Ranidae (one species). There are no consistent differences which will allow accurate use of the terms " frog " and " toad " for Australian amphibians. However, they are sometimes used to provide variety in common names, with " toad " being applied to the more globose, short-limbed, burrowing species, and " tree frog " to the more slender, long-limbed climbing species. Otherwise it is preferable to use the accepted general inclusive terms " frog " or " anuran ". Twenty-nine described species are known to occur in Victoria (Hylidae—nine species, Leptodactylidae—twenty species). Four additional subspecies are currently recognised and four forms of uncertain status are presently under investigation. The anuran fauna of Victoria is listed in the table on page 3.

Anurans have several general characteristics which make them suitable for experimental studies : convenient size, ready availability, ease of maintenance, external fertilisation and development, and relatively uncomplicated stereotyped behaviour patterns. These features, together with low dispersal ability and dependence on the availability of water, have resulted in anurans being extensively studied in the areas of zoogeography and evolutionary biology, especially for understanding the species concept in higher animals. Consequently, much more is presently known about species delimitation (taxonomy) and associated problems in anuran amphibians than in the other vertebrate groups. The Anura of southern Australia, particularly of south-western Western Australia and of Victoria, have been intensively investigated in this regard, and the results have contributed to a better understanding of the basic problems of species formation (speciation) and co-existence.

Taxonomic criteria

A fundamental biological problem is the understanding and delimiting of the diversity of living forms, with the species occupying the primary position. While there are difficulties in applying a species concept to asexual systems, some progress has been made with biparental, sexually reproducing forms. In these cases, species can be broadly defined as groups of individuals which share, or have the potential to share, a common heredity (genetic pool) through interbreeding. They are separated from other spatially co-existent (i.e., sympatric) interbreeding groups by a genetic gap imposed by the operation of factors which prevent effective genetic interchange—reproductive isolating mechanisms. Thus each biparental species is a closed genetic system maintaining its uniqueness and evolving along its own adaptive path.

Isolating mechanisms are the most important features of biparental species and operate at two levels : before or after mating. In the former category (premating) are differences in time and site of breeding, size, and courtship behaviour ; in the latter category (postmating) are infertility, hybrid inviability, and hybrid sterility. The expenditure of reproductive effort on the production of less-fit hybrids is very inefficient for co-existent species so that premating isolating mechanisms which prevent such wastage should be favoured by natural selection. In species of frogs the most important premating isolating mechanism is the distinctive male mating call and associated specific female response only to the call of a male of the same species. Thus the mating call will also be an ideal indicator of the presence of each sympatric species of frog.

VICTORIA—TAXONOMIC COMPOSITION AND ZOOGEOGRAPHIC DISTRIBUTION OF AMPHIBIANS

Taxon	Zoogeographic subregions			
	Bassian		Eyrean	Wide-ranging
	Southern	Eastern		
Hylidae				
Hyla aurea aurea	–	+	–	–
H. aurea raniformis	–	–	–	+
H. citropa	–	+	–	–
H. ewingi	+	–	–	–
H. ewingi complex (sp. nov.)	–	–	+	–
H. jervisiensis	–	+	–	–
H. lesueuri	–	–	–	+
H. maculata	+	–	–	–
H. peroni	–	–	–	+
H. phyllochroa	–	+	–	–
H. verreauxi verreauxi	–	+	–	–
H. verreauxi alpina	+	–	–	–
Leptodactylidae				
Crinia haswelli	–	+	–	–
C. laevis	+	–	–	–
C. parinsignifera	–	–	+	–
C. signifera	–	–	–	+
C. sloanei	–	–	+	–
C. victoriana	+	–	–	–
Heleioporus australiacus	–	+	–	–
Limnodynastes dorsalis dumerili	–	–	+	–
L. dorsalis insularis	+	–	–	–
L. dorsalis interioris	–	–	+	–
L. dorsalis (subsp. nov.)	+	–	–	–
L. fletcheri	–	–	+	–
L. peroni	–	–	–	+
L. tasmaniensis (Southern Call Race)	+	–	–	–
L. tasmaniensis (Northern Call Race)	–	–	+	–
Mixophyes balbus	–	+	–	–
Neobatrachus centralis	–	–	+	–
N. pictus	–	–	+	–
N. (sp. nov.)	+	–	–	–
Philoria frosti	+	–	–	–
Pseudophryne bibroni	–	–	+	–
P. dendyi	–	+	–	–
P. semimarmorata	+	–	–	–
Uperoleia marmorata	–	+	–	–
U. rugosa	–	–	+	–
Total	11	10	11	5

Unequivocal species of frogs are those which can co-exist with other closely related forms (i.e., are sympatric), and still maintain their distinctness. Such undisputed species are generally recognised by distinctive adult external morphology and unique male mating call. But morphological distinctness is not an essential requisite and many anuran species are so similar in appearance that initial recognition was based solely on the mating call (e.g., *Crinia parinsignifera, C. signifera,* and *C. sloanei*). Subsequent detailed investigations have usually led to the finding of slight but consistent morphological differences, and together with other information about various aspects of their biology, have confirmed the status of these concealed (cryptic) species. Other cryptic species which do not co-exist spatially (i.e., are allopatric) have been detected through artificial crossing experiments which have indicated their inability to hybridise successfully with their genetically closest, but geographically separated, relative.

Those populations which occupy geographically exclusive but contiguous ranges and form narrow hybrid zones are generally considered as separate species if the parental types are also present in the hybrid zone. Broader zones of intergradation are characteristic of subspecies, this latter term also being applied to slightly differentiated but completely geographically separated forms. Six cases of narrow hybrid zones and three of broader intergradation occur in Victoria and are currently under investigation. In cases such as these taxonomic decisions are difficult, and currently must be subjectively based. But these cases reflect the dynamic nature of divergent evolution and therefore attract the interest of biologists concerned with the processes of species formation. Sometimes the investigator does not consider the forms to have diverged enough even to be recognised as subspecies and he may refer to them informally as races. This term may also be used for well-differentiated populations still under investigation and awaiting formal description and naming. Species, subspecies, and races are collectively referred to as taxa (singular : taxon). Closely related groups of taxa representing crytic species or transitional stages in the process of species formation are generally referred to as species complexes (e.g., the *Hyla ewingi* complex which includes : *H. ewingi*, a similar but presently undescribed species, *H. verreauxi verreauxi*, and *H. verreauxi alpina* in Victoria ; or the four subspecies of the *Limnodynastes dorsalis* complex). If no subspecies are recognised, then the species is said to be monotypic and a two part latinised name (binomial) is applied (e.g., *Hyla lesueuri*). If subspecies are recognised, the species is said to be polytypic and the various taxa are each given a three part latinised name or trinomial (e.g., *Hyla aurea aurea* and *H. aurea raniformis*), the first described being termed the nominate subspecies.

Environment, climate, and distribution

Because of their limited ability to control water loss through the skin, and the requirement of fresh water or sustained high humidity for embryonic and larval development, anurans are strongly influenced by the amount, effectiveness, reliability, and seasonal distribution of precipitation. They are also intolerant of salt water. Solar radiation is important, perhaps to a lesser extent, in affecting rates of evaporation, availability and duration of free water, temperature extremes in shallow ponds, and larval development rates. These factors combine to determine the general distribution of anurans, but particular species' distributions will also be controlled by their special physiological adaptations, dispersal powers, and historical opportunities (e.g., availability of suitable migratory paths).

Within Victoria, the area of greatest abundance of anurans is warm, moist east Gippsland with more than seventeen taxa ; while the hot, dry Mallee represents the other extreme with one or two taxa. The Murray

River Valley provides a moist corridor through the Mallee allowing five taxa to penetrate an otherwise unsuitable area. Four taxa occur in the sub-alpine areas of Victoria (i.e., above 4,000 ft). Twelve to fourteen taxa occur in south-central Victoria, and at least nine in south-western Victoria.

Zoogeography

Of the several suggested schemes to subdivide the Australian Zoogeographic Region, a modified version of that advanced by Baldwin Spencer appears the most satisfactory at present. This proposal divides Australia into four subregions, which have distinctive faunas and which also fit the broad climatic areas of Australia, namely temperate, tropical, and arid. The subregions are:

1. *Bassian.* Temperate eastern and south-eastern Australia south of 30° S. latitude, including the highlands, Tasmania, and the Bass Strait islands. This subregion may be further subdivided on the basis of climate into (*a*) the warm eastern area characterised by rain at all seasons and either a uniform distribution or a slight summer maximum; and (*b*) the cool southern area characterised by rain at all seasons but with a winter maximum.
2. *Eyrean.* Arid and semi-arid central Australia, generally with an annual rainfall of less than 20 inches.
3. *South-western.* Temperate south-western Western Australia with a mediterranean climate.
4. *Torresian.* Northern and north-eastern tropical and sub-tropical areas with a high annual rainfall but a dry winter.

In this scheme approximately two thirds of Victoria is included within the Bassian Subregion and the balance within the Eyrean Subregion (see section on Reptiles for details, including life forms of vegetation). Hence four components within the Victorian anuran fauna may be recognised :

1. *Southern Bassian.* Eleven taxa are mostly restricted to the Dividing Range or southern coastal areas of Victoria (see table on page 3). There is a progressive reduction of this component eastward into south-eastern New South Wales and westward into south-eastern South Australia. The most widely distributed taxon is *Hyla ewingi* which extends to Moss Vale, New South Wales, in the north, and to the Mount Lofty Range and Kangaroo Island, South Australia, in the west. The most restricted is *Philoria frosti* which is known only from the Mount Baw Baw Plateau. Five of these taxa (*Crinia laevis, Hyla ewingi, Limnodynastes dorsalis insularis, Limnodynastes tasmaniensis* (Southern Call Race), and *Pseudophryne semimarmorata*) also occur in Tasmania.
2. *Eastern Bassian.* Ten taxa, whose northern limits are within or just beyond the northern boundary of the Bassian Subregion in New South Wales, also occur in southern Victoria with progressive recession westward through Gippsland to Port Phillip Bay (see table on page 3).
3. *Eyrean.* Eleven taxa have distributions mainly to the north of the Dividing Range and represent the Eyrean component of the fauna (see table on page 3). Three taxa (*Limnodynastes dorsalis dumerili, Neobatrachus pictus,* and *Pseudophryne biboni*) have been able to penetrate the Dividing Range through the Kilmore gap and reach south to the outskirts of Melbourne. *Limnodynastes fletcheri* is restricted to the valleys of the larger rivers

(Goulburn and Murray Rivers) ; the others are more generally distributed throughout the area with progressive recession to the west and north-west into the Mallee where, except along the moist Murray River valley which allows *Limnodynastes dorsalis dumerili, L. tasmaniensis* (Northern Call Race), and *Crinia parinsignifera* to persist. *Neobatrachus centralis* may be the only extreme arid-adapted species.

