Adaptation — The Secret of Survival of the Biota Through Geological Time©

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Look at The Mallee and the eucalypt that gives it its name, and at the river red gums, the eucalypt icons of the Murray — closely related but so distinctly different because of their specific habitat characteristics — and you see how adaptation and survival are connected.

Co-evolution of the biota and the environment has been the story throughout the 425 million years that terrestrial life has been evolving on Earth. Natural selection has favoured the individuals best adapted to their current environments, and at times of change has promoted those with ability to adapt to the changing circumstances. Imagine the difficulties encountered by the first plants on the land — having a green algal ancestor and all that that implied; no longer surrounded and supported by water and able to absorb nutrients from it; exposed to evaporation, sunburn, and weather changes. Without the symbiotic help from fungi from the start they would never have made the transition and the world would have been a very different place today.

Australia's plant fossil record documents the evolution of its flora from the time of first vascular plants to modern-style vegetation. For most of that time the Australian landmass was part of the Gondwana super-continent, and the biota that it contained when it became an island continent 45 million years ago was Gondwanan. Evolution in isolation from that Gondwanan stock as the continent travelled northwards away from Antarctica has resulted in the unique Australian flora and fauna of today.

It is the evolution of flowering plants and their situation prior to separation, when the Murray Basin was forming, and while its modern landscapes were emerging in the island continent, that is of interest as background to this conference.

The evolution of the flowering plants and their rapid diversification and radiation into all parts of Pangaea (Gondwana and Laurasia were connected into one super-super-continent at the time) was facilitated by the impending break-up of the landmass. Rift valleys were developing between all the component continents, which were richly vegetated with forests of conifers, cycads, and ferns, under globally benign, warm, and wet climatic conditions. Early angiosperms were evolving but facing stiff competition for space. The rifts were disturbed regions with a great variety of different environments — from saline swamps being invaded by the sea, to freshwater swamps, areas of poor soils and of rich volcanic soils, sandy deserts, and changing topography and drainage patterns. Competition in them was much reduced. The old-style vegetation did not have the genetic flexibility or comparatively rapid reproductive cycles of the angiosperms. Flowering plants were able to adapt and produce new modifications that suited them to the new conditions. Then they could invade the established forests when rifts became seaways and changing climates as landmasses moved made conditions less suitable for the gymnosperm-dominated vegetation.

At 80 million years ago, when we take up the story of the Murray Basin, such a "mixed" flora, the Palaeoflora-mixta of Edgardo Romera, in which the different components have since been sifted and sorted according to their suitability to changed climate regimes, was in the making. This was an interesting time for the eastern half of the Australian continent when high volcanic mountains formed a wide belt along the margin and two huge river systems, the ancestral Murray and Darling, were part of the "Congo style" drainage, running south-west right across the eastern half of the continent and discharging into the Ceduna Depression within the rift system off the Nullarbor coastline. The huge amount of sediment eroded from the mountains was spread across vast riverine plains that were the forerunners of the freshwater deposits of the Murray Basin.

At 60 million years ago the rifting had developed to a stage where a seaway had developed from the west along most of Australia's southern margin. A connection to Antarctica remained through the Tasmanian sector. The Murray Basin was starting to sink and to accumulate sediments. A pollen flora from the Otway Basin just south of its margin reveals that this part of the rift was a centre for evolution of the Proteaceae and that sclerophyll types suitable for dry habitats were present as well as genera that are now confined to tropical rainforests. The association contained Antarctic beech and many taxa that are essentially cool temperate — so this was a palaeoflora-mixta.

At 45 million years, when final rifting between the Tasmanian peninsula and Antarctica was accomplished, Australia set off as an island continent, traveling northward at 6 to 7 cm per year. We know, from fossil floras in the dead heart of Australia at Lake Eyre, that the centre was forested and the mixed broadleaf — sclerophyll components were what now occur in remnant Gondwanan rainforests in subtropical and tropical regions. The genus *Eucalyptus* was present, with Casuarinas.

