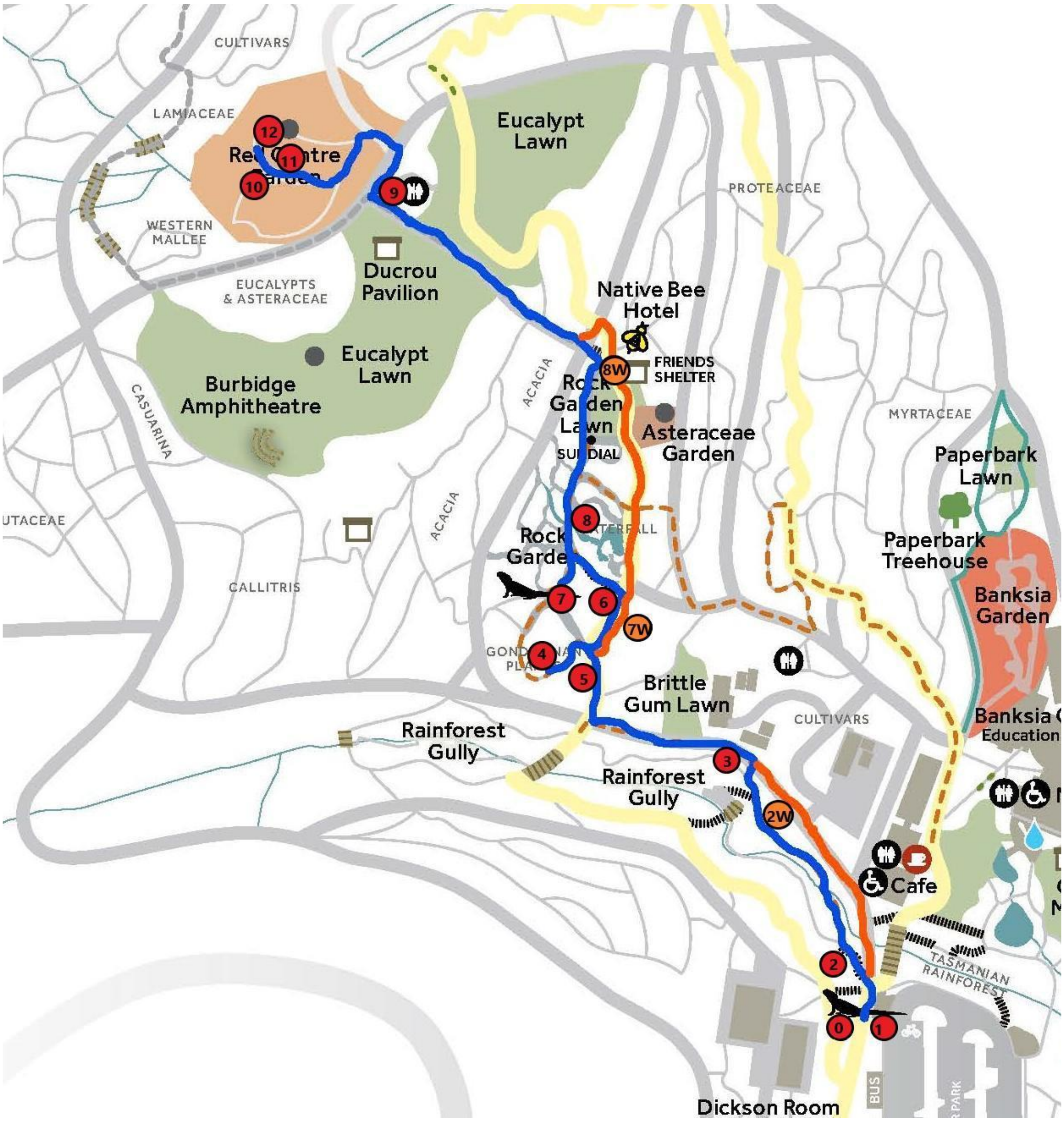
For stop 7, go back along the main path a little bit towards the gymnosperms to ***Casuarina cunninghamiana.*** Then progress along the main path past the Rock Garden to ***Hakea drupacea*** near the Friends Shelter for stop 8.