4. *Wide-ranging.* Five taxa range widely throughout south-eastern Australia and cannot easily be included in any of the other components. *Crinia signifera* is found through all Victoria except the Mallee; *Hyla aurea raniformis* is distributed through the northern plains and rivers, and southern Victoria, excluding the montane regions and East Gippsland; *Limnodynastes peroni* occurs through coastal eastern and south-eastern Australia and north-western Tasmania. *Hyla lesueuri* occurs in northern and eastern Australia and westward through southern Victoria to near Ararat, while *H. peroni* has an extensive eastern Australian distribution ranging into Victoria along the larger inland rivers and also along the east coast through Gippsland to near Rosedale. These latter two species may represent an intrusive Torresian element. (See table on page 3.)

General ecology

With a complex life cycle typically involving an aquatic larva and a terrestrial adult, anuran amphibians are able to exploit two major ecological adaptive zones. At present little is known about the ecology of Victorian anurans, but some generalisations can be made.

Larvae (tadpoles) of most species are herbivores feeding on phyto-plankton and encrusting algae, scavengers utilising fungal hyphae and animal remains, or a combination of these. Populations of tadpoles can reach very high densities in temporary ponds and shallow streams and represent a major component in the energy transfer pathways of such ecosystems.

All adult frogs are carnivores and are generally opportunistic rather than specialised feeders, taking virtually any small moving prey. Crawling and low-flying insects, spiders and mites constitute common elements of diet, with isopods, earthworms and snails being occasionally represented. Some of the larger species of frogs also prey on smaller species of frogs (e.g., *Hyla aurea, Limnodynastes dorsalis interioris*).

Frog eggs apparently are not commonly used as food by predators. However, larval stages are subject to heavy predation, particularly by carnivorous aquatic insects (water beetle adults and larvae, water scorpions, damself-fly larvae and dragon-fly larvae). Fish and turtles are probably important predators in larger, more permanent bodies of water such as lakes and river lagoons. Snakes and predatory water birds (e.g., white-faced heron, egret) also eat frogs. Leeches and mosquitoes attack adult frogs as external parasites, while the dipteran (fly) larva *Batrachomyia* lives under the skin of several species, particularly *Pseudophryne*. Both adult and larval stages can be infected with a wide variety of protozoan (e.g., species of *Protoopalina*) and platyhelminth (flukes and tapeworms) parasites.

Adaptations to extreme environments

Adaptations to drier environments include avoiding desiccation by burrowing deeply, often assisted by the possession of horny or fleshy tubercles (" spades ") on the feet (*Limnodynastes dorsalis* and *Neobatrachus spp.*) ; long adult life in order to live through extended droughts ; opportunistic breeding associated with the unreliable but heavy falls of rain which occur in the desert during the warmer seasons ; and a short aquatic larval life to allow metamorphosis to be reached before the ponds dry out. No species of anuran occurring in arid areas has terrestrial oviposition and development, presumably because of the inability to control water loss through the egg capsule.

High altitude conditions also present problems for amphibians. Exposed shallow pools can experience high daytime temperatures during summer (e.g., 90·7°F. at 4,500 ft on Lake Mountain) and drop to near freezing point at night, thus requiring a wide temperature tolerance by tadpoles. Modified breeding seasons and extended larval life may also occur because of the short growing season. At low altitudes (c. 1,000 ft) *Crinia victoriana* breeds during the period April–May ; the larvae reach a maximum size of 28 mm and metamorphose in October and November. At 4,500 ft on Lake Mountain, however, breeding begins in January and is almost completed by mid-March ; the larvae grow more slowly and reach body lengths up to 45 mm, suggesting that metamorphosis is delayed until the following season after the snow has melted.

Life histories

Breeding seasons

Three types of breeding season may be recognised :

1. *Short regular.* Breeding occurs at the same time each year and is confined to a 4-6 week period, the season presumably being triggered off by the annual temperature regime. *Crinia laevis*, *C. victoriana*, and the three species of *Pseudophryne* breed during a short period in autumn, while the montane species, *Philoria frosti*, has a short breeding season in late spring.
2. *Short irregular.* Populations occupying areas of low and unreliable rainfall are characterised by very short (2-3 days) breeding seasons following heavy precipitation. Populations of *Neobatrachus centralis* and *N. pictus* in the Mallee area may breed in this way.
3. *Extended.* (*a*) Several species begin breeding with the first heavy rains of autumn and continue intermittently throughout the winter into the early summer with a number of bursts of breeding. Breeding activity appears to follow the rainfall associated with the regular progression of cold fronts characteristic of southern Victoria. *Crinia signifera* and *Hyla ewingi* have breeding patterns of this type. (*b*) A large group of species begins breeding in late winter-early spring and continues through into summer, sometimes with a second peak in autumn.

Breeding behaviour

Most breeding activity occurs at night, although during the height of the season it may be continuous. The following is a general account of the breeding process.

Males arrive at the breeding site and establish calling stations or " territories ". The mating call indicates to other males that a particular area is occupied and a special " territorial call " may be used to discourage intruders ; sometimes physical contact may occur with associated aggressive behaviour. After a period of spatial adjustment, the males settle down to producing the distinctive mating call which is highly characteristic and serves to attract a breeding female of the same species. When the eggs are mature and ovulation has commenced, or can be initiated by the mating process, a female moves into the breeding area and is attracted to the male mating call. Close visual or physical contact results in the male clasping the female (amplexus). The pair then moves to the oviposition site where egg-laying and external fertilisation occur. Except, possibly, for species of *Pseudophryne*, where the pair or the male remains in the nest with the eggs, there is no parental care of the developing embryos.

Since it is usual for several species to breed in the same area at the same time, there can be serious problems associated with interbreeding, space sharing, and acoustic interference resulting from the simultaneous production of different mating calls. Each sympatric species has a distinctive mating call to which only a female of the same species responds, thus greatly reducing the possibility of attempts at cross-mating. Males seem to be indiscriminate and will attempt to clasp any moving object of the appropriate size, so that effective discrimination by the female is essential for reproductive efficiency. The selection of species-specific calling positions, or of single species aggregations into choruses in different parts of the breeding habitat, can minimise the spatial problem ; even so, males of different species may call in close proximity, suggesting that space may not always be a limiting factor. Acoustic interference may be reduced in three ways : spatial separation so that the intensities of calls of other individuals are below the threshold of hearing ; time sharing where one individual alternates his calls with those of another close individual of the same or a different species ; and frequency separation where the calls of different species are transmitted on different frequency bands with the ears acting as filters.

The following examples, taken from Yan Yean, twenty miles north of Melbourne, illustrate how some of these mechanisms operate. In the autumn males of *Crinia victoriana* and *Pseudophryne semimarmorata* use the same

VICTORIA—AMPHIBIANS : A SPRING CHORUS AT YAN YEAN

Species	Approximate dominant frequency of mating call (Hertz)	Usual calling site
Limnodynastes dorsalis	700	Floating, supported by emergent vegetation
Limnodynastes peroni	1,000	In water, concealed at bases of flooded tussocks
Hyla aurea	1,250	Floating in open water
Limnodynastes tasmaniensis	2,000	Floating in open situations, supported by emergent grass stems
Hyla verreauxi	2,050	On banks, sometimes more than 30 ft from the water
Hyla ewingi	2,600	At water's edge, above surface in emergent or marginal vegetation, or floating supported by vegetation
Crinia signifera	2,900	On banks at water's edge

breeding sites (locations of summer-dry ponds) and may call in close proximity, with the sound energy in the mating calls of each species being concentrated around 2,500 Hertz (the dominant, carrier, or transmission frequency). Electrophysiological studies have shown that the ears of both species are maximally sensitive at this frequency. Field play-back experiments have shown that acoustic interference is minimised by a *P. semimarmorata* male alternating or placing its much shorter calls in the intervals between the longer, more complex calls of nearby *C. victoriana* males (i.e., time sharing). In the early spring, seven other species call and breed at the same site (now flooded and an extensive swamp). In this case, there is strong evidence for the operation of both spatial separation and transmission frequency differentiation as shown in the table on page 8.

Eggs and oviposition

No field information is presently available on the eggs and oviposition sites of the following species : *Crinia haswelli, Hyla citropa, H. lesueuri, H. maculata, H. phyllochroa, Neobatrachus* sp. nov., *Uperoleia marmorata,* and *U. rugosa.*

Form of egg mass and method of oviposition show little variability within those species of the Family Hylidae for which data are available, closely following the "typical" pattern. Numerous small pigmented eggs are laid in water ; there is a short embryonic development and the larva hatches at a relatively immature stage, remaining quiescent and attached to the egg capsules or aquatic vegetation for some time before actively swimming and feeding. Even so, two types of egg mass may be recognised :

Type 1. Submerged bunches of eggs enclosed in a clear jelly and attached to grass stems, reeds, and other objects (most species of *Hyla*); and

Type 2. Floating mats of eggs which later sink to the bottom (*Hyla aurea*).