The movement of continents away from the Antarctic landmass, which remained straddling the South Pole, was to cause global climate change and set the world on a path towards an ice age. A circum-polar current developed round Antarctica after the Drake Passage opened between it and the tip of South America and when the gap between it and Australia's southern margin was wide enough. This current progressively prevented warm waters from equatorial regions reaching Antarctica and started a cooling that would lead to glaciation. Then, as ice built up and captured more of Earth's limited water budget, climates became drier. Sorting and sifting of the mixed floras that already contained plants with attributes suiting them to emerging environments proceeded. Natural fire became an environmental factor to which vegetation had to adapt as dryness increased from about 15 million years ago. By about 6 million years ago, Australia was already a fairly dry continent with rainforest remnants confined to still-suitable fefugia, the characteristic tough Australian vegetation widespread, and the wide-open spaces of the centre supporting grasslands and saltbush plains.

Glaciation of Antarctica was the driving force behind global climate change and progressive drying, and it was not until about 2.6 million years ago that the changes were sufficient to start the refrigeration of the North Polar regions. That marked the beginning of the Pleistocene ice age, in which we are living in an interglacial.

While all this was happening, the Murray Basin was undergoing physical as well as climatic changes. A minor marine incursion between 30 and 20 million years ago was followed by a major incursion and the Murravian Gulf occupied what is now

The Mallee until about 16 million years ago with fluctuating volume until about 5 million years. Marine sediments and coastal dune fields accumulated. Then a large section of terrain, the Pinaroo Block, started to rise, cutting the region off from the sea. The Pinaroo Block effectively dammed the river systems and Lake Bungunnia formed and reached its full, vast, extent by 2.5 million years ago. It occupied a large proportion of The Mallee until 700,000 years ago, when it started to drain, becoming a number of smaller lakes in the process. Lake Tyrell, a major salt lake, is the largest remaining bit of Bungunnia's lake bed.

Between 600,000 and 100,000 years ago the Mallee was established in its present form with its characteristic vegetation. Climatic instability was already pronounced and was to increase in the run-down to the last glacial stage of the ice age. While the centre was already acutely arid throughout the 75,000 to 35,000 years interval, good rainfall patterns persisted in the Murray Basin. At 55,000 years ago all the lakes in the Basin were full. The Willandra Lake system, fed by a tributary of the Lachlan, covered about 1000 km^2. This "Mungo Lacustral Phase" was followed by an arid time of low and fluctuating water levels, becoming more pronounced as the last glacial stage of the ice age approached. Lakes on the Darling River anabranch had a similar pattern of lake-full to drying episodes. (While the Northern Hemisphere was experiencing glaciation, ice and snow in glacial stages, the fluctuations from glacial to interglacial times in Australia, in contrast, meant times of intensification of dryness and windiness and some decrease in temperature alternating with warmer, wetter times.)

It was the last glacial stage of the Pleistocene Ice Age, that had its peak at 20,000 years ago, that made an already dry Australia into the driest vegetated continent. The intensity of this stage was unprecedented. About 80% of the continent was under desert regimes with blowing sand and salt. The whole continent suffered with half the present-day rainfall and twice the windiness (and presumably increased fire frequency and intensity). The Murray Basin, suffering the full strength of the westerly salt-laden winds, was a salt desert. The major dunefields of today's deserts show the intensity of this phase, with linear dunes as high as houses running up to 300 km downwind. Siltation resulted in changes to river and tributary patterns and function, and the Willandra Lake system and Darling anabranch lakes were no longer fed by rivers except as overflow channels in rare times of flood.

The 16,000 years of recovery from this "desert island" phase established the landscapes and ecosystems of today's Australia. The modern climate regimes, orchestrated by ENSO, the El Nino-Southern Oscillation syndrome, perpetuate the dry to wet fluctuations that had been moulding ecosystems through millions of years.

What major adaptations have had to be made by the Gondwanan flora that Australia inherited when it set off as an island continent 45 million years ago! The foregoing account tells only part of the story and does not mention that this extremely ancient and stable landmass, Australia, has worn-out soils made from deeply weathered rock over 94% of its surface; or that it is the flattest land with least relief and is largely inward draining, accentuating the retention of sediment and salt. As a result it is a land of floodplains with saline water tables. (The huge Murray-Darling catchment has a single exit to the sea at Murray Mouth.)

Adaptation has been, and still is, the key to survival of a unique flora in a unique continent.