Stop List and Time Scale

Stop	Plant	Time in Year	Where
0	Cyanobacteria (3000 mya)	January 1	Clock
1	Green algae (1000mya)	August 31	Clock pond
2	Mosses and liverworts (475mya)	November 3	Rainforest walls
3	Ferns (385mya)	November 9	Seed Bank
4	*Macrozamia spiralis* (280mya)	November 22	Gymnosperms section 105
5	*Araucaria cunninghamii*: age of dinosaurs(230 – 65mya)	December 3-23	Main path in gymnosperms
6	Flowering plants (150 mya) various	December 14	Bottom of Rock Garden
7	*Allocasuarina grampiana*: rise of the megafauna (2.5 mya)	December 31	In Rock Garden
8	*Hakea obtusa* or *Hakea drupacea (40-20 kya)*	December 31	In Rock Garden
9	*Syzygium smithii (12 kya)*	December 31	Toilets opposite Red Centre Garden
10	*Maireana sedifolia* Extinction of megafauna	December 31	Just before art work
11	*Livistona mariae*	December 31	View from art work in Red Centre Garden
12	Triodia scariosa	December 31	Red Centre Garden

mya million years ago
kya thousand years ago

Map


CULTIVARS
LAMIACEAE
WESTERN MALLEE
EUCALYPTS & ASTERACEAE
Ducrou Pavilion
Eucalypt Lawn
Burbidge Amphitheatre
Eucalypt Lawn
PROTEACEAE
Native Bee Hotel
FRIENDS SHELTER
Asteraceae Garden
ACACIA
MYRTACEAE
Paperbark Lawn
Paperbark Treehouse
Banksia Garden
CASUARINA
CALLITRIS
Brittle Gum Lawn
CULTIVARS
Rainforest Gully
Rainforest Gully
Cafe
TASMANIAN RAINFOREST
Dickson Room
BUS

Stop 1 Pond by the Clock

Theme Point: First steps in the emergence of plants

January 1 3000mya The Beginning
On January 1st of our calendar year, the earth was about 1,500 million years old. And it was not a nice place. The atmosphere was composed of toxic gasses. Volcanoes spewed ash into the air. The UV light from the sun was intense and there were violent storms. However, on the ground were pools of water and it was in these pools that the story of plants began. Microscopic cyanobacteria were living in the water. These blue-green algae were the first to demonstrate photosynthesis, capturing the energy from the sun and converting it to stored energy, releasing oxygen in the process. There are still many ancient cyanobacteria on the earth. [*Image of cyanobacteria*]
A stromatolite is a calcareous mound built up of layers of lime-secreting cyanobacteria and trapped sediment, found in Precambrian rocks as the earliest known fossils, and still being formed in lagoons in Australasia, such as at Hamelin Pool in Western Australia. They closely resemble their ancient ancestors. [*Image of stromatolites*]

August 31 – 1000mya The First Step
The cyanobacteria continued to produce oxygen as part of the photosynthetic process and once the free iron on the earth's surface had all oxidised, there was free oxygen in the air and the sky became blue. However, it took a long time for the next step in the development of plants, 2,000 million years in fact. That corresponds to August 31st on our calendar. The change occurred around 1000 mya and this big step was the emergence of chlorophyll in green algae. These were the first plants that used chlorophyll to photosynthesise and were the forerunners of all of our modern plants. Photosynthesis, is, of course, that amazing process where the plants take the energy from the sun and using some carbon dioxide and water, stores this energy in a chemical form, usually a sugar or a starch. This stored energy also fuels the life of the animal kingdom and enabled the development of the dinosaurs and megafauna later on in the calendar.

You may be able to find some green algae in the pond water but if not there is a green algae image.

LINK: Green algae continued to thrive in the water for a long time. In fact, on our calendar year, it wasn't until early November, more than two months later, that the next significant step took place, about 525my later. Let's go and find a plant to illustrate that step.

Stop 2 Down the steps into the Rain Forest along the walls.

Theme Point: Leaving the water

Plants to see include mosses and liverworts

November 3rd – 475mya Mosses, liverworts and hornworts
The green algae were happy in the water. They became multicellular and branched organisms. Sexual reproduction developed. They needed nutrients and there were more nutrients around the edges of ponds of water and algae proliferated around the edges of the ponds. The next step was to move out of the water to take advantage of the food on the land. This happened on about November 3rd on our plant development calendar, some 450mya. To thrive on land, plants needed strong cells wall for support and a waxy coating to prevent water loss. They also developed root like structures to anchor them to the ground. These new plants that left the water were the ancient bryophytes – the mosses, liverworts and hornworts. These examples you can see on the side of the

path are modern descendants of the early bryophytes. While they do reproduce sexually, it normally happens out of sight. The spores that the plants produce are a developmental phase. [*Image: Life cycle of mosses*]

LINK: Once the plants were out of the water, the changes came thick and fast. While it took 8 months for the first developmental change to occur it was only 10 days on the calendar for the next major change.