In contrast to the relatively uniform hylid pattern, the species of the Family Leptodactylidae, for which information is available, show considerable variation in type of egg mass and site of oviposition. Five additional categories may be recognised :

Type 3. Foamy egg masses floating in open water or concealed by emergent vegetation (all species of *Limnodynastes*);

Type 4. Foamy egg masses concealed in a flooded burrow or nest (*Heleioporus australiacus, Philoria frosti*) ;

Type 5. Strings of eggs with clear jellies attached to submerged vegetation (*Neobatrachus pictus*) ;

Type 6. Submerged clumps of eggs or individual eggs resting on, or attached to, the substratum (*Crinia parinsignifera, C. sloanei, C. signifera, Mixophyes balbus, Neobatrachus centralis*) ; and

Type 7. Clumps of eggs laid on land, either under vegetation (*Crinia laevis, C. victoriana*) or in shallow burrows (all species of *Pseudophryne*).

Larval stages

No information is available on the tadpoles of *Hyla citropa, H. maculata,* and *H. phyllochroa.* For the remainder, four main adaptive types may be recognised :

1. *Generalised.* This is the form of the typical and familiar tadpole, and most Victorian species are of this type, occupying still-water habitats and

feeding on detritus and encrusting algal films ;
2. *Nektonic.* Deep-bodied, high-finned actively swimming tadpoles are also found in some still-water habitats and may use suspended microscopic algae (phytoplankton) as their principal food source (*Crinia haswelli, Hyla ewingi complex*) ;
3. *Mountain stream.* These are the very strongly swimming tadpoles of fast-flowing aquatic habitats ; they are characterised by flattened bodies, well-developed tail musculature, narrow fins and large suction mouths allowing attachment to the rocky substratum and maintenance of position in a current (*Hyla lesueuri, Mixophyes balbus*) ; and
4. *Direct development.* Larvae adapted for intra-capsular development are characterised by vestigial mouth parts, reduced musculature, no pigmentation, and an adequate supply of yolk to carry the embryo through to metamorphosis (*Philoria frosti*).

Modification of life history

Not all species show the typical anuran life cycle with aquatic oviposition and a free-living active larval stage. Trends towards terrestrial development within the egg capsules, or direct development through suppression of the larval stage, have occurred many times within the Anura. Presumably there are advantages in reducing predation pressure (avoidance of specialised aquatic predators), interspecific competition (tadpoles of several species may hatch at the same time and thus compete for limited food resources), and in obviating the need for free water breeding sites. But such modifications can only occur in areas of sustained high humidities since amphibians have not been able to evolve shelled eggs and the associated water impermeability characteristic of the reptiles and birds.

The fullest expression of this trend is reached when the eggs are placed in specialised pouches in the body of one of the parents and transported about under favourable microclimatic conditions until development is completed and small frogs hatch out. No Victorian species exhibits this type of life cycle but in *Crinia darlingtoni,* a rain forest species of the McPherson Range area on the Queensland-New South Wales border, the fertilised eggs are placed in lateral pouches in the male, where the larvae develop and metamorphose into small frogs.

An alternate modification is seen in the terrestrial oviposition of large, yolky eggs in nests which can be maintained at high humidities for long periods. In such cases the tadpole stage is retained within the egg mass while it develops and eventually metamorphoses. Only one Victorian species, *Philoria frosti,* has this type of life history. Large, yolky, unpigmented eggs are laid in small nests in saturated sphagnum moss ; an unpigmented tadpole with rudimentary mouth parts is formed, but it does not feed and subsists on its generous supply of yolk. The tadpole is capable of swimming, but is normally retained within the egg mass until it metamorphoses. The terrestrial oviposition and advanced stage of larval development at hatching seen in *Crinia laevis, C. victoriana,* and the three species of *Pseudophryne* may represent earlier stages in this trend.

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Reptiles

Introduction

Among the vertebrates (Sub-phylum Vertebrata), amphibians (Class AMPHIBIA) were the first to invade the land surfaces. The reptiles (Class REPTILIA) evolved from amphibian ancestors during the Carboniferous Period over 300 million years ago. Altogether sixteen Orders of reptiles are known to have existed, only four of which survive to the present day. From two of the extinct Orders evolved the so called higher vertebrates, birds (Class AVES) from the ancestors of the Order THECODONTIA, and mammals (Class MAMMALIA) from members of the Order THERAPSIDA.

Reptiles were the first completely terrestrial vertebrates and they evolved a number of adaptations to terrestrial life not found in amphibians. Most important of these was the *cleidoic egg* which is enclosed in a protective shell that prevents the free exchange of any materials other than respiratory gases; thus the egg is resistant to desiccation making it suitable for laying on land. The egg also has an abundant yolk supply so that the embryo can develop to a large size and hatch at an advanced state, eliminating the need for a larval stage. A typical vertebrate cleidoic egg soon after fertilisation consists of an embryo and a large yolk sac surrounded by an egg shell. As development proceeds three membranes form; the *chorion* which sheathes the embryo and yolk inside the egg shell; the *allantois* which is sac like, stores waste products as uric acid, and its vascular outer layer contacts the chorion and acts as a respiratory organ; and the *amnion* which encloses the developing embryo in a fluid filled space. The egg is laid in a terrestrial nest and after a period of incubation the hatchling emerges as a small version of the adult.

Reptiles, birds, and mammals all basically reproduce by cleidoic eggs although in Eutherian (placental) mammals the fertilised egg is retained in the uterus, no egg shell is laid down, and the chorion and allantois become firmly attached to the wall of the uterus, allowing exchange of materials directly from the maternal to the embryonic blood stream. This structure is the placenta, and its evolution has allowed a great reduction in the yolk content of the egg as the embryo can be nourished continuously until it is born alive and fully developed. The mode of reproduction varies in reptiles: in some species an egg shell is deposited after fertilisation and the egg is laid almost immediately ; these species are said to be " oviparous ". In others, an egg shell is deposited after fertilisation, but the egg is retained in the oviduct until the embryo has reached an advanced stage and the egg hatches soon after it is laid ; these species are said to be " ovoviviparous ". In the reproductively most advanced reptiles, no shell is deposited after fertilisation; the egg is retained in the uterus and the chorion and allantois become attached to the uterine wall allowing exchange of materials directly from the maternal to the embryonic blood stream. This structure is analagous to the mammalian placenta ; the young are born alive and fully developed ; and these species are said to be " viviparous ". Thus some reptiles and mammals do not have a typical cleidoic egg, but in all cases the amnion survives in its original form, and the reptiles, birds, and mammals are grouped as " amniotes " to indicate their affinities.

Excretion of nitrogenous waste in fish and amphibians is through ammonia (ammonotely) or urea (ureotely) ; however, both ammonia and urea are soluble in water and require a continual flow of water through the animal to maintain their concentrations below toxic levels. Thus an essential physiological adaption in the cleidoic egg was some form of insoluble, non-toxic, excretory end product. For this reason, uric acid excretion (uricotely) evolved with the cleidoic egg. Uricotely was also retained in the adult as water is not needed in the excretion of waste, and this made reptiles independent of permanent water.

The evolution of the cleidoic egg also brought the need for internal fertilisation in reptiles and associated with this was the development of a male intromittant organ, the penis, for inseminating the female. Thus reptiles did not need to return to the water for fertilisation to occur. Another reproductive advance first seen in reptiles is the evolution of the metanephric kidney in which the genital ducts are separate from the urinary ducts (ureters).

Freedom from water for reproduction and excretion gave reptiles the potential to exist away from permanent water and they evolved a heavily keratinised dry scaly skin which prevented water loss from the body. The impervious skin prevented cutaneous (skin) respiration, so that reptiles came to rely exclusively on pulmonary (lung) respiration. The need for a regular supply of air to the lungs caused the development of a true sternum from the ribs which allowed rhythmic breathing. However, the efficiency of the respiratory system in reptiles is restricted, as the pulmonary (lung) and systemic (body and visceral) blood circulations are not completely separated and mixing of oxygenated and de-oxygenated blood occurs in the partially divided ventricle of the heart which is common to both circulations. Mixing is increased by the retention of two aortic arches from the ventricle to supply the body. In mammals and birds the ventricle is completely divided and there is only a single aortic arch, thereby creating two separate circulations and preventing the mixing of oxygenated and de-oxygenated blood.

Reptiles are restricted in terrestrial environments mainly by temperature. This results from the fact that they have no true physiological control of body temperature and they must rely on environmental (external) factors for the maintenance of body temperature. For this reason reptiles are said to be ectothermic. Only birds and mammals have true physiological (internal) control of body temperature and they are said to be endothermic.

Reptiles thus show advances over amphibians in that they can reproduce on land, and they have good physiological control of osmoregulation, evaporative and excretory water loss, and ionic balance ; however, they are not as advanced as birds and mammals as they have no true physiological control of body temperature.

Ecological requirements of reptiles

Body temperature regulation is the only function for which reptiles lack internal controls. However, all species have innate (inherited) behaviour patterns which cause them to select the most favourable environmental conditions. During activity, reptiles select conditions which enable them to maintain relatively constant body temperatures. Reptiles can be divided into two groups depending on the method they use for maintaining body temperature during activity:

1. Heliotherms (basking reptiles) use the energy in solar radiation to elevate body temperature ; thus, they can remain active in low environmental temperatures if they have access to sunshine.
2. Thigmotherms (non-basking reptiles) simply select suitable temperatures in shaded situations ; thus, they are limited directly by environmental temperatures.

When environmental conditions become unfavourable (either too hot or too cold) reptiles seek out a suitable microenvironment, such as under a rock or log, and remain inactive until conditions become favourable once more. Oviparous species also need a warm, dry site for laying eggs.

Thus the major ecological requirements for reptiles are first, a suitable thermal area for activity, which must include a basking site for a heliotherm ; second, a suitable microenvironment where the reptile can remain inactive and sheltered during unfavourable conditions ; and third, a warm, dry egg nest site for oviparous species.