Stop 3 - On the road along the Rain Forest verge – opposite the Seed Bank.

Theme Point: Development of a vascular system

Plants include ***Pteris umbrosa*** (Jungle brake), ***Asplenium australasicum*** (Bird's nest fern) and ***Cyathea australis*** (Rough tree fern)

November 9 – 430 mya Vascular System
At the start of the second week in November on our calendar, about 430mya, the next main step in the evolution of plants occurred. Plants developed a vascular system that transported water and nutrients through the plant. This meant that different parts of the plant could specialise. The ferns show this. They were some of the earliest plants to have a basic root system, leaves and stems.

At this stop, you can see modern ferns growing here, descendants of the ancient ferns. The vascular plants, which included the ferns, club mosses and seed ferns, grew in extensive forests. This period covered the carboniferous era when the main peat and coal deposits were formed from the dead plants in the forests.

But the ferns still relied on water for reproduction [*Image: Life Cycle of Ferns*]. Like the mosses, they produced spores. (Show the back of fern leaf). When the spores are released, they develop into a flat heart-shaped green structure on the ground and from different parts of this prothallus, male and female gametes are released. Water is needed to facilitate the union between these parts which unite and grow into a new fern.

1. Mary White (1998) The Greening of Gondwana, 3rd edition, ISBN 9780864178954
2. 10.6: Seedless Vascular Plants - Biology LibreTexts

LINK: About another two weeks passed before the next major development. Let's see what that was.

Stop 4 – Section 105 Off the Main Path to the left after the Hoop Pine.

Plant is ***Macrozamia spiralis*** from dry sclerophyll forests in central eastern NSW.

Theme Point: seeds and pollen

November 22 – 320 mya Gymnosperms
The next major step was a dramatic change in reproduction. Plants developed seeds and pollen. Pollen is sperm cells with a durable coating. The male sperm cells no longer needed to be transported by water but could be moved in the air by wind, water or insects to the female cone that contains the female ovules. Once fertilization occurs, a seed develops.

A seed is an undeveloped plant embryo along with a food reserve enclosed in a protective outer covering, also durable and able to be carried by wind, water or animals.

Sometimes the plant will have both male and female cones on the same plant but other species have male and female cones on different plants like here at this cycad – Macrozamia spiralis. This plant near the path is a female plant bearing large seed cones. A male cycad which produces the pollen can be seen growing a little further from the path.

The seeds of the cycads are very large. A recent study on one cycad species in Queensland showed that only about 3% of the large ripe seeds were moved further than 1m from the female plant. The authors of the study suggest the current suite of animals in Australia are not able to spread the seeds any further and that these large seeds are adapted for dispersal by large animals like the megafauna. But this was a relatively recent development.

Cycads have been around a long time and are only one member of the gymnosperms which include the conifers (pines, cypresses, and relatives). They dominated the plant communities on the land during the time that the dinosaurs roamed the earth.

https://pubmed.ncbi.nlm.nih.gov/23711908/

LINK: Let's take a closer look at this association between the gymnosperms and the dinosaurs.

Stop 5 Return to Main Path to *Araucaria cunninghamii* (Hoop Pine)

Theme Point: The Age of the Dinosaurs

December 3-23 – 200 to 65 mya

Dinosaurs were very successful animals. They dominated the animal world for around 150 million years. Fossil evidence indicates that the Araucaria family of plants reached their maximum diversity between 200 and 65 million years ago and were a dominant plant family in the time of the dinosaurs. Sauropods, a group of plant eating dinosaurs included the biggest land animals ever to live. They would have consumed 200 to 900 kgs of plant material per day. How did they do that?

- They had a huge hind gut allowing them to process tough plant material.
- They had a long neck, sturdy legs and tail allowing them to move their head through the foliage without moving their body thus saving energy.
- They had peg like teeth and could pull large amount of foliage off branches which was swallowed whole (no chewing or grinding teeth). Demonstrate how the teeth might have stripped the branchlets of an araucaria like a rake.

Other*:*

Dinosaurs were animals living on land during the Mesozoic Era (252 to 66 million years ago) that:

- laid eggs;
- had hind legs that came straight down from their body (eg like birds and mammals), not to the side (eg like a crocodile) so they could run faster;
- and had two extra openings near the top of their skull to allow extra room for their large jaw muscles to fully contract and allowed them to open their mouths very wide.