Zoogeographic regions in Victoria

On the basis of animal distribution patterns, it is possible to divide the Australian continent into four zoogeographic subregions, the tropical Torresian, arid Eyrean, and temperate Bassian and South-western (see page 5 for a fuller discussion). Each of these subregions has a characteristic fauna. Two of these subregions, the Eyrean and Bassian, are represented in Victoria, and the boundary between them (see map opposite page 14) falls at about the 20 inch rainfall isohyet.

Eyrean subregion

Approximately one third of the State in the north and north-west is included in this region. It is a relatively flat and arid area with poor surface drainage, especially in the sandy north-west. The vegetation varies from woodlands, tree savannah, and grasslands in the north to heath, semi-arid mallee scrub, and arid scrub in the north-west. Thus the vegetation is very open, and solar radiation penetrates to ground level easily. As daily air temperatures usually exceed 85° to 90°F. in summer, the penetration of intense solar radiation to the ground causes extremely high air to ground interface temperatures, measurements in excess of 160°F. being common. The Murray River, with its associated swamps, lagoons, and red gum woodlands, provides a more temperate corridor through this hot arid area.

Thus the major ecological requirement for an Eyrean reptile species is a microenvironment to shelter from the high surface temperatures in summer.

Bassian subregion

The remaining two thirds of the State in the east, south, and south-west are included in the Bassian subregion (see map). The Bassian area of Victoria includes the Eastern Highlands, South Gippsland Highlands, and Otway Ranges, as well as the western coastal and volcanic plains and the East and West Gippsland coastal plains. Thus topography varies greatly in the Bassian. The vegetation also varies greatly—from open coastal grasslands to dense forests, and on to alpine herbfields, swamps and grasslands. By comparison with the Eyrean, the Bassian has a cooler climate—daily summer temperatures do not usually exceed 80°F. The Bassian also has a much higher and less variable rainfall, which is distributed more or less evenly throughout the year. As a result of the higher rainfall and more varied topography, drainage patterns are well developed.

The Bassian subregion is the coldest of the four Australian zoogeographic subregions as it includes the highest latitudes and altitudes. Thus reptiles in the area are generally faced with low environmental temperatures. During activity, heliotherms can overcome this problem if they have access to sunlit areas, but thigmotherms must lower their thermal preferences. When inactive, both heliotherms and thigmotherms require a microenvironment to shelter from the low surface temperatures in winter. The three important ecological requirements for Bassian reptile species are first, prevailing environmental temperatures, second, availability of sunshine, and third, a suitable microenvironment to shelter from the low surface temperatures in winter.

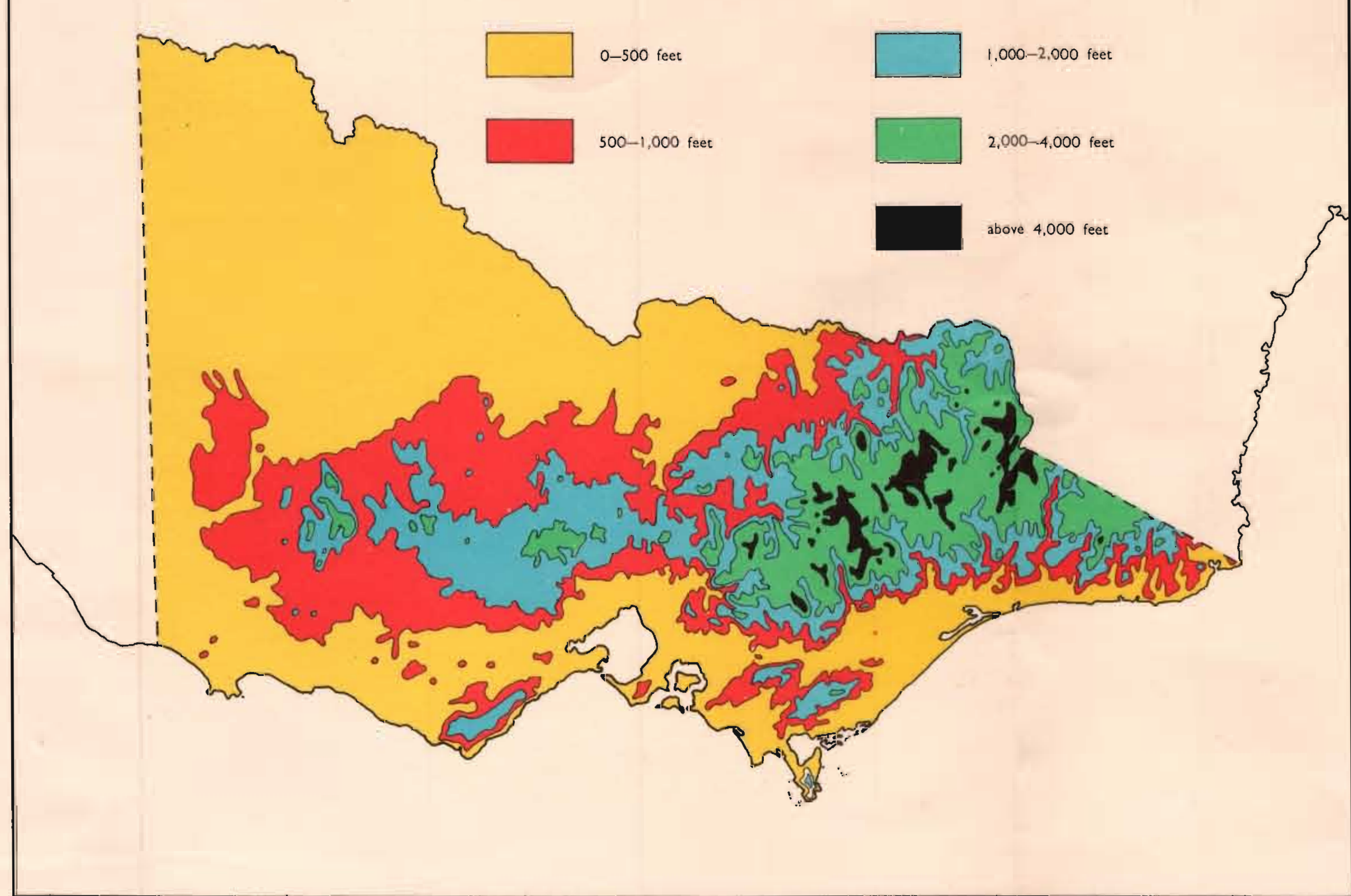
Variation of these three factors within the Bassian makes it possible to recognise three distinct thermal zones (see map) each of which has a characteristic reptile fauna. These regions are :

1. *Warm temperate zone.* The coastal plains of south-eastern Victoria, the volcanic and coastal plains of south-western Victoria, the inland margins of the Eastern Highlands and the Kilmore gap. The low elevations of these areas (less than 1,000 ft), low average annual rainfalls (less than 30 inches), and the open nature of the climax vegetation (woodlands, tree savannah, and tussock grasslands) result in high summer surface temperatures and intense solar radiation penetrates to the ground.

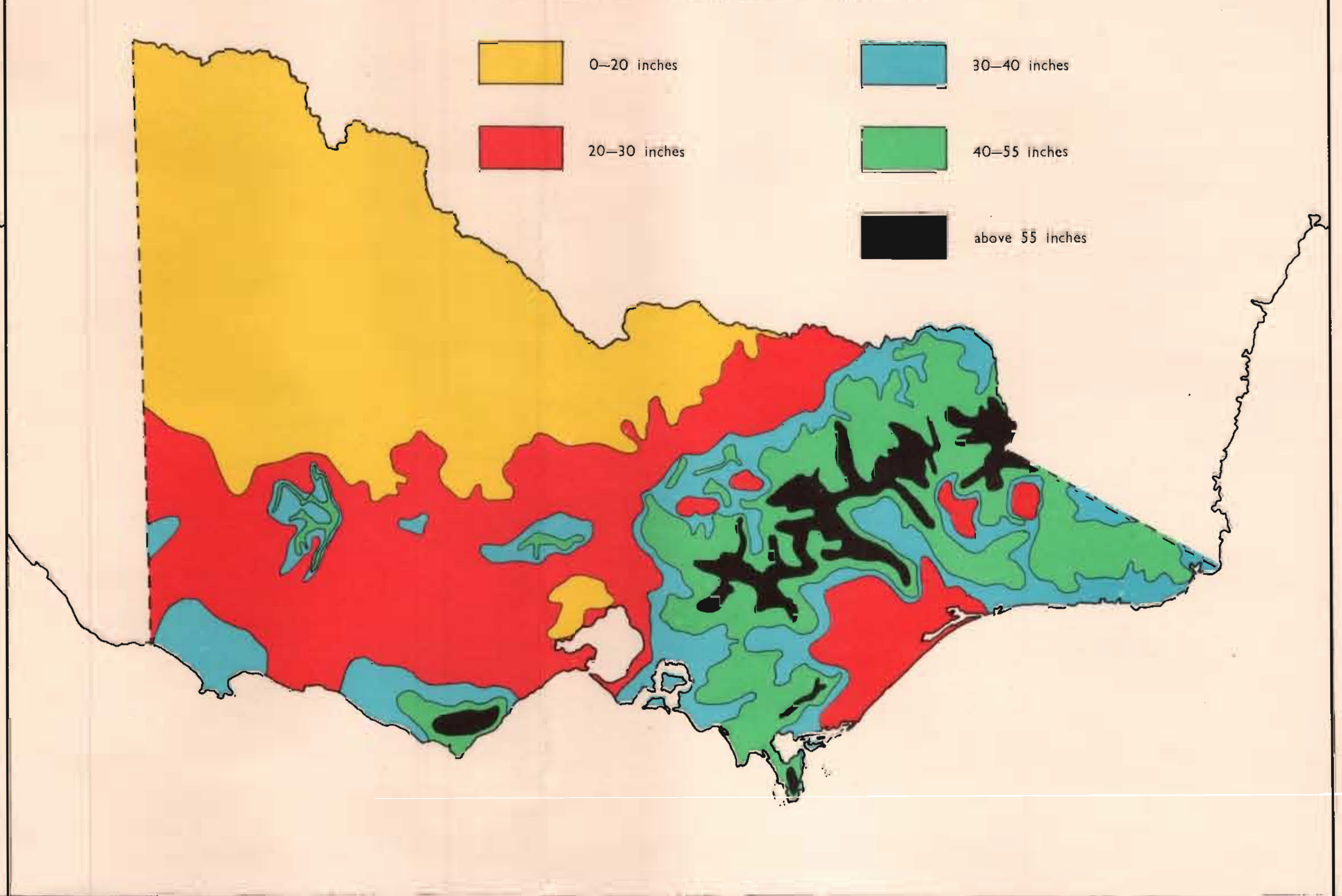
2. *Cool temperate zone.* The Eastern Highlands below 4,000 ft including the Otway Ranges and South Gippsland Highlands. In this zone the higher elevations result in lower surface temperatures and higher average annual rainfalls (more than 30 inches) than are found in the warm temperate zone. Climax vegetation varies from dry and wet sclerophyll forest to temperate rainforest, but the vegetation is always dense and prevents much of the available sunshine from penetrating to the ground. The