Araucariaceae is a family of 41 species in three genera - Agathis, Araucaria and Wollemia. At their peak they were a dominant plant on all land masses. Sometime after the Jurassic, i.e. 145mya, they disappeared from land masses in the north. They remained dominant in the southern hemisphere until about 30 million years ago. Reasons for their decline include reduced areas of suitable climate, sensitivity to fire, their slow reproductive cycle and competition from angiosperms.

Stop 6 Bottom of the Rock Garden

Theme Point: Emergence of Flowering Plants

Plants here include Grevillea lanigera, ***Doryanthes excelsa*** (Gymea lily), Banksia integrifolia (Coast Banksia), Correa sp.

November 29 to December 14 – 270 to 140 mya

Fossil evidence indicates that flowering plants emerged about 140 million years ago - in the early Cretaceous period. Genetic studies, by contrast, indicate that flowering plants may have appeared from deep into the Permian era (187–267 million years ago). Regardless, it was only after dinosaurs disappeared 66 million years ago (ie on 23 December) that flowering plants really made big changes and restructured the world's ecosystems.

Flowering plants (angiosperms) have several advantages over cone-bearing plants that do not have flowers (gymnosperms).

- The seeds of gymnosperms are naked, whereas the female reproductive part of a flower (carpel) consists of stigma, style and ovary where the ovule develops; the carpel and other structures develop into fruit.
- Angiosperms have drastically smaller-sized pollen, thus reducing the time between pollination and fertilisation, which in gymnosperms can be up to a year.
- Gymnosperm xylem cells (tracheids) have small pores in the top and bottom cell walls. Angiosperm xylem cells are tubular without any cell walls at bottom or top so water can pass through from cell to cell more efficiently.
- The phloem cells in gymnosperms have metabolic structures whereas angiosperm phloem cells don't have any cellular metabolic structures, and companion cells provide all those services to them. Thus in angiosperms nutrients pass more efficiently from cell to cell.

Gymnosperm forests and open spaces contained fewer species. When the dinosaurs died out, modern groups of animals filled their places. Flowering plants drive the evolution of the animals and similarly evolving animals can drive the evolution of plants. Animals pollinate plants, or feed on their fruit and disperse their seeds. Together they build complex ecosystems that are homes to thousands of species.

Angiosperms also capture much more of the Sun's energy than conifers and their relatives, and this extra energy passes through the whole ecosystem. There are ten times more species on each hectare of the Earth's surface than if flowering plants had not become established when they did.

Segue to megafauna.

References:

1. Charles S.P. Foster (2016). The evolutionary history of flowering plants. Journal & Proceedings of the Royal Society of New South Wales, vol. 149, parts 1 & 2 pp. 65-82.
2. Foster - flowering plants 20170131 (researchgate.net)
3. Philip Donoghue (2019). Evolution: The Flowering of Land Plant Evolution. Current Biology 29, R738–R761, pp. R753 - R756. https://doi.org/10.1016/j.cub.2019.06.021

Stop 7 *Allocasuarina grampiana* (Grampian's Sheoak) in the Rock Garden

Theme Point: The rise of the megafauna

December 31 5.30 pm 2.5mya

Definition: *Megafauna were large animals that roamed the Earth during the Pleistocene (known as the Ice Age), 2.5 million to ~12,000 years ago and went extinct at the end of that period.*

During this time there were over 11 cycles of temperature rise and fall that created sheets of ice that expanded and contracted. Each cycle lasted between 40,000 and 100,000 years causing the mean temperatures to move up and down about 10 degrees. During these glaciation periods, sea levels were probably 120 metres lower than today. These cycles favoured open vegetation of smaller trees and shrubs and rain forests would have contracted.

The change in vegetation coincided with the evolution of megafauna. These large animals adapted to the temperature and vegetation due to their ability to better regulate their body temperature, greater mobility to seek suitable vegetation, to their larger hind gut to process tougher, drier material.
How do we know what these megafauna ate? One way is finding plant material and animal remains together. The *Diprotodon opatum* [*Image Diprotodon*] was the largest marsupial to have ever lived. It was just under 4 metres long and about 2,800 kgs. It ate 100 to 150 kilograms of vegetation daily. Its chisel-like incisors may have been used to root out vegetation. Its remains have been found near parts of Allocasuarina.