VICTORIA—AMPHIBIANS AND REPTILES: ENVIRONMENTAL FACTORS AND ZOOGEOGRAPHIC PATTERNS

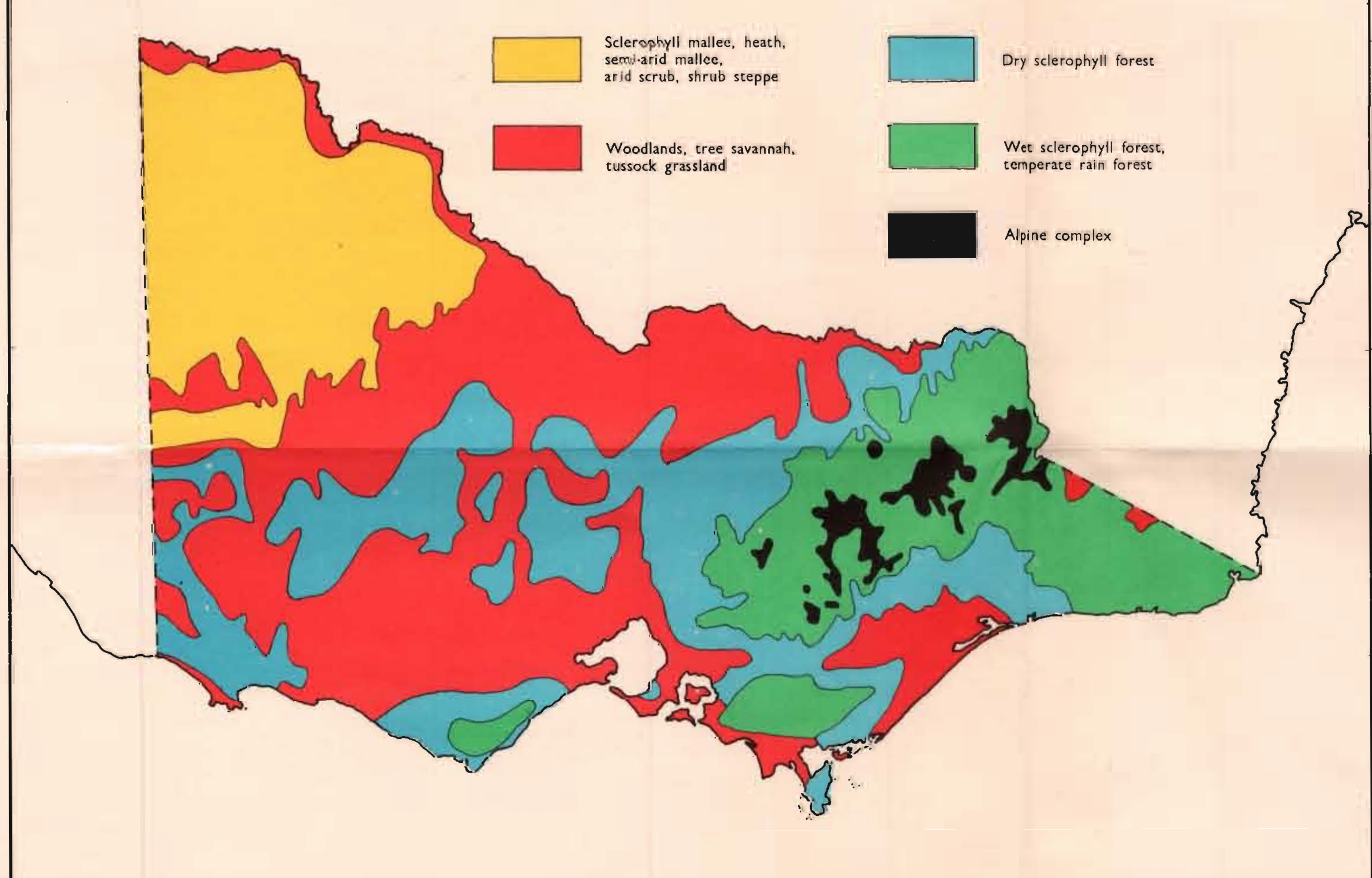
OROGRAPHIC MAP OF VICTORIA



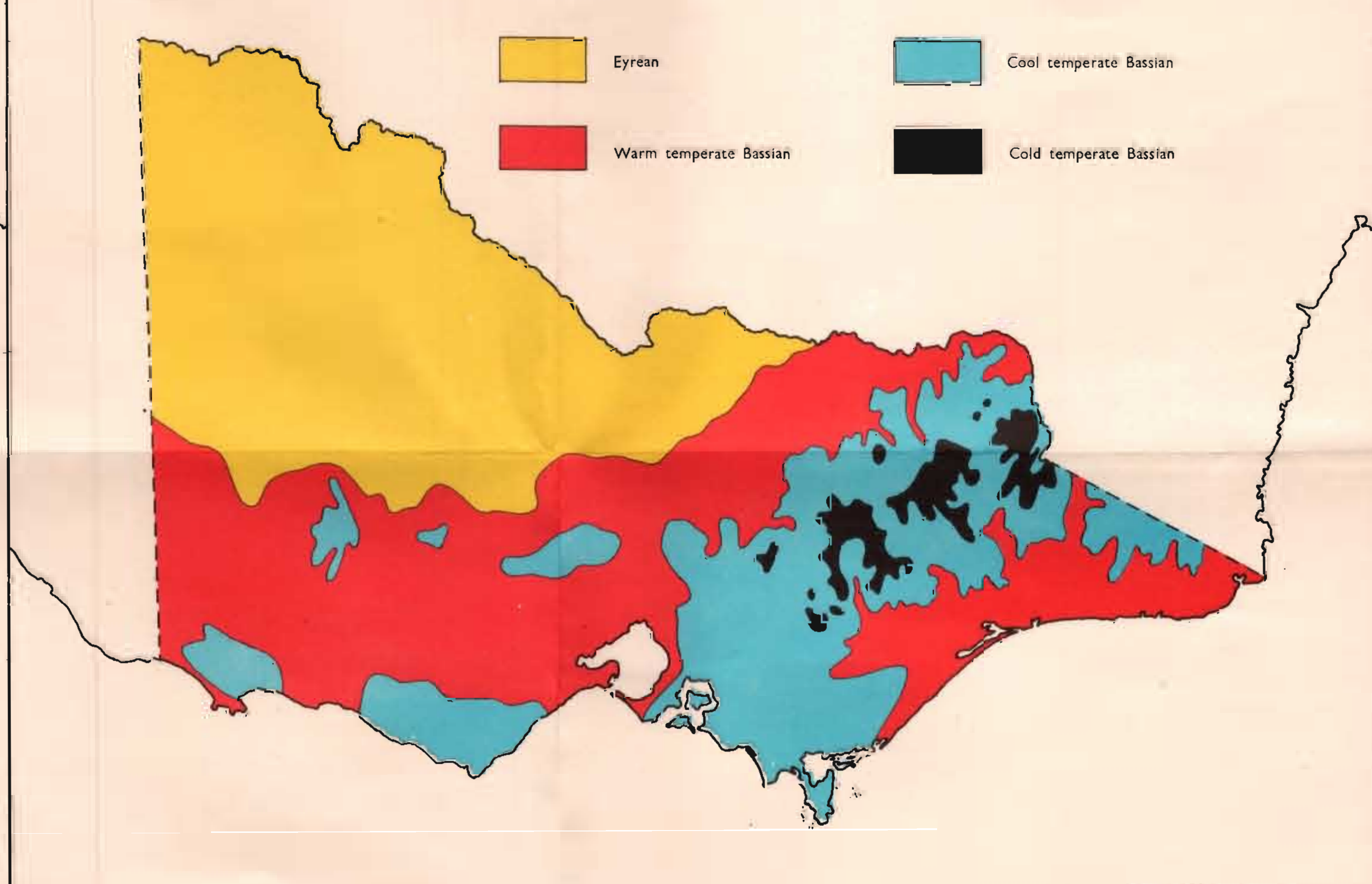
AVERAGE ANNUAL RAINFALL OF VICTORIA



MAIN VEGETATION FORMS OF VICTORIA



MAIN ZOOGEOGRAPHIC REGIONS OF VICTORIA



Map: P. A. Rawlinson

density of the vegetation and higher altitudes result in low prevailing surface temperatures even during summer.

3. *Cold temperate zone.* The alpine and sub-alpine areas above 4,000 ft in the Eastern Highlands. The high elevations result in very low environmental temperatures in summer and winter, and also produce high average annual rainfalls (more than 55 inches). Although the rainfall is suitable for the development of wet sclerophyll forests and temperate rainforest, the increasing severity of cold with increasing altitude prevents these vegetation forms from extending much above 4,500 ft. Climax vegetation varies from dense temperate rainforest and montane wet sclerophyll forest at the lower altitudes to open sub-alpine woodlands to alpine herbfields, swamps, and grasslands. Thus the high altitudes cause very low environmental temperatures, but the open nature of alpine vegetation allows intense solar radiation to reach the ground in summer, making it possible for heliotherms to be active. In winter, snow covers the ground for up to 5 months making reptile activity impossible.

Thus the major ecological requirements for Bassian reptile species are a habitat warm enough for activity which must include a basking site for a heliotherm and also a microenvironment for shelter from low winter temperatures.

Reptilian fauna

Included in the four living Orders of reptiles are more than 6,000 described species: 335 species in the Order CHELONIA (turtles and tortoises); twenty-three species in the Order CROCODILIA (crocodiles, alligators, and gavials); the Order SQUAMATA is divided into two Sub-Orders, with about 3,000 species in the Lacertilia (lizards) and about 2,700 species in the Ophidia (snakes); the fourth living Order, RHYNCOCEPHALIA, has only one species, the Tuatara, which is found in New Zealand.

More than 400 of the known living species of reptiles, representing fourteen families and three Orders, occur in Australia. The order CROCODILIA has one family; the Order CHELONIA has three families; and in the Order SQUAMATA the Lacertilia and the Ophidia have five families each.

Nine of the fourteen Australian reptile families occur in Victoria. The three marine families Cheloniidae (marine turtles), Dermochelyidae (leatherback turtles), and Hydrophiidae (sea snakes) do not normally occur, although single specimens are occasionally carried into Victorian waters where they cannot survive for long. Victoria also lacks representatives of the aquatic family Crocodylidae (crocodiles) which are found in the estuarine and fresh waters of northern Australia. The only terrestrial Australian reptile family missing from Victoria is the Colubridae (harmless and rear-fanged snakes).

Until the present time 102 taxa of reptiles (ninety-nine described species, two undescribed species, and one sub-species) representing forty-one genera and nine families have been recorded from within the borders of Victoria. All the species, genera, sub-families, and families known to occur in Victoria are listed in the table on pages 16 to 19. This table shows how the taxa are distributed in each of the main zoogeographic areas discussed above and shown on the map.

VICTORIA—DISTRIBUTION, THERMOREGULATION, AND REPRODUCTION OF REPTILE SPECIES

Species	Distribution of species					Thermoregulation and reproduction of species			
	Eyrean		Bassian			Method of thermoregulation		Mode of reproduction (*a*)	
	True Eyrean	Murray River corridor only	Warm temperate zone	Cool temperate zone	Cold temperate zone	Thigmotherm	Heliotherm	Oviparous	Viviparous
CHELONIA									
Chelyidae									
Chelodina expansa	—	+	—	—	—	+	—	+	—
C. longicollis	—	+	+	—	—	+	—	+	—
Emydura macquarrii	—	+	—	—	—	+	—	+	—
SQUAMATA									
LACERTILIA									
Agamidae									
Amphibolurus adelaidensis	+	—	—	—	—	—	+	+	—
A. barbatus	+	—	+	—	—	—	+	+	—
A. diemensis	—	—	—	+	+	—	+	+	—
A. fordi	+	—	—	—	—	—	+	+	—
A. muricatus	+	—	+	—	—	—	+	+	—
A. pictus	+	—	—	—	—	—	+	+	—
Physignathus gilberti	+	—	—	—	—	—	+	+	—
P. lesueuri	—	—	+	—	—	—	+	+	—
Tympanocryptis lineata	+	—	+	—	—	—	+	+	—
Gekkonidae									
Diplodactylinae									
Diplodactylus ciliaris	+	—	—	—	—	+	—	+	—
D. damaeus	+	—	—	—	—	+	—	+	—
D. tessellatus	+	—	—	—	—	+	—	+	—
D. vittatus	+	—	—	—	—	+	—	+	—
Phyllurus milii	+	—	—	—	—	+	—	+	—
Rhynchoedura ornata	+	—	—	—	—	+	—	+	—
Gekkoninae									
Gehyra variegata	+	—	—	—	—	+	—	+	—
Heteronotia binoei	+	—	—	—	—	+	—	+	—
Phyllodactylus marmoratus	+	—	+	—	—	+	—	+	—

Pygopodidae									
Aprasia striolata	+	−	+	−	−	+	−	+	−
Delma fraseri	+	−	−	−	−	+	−	+	−
D. impar	+	−	+	−	−	+	−	+	−
Lialis burtonis	+	−	−	−	−	+	−	+	−
Pygopus lepidopodus	+	−	−	−	−	+	−	+	−
Scincidae									
Lygosominae									
Anotis maccoyi	−	−	−	+	−	+	−	(*a*) +	−
Carlia maccooeyi	−	−	+	−	−	−	+	+	−
Cryptolepharus boutoni	+	−	−	−	−	−	+	+	−
Ctenotus brachyonyx	+	−	−	−	−	−	+	+	−
C. regius	+	−	−	−	−	−	+	+	−
C. robustus	+	−	+	−	−	−	+	+	−
C. schomburgkii	+	−	−	−	−	−	+	+	−
C. taeniolatum	−	−	+	−	−	−	+	+	−
C. uber	+	−	−	−	−	−	+	+	−
Hemiergis decresiensis	−	−	+	−	−	+	−	−	+
H. peronii	−	−	+	−	−	+	−	−	+
Leiolopisma delicata	−	−	+	+	−	+	−	+	−
L. entrecasteauxi	−	−	−	+	+	−	+	−	+
L. guichenoti	−	−	+	+	−	−	+	+	−
L. metallicum	−	−	−	+	+	−	+	−	+
L. mustelinum	−	−	+	+	−	+	−	+	−
L. trilineatum	−	−	+	+	−	−	+	+	−
L. weekesae?	−	−	−	+	+	−	+	−	+
Lerista bipes	+	−	−	−	−	+	−	−	+
L. bougainvilli	+	−	+	−	−	+	−	−	+
L. lineata	+	−	−	−	−	+	−	+	−
L. punctovittata	+	−	−	−	−	+	−	−	+
L. timidus	+	−	−	−	−	+	−	+	−
Menetia greyi	+	−	−	−	−	+	−	+	−
Morethia lineoocellatus	+	−	−	−	−	−	+	+	−
Pseudemoia spenceri	−	−	−	+	+	−	+	−	+
Sphenomorphus fasciolatus	+	−	−	−	−	+	−	−	+
S. quoyi	−	+	−	−	−	−	+	−	+
S. tympanum (cool temperate form)	−	−	−	+	+	−	+	−	+
S. tympanum (warm temperate form)	−	−	+	−	−	−	+	−	+

Species	Distribution of species					Thermoregulation and reproduction of species			
	Eyrean		Bassian			Method of thermoregulation		Mode of reproduction (*a*)	
	True Eyrean	Murray River corridor only	Warm temperate zone	Cool temperate zone	Cold temperate zone	Thigmotherm	Heliotherm	Oviparous	Viviparous
Scincinae									
Egernia cunninghami	+	—	+	—	—	—	+	—	+
E. inornata	+	—	—	—	—	—	+	—	+
E. luctuosa	—	—	+	—	—	—	+	—	+
E. saxatilis	—	—	+	+	—	—	+	—	+
E. striolata	+	—	—	—	—	—	+	—	+
E. whitei	—	—	+	+	+	—	+	—	+
Tiliqua casuarinae	—	—	+	+	+	—	+	—	+
T. nigrolutea	—	—	—	+	—	—	+	—	+
T. occipitalis	+	—	—	—	—	—	+	—	+
T. rugosa	+	—	+	—	—	—	+	—	+
T. scincoides	+	—	+	—	—	—	+	—	+
Varanidae									
Varaninae									
Varanus gouldii	+	—	—	—	—	—	+	+	—
V. varius	+	—	+	—	—	—	+	+	—
OPHIDIA									
Boidae									
Pythoninae									
Morelia argus argus	—	—	+	—	—	+	—	+	—
M. argus variegata	—	+	—	—	—	+	—	+	—
Elapidae									
Elapinae									
Acanthophis antarcticus	+	—	—	—	—	+	—	—	+
Aspidomorphus diadema	+	—	—	—	—	+	—	+	—
Brachyaspis curta	+	—	—	—	—	+	—	—	+
Demansia nuchalis	+	—	—	—	—	—	+	+	—
D. psammpohis	+	—	—	—	—	—	+	+	—
D. textilis	+	—	+	—	—	—	+	+	—

Denisonia brevicauda	+	—	—	—	—	+	—	—	+
D. coronoides	—	—	—	+	+	—	+	—	+
D. devisi	+	—	—	—	—	+	—	—	+
D. flagellum	—	—	+	—	—	+	—	—	+
D. gouldii	+	—	—	—	—	+	—	—	+
D. mastersi	+	—	—	—	—	—	+	—	+
D. nigrescens	—	—	+	—	—	+	—	—	+
D. nigrostriata	+	—	—	—	—	+	—	—	+
D. superba (highlands form)	—	—	—	+	+	—	+	—	+
D. superba (lowlands form)	—	—	—	+	—	—	+	—	+
D. suta	+	—	—	—	—	+	—	—	+
Notechis scutatus	—	+	+	+	—	—	+	—	+
Oxyuranus scutellatus	+	—	—	—	—	—	+	+	—
Pseudechis australis	+	—	—	—	—	—	+	—	+
P. porphyriacus	—	+	+	—	—	—	+	—	+
Rhynchoelaps australis	+	—	—	—	—	+	—	+	—
Vermicella annulata	+	—	—	—	—	+	—	+	—
Typhlopidae									
Typhlopinae									
Typhlops australis	+	—	—	—	—	+	—	+	—
T. bituberculatus	+	—	—	—	—	+	—	+	—
T. broomi	+	—	—	—	—	+	—	+	—
T. ligatus	+	—	—	—	—	+	—	+	—
T. nigrescens	+	—	—	—	—	+	—	+	—
T. pinguis	+	—	—	—	—	+	—	+	—
T. proximus	+	—	—	—	—	+	—	+	—
T. unguirostris	+	—	—	—	—	+	—	+	—
Totals	67	7	33	19	10	51	51	(*a*) 62	40
	74		44			102		102	

(*a*) The only known ovoviviparous species, *Anotis maccoyi*, is listed with the oviparous species.