Allocasuarina is dioecious (male and female flowers on separate plants). This plant is a female plant as evidenced by its woody fruit, resembling cones. This species is endemic to the Grampians NP in Victoria and is endangered.

Diprotodon optatum - The Australian Museum

https://www.britannica.com/science/Pleistocene-Epoch/Pleistocene-fauna-and-flora

Allocasuarina grampiana : Grampians Sheoak | Atlas of Living Australia (ala.org.au)

Stop 8 *Hakea obtusa*, in the rock garden, and Hakea corymbosa (Cauliflower hakea) or *Hakea drupacea* (Sweet scented Hakea) near the friends shelter (section 20 sign)

Theme point: Megafauna and plants adapt to each other.

December 31 11.53 pm (40,000 to 20,000 years ago)

At the peak of the Pleistocene, up to 55 species of large mammals roamed Australia. Some of them were browsers, i.e. they ate foliage. An unusual looking megafauna was the Palorchestes azael (pronounced 'pal-or-kestees') [*Image Palorchestes*]. It probably weighed about 1000 kgs, being much more bulky than earlier thought. It had especially long and powerful forearms and very sharp claws. It also had a short trunk and would stand on its back legs, and pull branches down. Bones of some of these animals have been found in caves in Naracoorte where there are open dry forests and hakeas are common.

Herbivory can have devastating effects on plants, so plants defend themselves against it. Structural defences against larger vertebrates include spines, thorns and plants also use small leaf size and thicket-forming growth habit to increase the effectiveness of spines. These features are common in the genera *Hakea, Solanum* and *Acacia*. No living mammals eat *Hakea*. It is contended that these physical features evolved as defences against large browsers that are now extinct.

This Hakea corymbosa has very spiky leaves

The megafauna became extinct in the Pleistocene. Today no native mammals eat hakeas though the hakeas are still 'protecting' themselves with spiky leaves.

Other
The flower is similar to grevilleas – but has a woody fruit.

https://australian.museum/learn/animals/mammals/palorchestes-azeal/

Stop 9 *Syzygium smithii* (Lilly Pilly) near toilets facing Red Centre

Theme point: Dispersal of seeds by megafauna birds

Dec 31 11.58 pm about 12kya

Syzygium is a genus in the Myrtaceae family – a rainforest tree. Interestingly, it is one of the earlier members of this family and still has the soft fruits, whereas later members like the Eucalypts, Callistemons etc have very woody fruits.

One of the great megafauna families were the Dromornithids, commonly known as mihirungs (pronounced My-rungs). A family that existed for over 23 million years, i.e. preceding the megafauna but also living through the megafauna era. They were large, flightless birds, more closely related to ducks and geese rather than emus.

The largest was Dromornis planei, [*Image: Bullockornis*] possibly the largest bird ever, weighing about 600 kgs and over 3m tall, with a very long neck, strong, and a bird-like beak. It lived in warm, wet forests. Its fossils were found in Northern Territory (Bullock Creek) with genera of crocodile and tortoise. It had a higher metabolic rate than the marsupial megafauna so needed a higher energy plant product – expected to be fruit, nuts and seeds.

Many fruits and nuts of Northern Aus. are left on the tree or fall and rot because the existing Northern Aust. animals don't eat many of the fruits. It is calculated that *Dromornis planei* may have spread 2-4 kgs of fruit seeds 30 kms per day. The loss of the animal dispersing the seed will have had a large impact on the plants. Murray says that at least one third of the fifty or more larger drupes and nuts that occur in sub-humid to semi-arid fire sensitive woodlands are of a type most likely to have been dispersed by large-bodied species.

This Bullock Creek site at the start of the Pleistocene period was a rainforest but by mid-Pleistocene it was semi-arid with seasonal wetland. The habitat available for the Syzygium was reduced. This reduction would have had an impact on birds eating the fruits.

Murray PF, and Vickers-Rich P. 2004. Magnificent Mihirungs: The Colossal Flightless Birds of the Australian Dreamtime. Indiana University Press, Bloomington.

Stop 10 Maireana sedifolia (pearl blue bush) just before Art Work

Theme point: Procoptodon and shrubs

The fluctuations of temperature in the Pleistocene also impacted the amount of carbon dioxide in the atmosphere. There was high CO_2 in the warm regions and low CO_2 in the cool areas. Periods of low CO_2 were more difficult for larger trees. Some plants, known as C4 plants are less dependent on CO_2 for photosynthesis so would have been very successful in this period. The main C4 plants are grasses and a group of plants called chenopods.