The most striking feature of Victorian reptile distribution is the rapid decrease in the numbers of families, genera, and species in a sequence from the Eyrean to the warm, cool, and cold temperate zones of the Bassian. Seventy-four species occur in the Eyrean and all nine Victorian families are represented, although one family (Boidae) has only a single species. Thirty-three species occur in the warm temperate Bassian. These represent eight of the nine Victorian families (the Typhlopidae are absent), although four of the families (Chelyidae, Gekkonidae, Varanidae, and Boidae) are represented by only a single species and another family (Pygopodidae) is represented by only two species. Nineteen species occur in the cool temperate Bassian, and these belong to only three families (Agamidae, Scincidae, and Elapidae). The five families represented by only one or two species in the warm temperate Bassian are absent from the cool temperate. Only ten species occur in the cold temperate Bassian, all being shared with the cool temperate, and the same three families (Agamidae, Scincidae, and Elapidae) are represented.

The Victorian reptile fauna is discussed below. For the sake of brevity, the major features of the anatomy, biology, and distribution of Victorian reptiles are dealt with under the major taxonomic groupings. All taxa (orders, families, genera, species, etc.) known to occur in Victoria are listed in the table on pages 16 to 19 which shows detailed information on the major points of the discussion. It should be noted that in the section on distribution occurrence of a species in a zoogeographic area (e.g., Bassian or Eyrean) does not necessarily imply the species is characteristic of that area (i.e., a Bassian or Eyrean species).

Order CHELONIA (*tortoises and turtles*)

The stem reptiles (Order COTYLOSAURIA) inherited from their amphibian ancestors a skull with a complete covering of dermal bone perforated only by the nostrils (external nares) and eye sockets (orbits). Chelonians are the only living reptiles which have retained this type of skull, known as the *anapsid* skull. In some groups of chelonians the dermal bone has been reduced especially in the temporal region to allow more freedom for the jaw muscles ; however, the quadrate bone which articulates with the lower jaw bones (mandibles) is rigidly sutured to the other bones of the skull.

Chelonians are also unique among the living reptiles for a number of other features : the body is enclosed in a shell comprising a dorsal carapace and a ventral plastron formed by the fusion of dermal and skeletal bones and overlain by large keratinised epidermal scales ; the pectoral and pelvic girdles lie inside the rib cage ; teeth are lacking, beak like horny plates serving in their place ; the cloacal vent is a horizontal slit ; and the male possesses only a single copulatory organ (penis).

Chelonians have probably descended from aquatic or semi-aquatic ancestors and most living forms have retained this habit, although some have returned to a completely terrestrial existence. All chelonians, however, are oviparous (egg laying) and require a warm, well drained terrestrial site such as a sand bank to lay their eggs in.

Sub-Order PLEURODIRA (*side-necked tortoises*)

This group is distinguished from other chelonian groups in that its members retract their heads by bending the neck vertebrae laterally rather than vertically.

Family Chelyidae (freshwater tortoises). All Victorian chelonians belong to this family which is characterised by the possession of nasal bones in the skull, lack of two bony plates (the masoplastra) in the plastron, and the inability to shield the neck when the head and neck are retracted under the margin of the carapace. These tortoises inhabit freshwater rivers, swamps and lagoons, and are basically aquatic thigmotherms but they may emerge from the water to bask for limited periods. The limbs are well developed and provided with webbed feet for swimming and clawed toes to assist in tearing food apart, digging egg-nests and hibernation sites, and also for the occasional terrestrial journey. Tortoises are usually easy to sex as the male has a longer tail.

Three species representing two genera occur in Victoria. The largest species, the broad-shelled tortoise *Chelodina expansa*, may have a carapace exceeding 2 ft in length. This species is restricted to the Murray River corridor in the Eyrean, while its smaller relative, the long-necked tortoise *Chelodina longicollis*, occurs extensively throughout the Murray River basin and in the warm temperate Bassian in south-east and south-west Victoria, including the Grampians. *Emydura macquarrii,* the short-necked tortoise, is restricted to the warmer reaches of the Murray River and its tributaries, but ranges more widely than *C. expansa.* Tortoises are probably limited in the Bassian by low water temperatures and the lack of suitable egg-laying sites.

Order SQUAMATA (*lizards and snakes*)

This order contains 95 per cent of the described species of living reptiles. Their ancestors (Order EOSUCHIA) advanced from the stem of reptiles (Order COTYLOSAURIA) by evolving a skull in which the solid dome of dermal bone was penetrated by two temporal openings, allowing great freedom of movement for the jaw muscles. The temporal openings resulted in two arches of dermal bone and hence this kind of skull is known as the *diapsid* skull (derived from the Greek root " apse " which means arch).

In the living members of the SQUAMATA (lizards and snakes) the original diapsid condition has been modified by the loss of the lower temporal arch, and the quadrate bones of the skull which articulate with the lower jaw bones (mandibles) have become movable. These features enable even more freedom of jaw movement. All members of the SQUAMATA have teeth which may be attached to the upper margin of the jaw (*acrodont*) or the inner side of the jaw (*pleurodont*). They are also characterised by a number of other features : all have epidermal scales ; the cloacal vent is a transverse slit ; and in the male the copulatory organs are paired (hemipenes).

An important feature of members of the SQUAMATA is the development of Jacobson's organ. This vomeronasal organ first appears in amphibians and is apparently associated with the senses of " taste " and " smell " as it connects with the nasal passages and is innervated by the olfactory nerve. In most reptiles the organ is vestigial, but in the SQUAMATA it is highly developed and no longer connects with the nasal passages ; instead it opens directly into the mouth (buccal) cavity. The tongue is protruded to sample the air and substrate by direct contact, and is then applied to the lobes of Jacobson's organ in the roof of the mouth. These analyse the " tastes " and " smells " and relay the information to the brain.

Sub-Order LACERTILIA (*lizards*)

In lizards the two halves of the lower jaw (mandibles) are firmly united at the front, a feature which limits the size of the mouth opening. Most lizards possess two pairs of pentadactyl limbs ; however, the limbs may be reduced or absent in some groups, but all at least show traces of both the pectoral and pelvic limb girdles. External ear openings and movable eyelids with nictating membranes are other lizard features which may be subject to reduction or modification in more specialised groups. Further features which help to distinguish members of the Sub-Order LACERTILIA from members of the Sub-Order OPHIDIA include a skull in which the brain cavity is not enclosed anteriorally by bone; possession of a middle ear, a sternum, and a urinary bladder ; and the absence of an undivided row of enlarged ventral scales connected directly to the ribs. In addition, many groups of lizards practise caudal autotomy—the tail can be shed during moments of stress and a new tail regenerated afterwards.

Family Agamidae (dragon lizards). In dragon lizards, the skull is high and laterally compressed, the upper temporal arch is present, but the postfrontal and lacrimal bones are absent. The skull has a well developed parietal foramen (third eye aperture) and the teeth have an acrodont attachment to the jaw bones. The teeth of dragon lizards are remarkable as they show some differentiation ; the anterior teeth have become enlarged and resemble the incisor and canine teeth of mammals.

The body of dragon lizards is usually rather short and stout and it may be laterally compressed with a spinal ridge. The limbs are always well developed and most species are capable of running at high speed. All species of dragon lizards have pentadactyl limbs (i.e., bear five digits on each limb) and the digits are cylindrical and equipped with claws. Dragons are typically covered with small, pointed, rearwards directed, non-overlapping (juxtaposed) scales. In most species some of the scales are enlarged to form spines and tubercles. The tail is usually much longer than the combined length of the head and body, and tapers uniformly from its base to a fine point. In some species the tail is laterally compressed. Dragons do not practise caudal autotomy and if the tail should be broken it cannot be regenerated. The tongue of dragons is large and flat and may be brightly pigmented in some species. Hearing is well developed and the tympanum is visible in most species, although in some it is hidden below a layer of skin. The eye has not been modified or specialised ; eyelids are present ; and the pupil is round. Dragons cannot vocalise, but most species have elaborate threat displays. When challenged, they inflate the body, adopt various postures, and open the mouth widely. Femoral and preanal pores occur in many species, although these may be restricted to the male. The sexes are easy to differentiate in many species during the mating season as the males and females are differently coloured.

All dragon lizards are oviparous, the size of the clutch depending mainly on the size of the lizard. Small species may lay only three eggs while large species may lay up to sixteen eggs. Dragon lizards tolerate high body temperatures and all species are true heliotherms. During activity these lizards maintain body temperatures around 95°F. by basking in the sun.

Nine species representing three genera are found in Victoria. Seven of the species are found in the Eyrean, the commonest of which is the bearded dragon *Amphibolurus barbatus* that may exceed 20 inches in length. All of the species found in the Eyrean build subterranean tunnels for sheltering from the hot surface layer in summer. Four species occur in the warm temperate Bassian, only one of which (the tree dragon *Amphibolurus muricatus*) has its centre of distribution in this zone, another two (*A. barbatus* and the earless dragon *Tympanocryptis lineata*) intrude in from the Eyrean, while the fourth, the water dragon *Physignathus lesueuri,* is found only in the rivers and streams of the south-east. The latter species is semi-aquatic and grows to 3 ft in length, making it Victoria's largest dragon lizard. Only one species, the mountain dragon *Amphibolurus diemensis,* occurs in the cool and cold temperate zones; it burrows under logs or rocks to shelter from the winter cold.