In the Pleistocene period, 55 species of mammals became extinct – over half were types of kangaroo.

One sub-family were the procoptodons, or short-faced kangaroos. Its upper and lower incisors were small, and would have been used to nip vegetation. They were browser feeders on small shrubs and the soft parts of trees. One of the largest was Procoptodon goliah [*Image: Procoptodon*]. It was known to eat a lot of chenopod plants.

This environment may seem poor, but these plants are nutrient rich and are valued in livestock pastures for their high protein content.

Look to distant **Grevillea, Allocasuarina and Acacia** on the mounds in the middle. These kangaroos were about 2 metres high and much more heavily built. They could stand on their hind legs and, using their tail as a prop, reach their arms up. Many had a hook like claw on their front legs which would allow them to pull down the new branched and soft growth of trees.

Procoptodon Goliah and a species of Dromornithidae (Genyornis newtoni flightless bird) were among the last of the megafauna to become extinct.

Other

This chenopod*, Maireana sedifolia* (bluebush, pearl bluebush), has very deep roots, grows slowly, and lives for 200 years.

On the other hand, *Atriplex vesicaria* (bladder saltbush) has shallow, fan-like roots that spread two metres wide. It grows rapidly, shuts down when dry and lives about 25 years.

Stop 11 Art work in Red Centre Garden

Theme Point: An interesting question about spread of plants.

Dec 31 11.49 pm about 60kya

Look at *Livistona mariae subsp mariae* (red cabbage palm) in the distance on the left back wall. It was at one time thought that the palms in central Australia were a relict population, left as the continent dried out. However, this species from central Australia has been shown to be genetically identical to a Livistona species in the far north of Australia (now called *Livistona mariae subsp. rigida*). In fact, they have been shown to diverge between 30,000 and 15,000 years ago.

How did they get to central Australia? No rivers link the Roper River in the north, where the northern Livistona grow, and the Finke River in central Australia and there are no intermediate populations of palms that might indicate dispersal by birds or bats. The missionary and anthropologist, Carl Strehlow, recorded that according to traditional local beliefs, the gods from the high north brought the seeds to this place a long time ago.

These 'gods' may have been people or megafauna. There is physical evidence of overlap of megafauna and Aboriginal peoples. Megafauna are potential sources for dreamtime stories. Megafauna extinction is believed to be due to a combination of factors, mainly being the Pleistocene variability that placed the existing fauna under stress; and the arrival of Aboriginal people who hunted and used fire. The jury is still out on these theories.

Red Cabbage Palm (Livistona mariae) · iNaturalist Australia (ala.org.au)

Livistona mariae subsp. mariae - Central Australian Cabbage Palm (mq.edu.au)

Chris Johnson - ABC Radio National

Stop 12 *Triodia scariosa* (Porcupine Grass) in Red Centre Garden

Theme Point: End of Pleistocene period and appearance of homo sapiens

Last hour before midnight, up to date with the year of plant development.
But there is one more thing to mention. In the last half-hour on the last day of the plant year, something else happens – thanks to the plants and in particular, thanks to the plants known as grasses, like this spinifex.

The grasses are flowering plants but their flowers are quite insignificant because they are pollinated by the wind. They don't need to attract a pollinator. They have developed very light pollen grains that are carried on the breeze from one flower to the next.

In this last hour before midnight, modern humans appeared. And some of the grasses were and still are vital to the emergence and survival of human beings. The basic staple foods of many people in the world are all grasses – wheat, barley and oats, rice, maize (corn) and sorghum.

Australian Indigenous people ate the grains from *Triodia*.

In Conclusion

Plants give us the energy to live. Plants are the organisms that take the energy of the sun and through photosynthesis, fix it in a chemical form that is then available to every other life form including humans. We use energy to grow and to live. We get this energy from plants through what we eat.

But plants not only give us energy. During photosynthesis, they take carbon dioxide out of the air and release the oxygen that we need to breathe in and so release the energy from the food we have eaten. Plants are essential to our lives.

And on top of that, they are beautiful to look at. And especially the Australian native plants that we have seen today. So as the walk finishes and the end of our plant evolution year has caught up with us, you can see around you the wide variety of plants that have evolved from the original cyanobacteria.

Appendix

Flowering plants: an evolution revolution. https://www.bristol.ac.uk/news/2021/november/flowering-plants-evolution.html - source for the following figure.