Family Gekkonidae (gekkos). In gekkos the skull is short and flat; the upper temporal bone arch is missing; the post-orbital and lacrimal bones are absent; and the jugal bone is very reduced. The skull also lacks a parietal foramen (third eye aperture) and the teeth have a pleurodont attachment to the jaw bone.

Gekkos usually have a stout rather flat body and the limbs are always relatively well developed. The digits (fingers and toes) vary greatly from species to species; they may be long, slender and clawed, or expanded with adhesive pads, and are often used as an aid in identification. The only limb degeneration known is that some species lack the fifth digits and others lack claws. Gekkos do not have the typical scaly reptilian look as the skin is thin and loose, and the scales are very small and granular and do not overlap. In many species some of the scales are enlarged and modified to form spines and tubercles. Like their digits, gekko tails vary greatly from species to species: they may be long and tapered, flattened and leaf-like, or short and stubby. All species practise caudal autotomy and the regenerated tail always differs in appearance from the original. Gekkos resemble most other lizards in possessing a large flat tongue. The eyes are large and bulbous, and equipped with a pupil that can fill the whole eye in the dark or contract to a narrow vertical slit in the light. Some primitive gekkos (not represented in Australia) have eyelids, but in all others the eyelids have evolved to form a clear spectacle that covers, and is fused to, the surface of the eye. In the absence of eyelids gekkos use their tongues to lick the eye surface clean. In gekkos the ear is well developed and the tympanum is obvious; this feature is apparently associated with the fact that gekkos can vocalise—they make sounds such as clicks, hisses, barks, and chirps which may be specific to the species and are probably territorial in nature.

Gekkos are remarkably uniform in their mode of reproduction. Primitively they are oviparous and lay two eggs, and the only exceptions are the New Zealand gekkos which are viviparous, and some Central and South American species which lay only one egg. Gekkos do not tolerate high temperatures and all except the New Zealand species are true thigmotherms. Their thigmothermic habits restrict surface movements to the night and gekkos are commonly stated to be nocturnal, but they may be very active during the day under shelter.

Four sub-families of gekkos are currently recognised on the basis of a combination of features. Only two of these sub-families occur in Victoria and these are listed below with the main characteristics that separate them from each other.

Sub-family Diplodactylinae. In the skull, the premaxilla forms from two centres of ossification and may be paired in the adult, and the frontal bone is always single. There are always more than twenty-one scleral ossicles around the eye, and post-cranial calcified endolymphatic sacs are absent.

Six species representing three genera are found in Victoria, all of which are restricted to the Eyrean. The genus *Diplodactylus,* with four species, has been the most successful. They are ground-dwelling forms and lack large adhesive pads on the digits ; during the day they exploit a variety of microenvironments such as in porcupine grass, in spider burrows or under rocks.

Sub-family Gekkoninae. The premaxilla forms from one centre of ossification and is never paired in the adult ; and the frontal bone is sometimes divided. There are always less than seventeen scleral ossicles around the eye, and post-cranial calcified endolymphatic sacs are always present.

Three species representing three genera are found in Victoria, two of which are restricted to the Eyrean but the third, the marbled gekko, *Phyllodactylus marmoratus*, extends from the Eyrean into the warm temperate Bassian, through the Kilmore gap. Two of the species, the tree dtella *Gehyra variegata* and marbled gekko *P. marmoratus,* have large adhesive toe pads and can exploit vertical microenvironments such as under the bark on trees and in rock crevices, but the third species, the prickly gekko *Heteronotia binoei*, is a ground dwelling species and exploits microenvironments similar to those described above for the sub-family Diplodactylinae. Gekkos are probably restricted in the Bassian by their thigmothermic habits and oviparous mode of reproduction.

Family Pygopodidae (legless lizards). These lizards are closely allied to the gekkos and the skull is similar in that the upper temporal bone arch is missing ; the post-orbital and lacrimal bones are absent ; and the jugal bone is very reduced. The skull lacks a parietal foramen (third eye aperture) and the teeth have a pleurodont attachment to the jaw bone.

Legless lizards have a very elongate snake-like body with no external trace of the forelimbs and only a small pair of scaly flaps in front of the cloaca remain as external evidence of the hind limbs. Thus in body form legless lizards do not resemble their gekkonid relatives and the external dissimilarity is heightened by the fact that legless lizards are covered by a thick skin which is folded into overlapping (imbricate) scales. All legless lizards have very elongate tapering tails which, if unbroken are longer than the combined length of the head and body. All species practise caudal autotomy. The tongue is large and flat as in most other lizards. The eyes resemble those of gekkos closely in that they are equipped with a pupil that fills the whole eye in the dark and contracts to a narrow vertical slit in the light; they lack eyelids, the eye being covered with a clear spectacle; and the tongue is used to lick the eye surface clean. In all legless lizards except the burrowing forms, the ear is well developed and the external ear opening obvious. Like the gekkos, these lizards can vocalise, they make similar sounds to gekkos and the function of the calls is probably identical.

All legless lizards are oviparous, but there is not sufficient knowledge at the present time to generalise about clutch size. Legless lizards also resemble gekkos in their habits as all species are true thigmotherms. Although they are commonly stated to be nocturnal, many species are very active in shaded areas during the day and the earlier generalisation should be discarded.

Five species representing four genera are found in Victoria. All occur in the Eyrean, but only two, the worm lizard *Aprasia striolata* and spinifex lizard *Delma impar*, occur in the Bassian where they are restricted to the warm temperate. One of the species, the worm lizard *A. striolata*, is a true burrowing form and leads a subterranean existence. The other four species utilise subterranean microenvironments for shelter, but feed above the soil surface. Like the gekkos, legless lizards are probably restricted in the Bassian by their thigmothermic habits and oviparous mode of reproduction.

Family Scincidae (skinks). The skinks are the most successful group of reptiles in Victoria, especially in the Bassian. The skull is generally high, long and slender; the upper temporal arch is present; but the temporal opening is reduced to a slit by backward expansion of the postfrontal. The skull has a well developed parietal foramen (third eye aperture); it lacks the lacrimal bone; and some of the other skull bones, such as the supratemporals and postorbitals, may be very reduced or absent. The teeth have a pleurodont attachment to the skull. Typically, skinks are covered with polished overlapping (imbricate) scales which form large symmetrical shields on the head. Skinks practise caudal autotomy, and the regenerated tail usually differs in appearance from the original. The tongue of skinks is large and flat.

Four sub-families of skinks are currently recognised on the basis of the structure of the bony palate and the penetration of the nostril. Two of these sub-families occur in Australia and Victoria, and these are listed below with the main characteristics that separate them from each other.

Sub-family Lygosominae (skinks). The palatine bones contact on the median line of the palate; the pterygoid bones contact anteriorly; and the palatal notch does not extend anteriorly to the level of the centres of the eyes.

Lygosomid skinks have elongate streamline bodies and long tails which taper uniformly to a fine point. Limb structure is extremely variable; surface dwelling forms have well developed pentadactyl limbs; while in the burrowing groups there is a complete range of forms from the pentadactyl to species lacking limbs entirely. In all cases, however, there are at least remnants of the pectoral and pelvic girdles. Typically the digits of skinks are cylindrical and equipped with claws. Lygosomid skinks practise caudal autotomy; in fact some species seem very ready to shed their tails, and it is difficult to find an adult with a complete, unregenerated tail. In surface dwelling forms the external ear opening is obvious and hearing is probably a well developed sense; however, in the burrowing forms, the ear opening is covered with skin and hearing is presumably not as important. The eye is another organ that is extremely variable in lygosomid skinks. Primitively, the eye is provided with scaly eyelids and this structure is still seen in many species, e.g., *Ctenotus* and *Sphenomorphus* species. Some specialised species, e.g., *Leiolopisma* species, evolved a small transparent " window " in the lower eyelid which enabled them to see with the eyelids shut. This feature evolved further in some groups until the transparent " window " filled the lower eyelid, thus providing a complete spectacle for the eye, e.g., *Pseudemoia spenceri.* The final stage in the evolutionary sequence has been for the lower lid to become immovable and fused to the surface of the eye, and the upper lid has been completely lost, e.g., in the *Cryptoblepharus, Menetia,* and *Morethia* species. Lygosomid skinks completely lack the ability to vocalise. Threat displays are simple and usually only involve a lateral lashing of the tail which may be followed by a forward lunge with the mouth open. The sexes are usually hard to distinguish as males and females are similar in appearance.

The mode of reproduction is another feature of lygosomid skinks which is highly variable. Some species are oviparous, others are ovoviviparous, and many are truly viviparous; in fact the most advanced reptilian placentae known occur in species belonging to this sub-family (*Leiolopisma entrecasteauxi* and *Pseudemoia spenceri*). It is even impossible to generalise about the mode of reproduction at the generic level as one genus, *Leiolopisma,* exhibits several stages; *L. delicata* is oviparous, and *L. entrecasteauxi* is viviparous and has the most advanced type of reptilian placenta. The number of young produced varies from one to ten.

Most lygosomid skinks will not tolerate high body temperatures, and the sub-family probably descended from a thigmothermic group as all members voluntarily allow wide variations in body temperature. Many of the present day species are thigmotherms, although there are heliothermic species in many genera. During activity the thigmothermic species maintain mean body temperatures from 70° to 85°F., while the heliothermic species maintain mean body temperatures from 85° to 90°F. by basking in the sun.

Thirty species of lygosomid skinks representing eleven genera are known to occur in Victoria. Fourteen species from six of these genera are found in the true Eyrean. The least heat tolerant forms are burrowing thigmotherms and this group includes the five *Lerista* species, *Menetia greyi,* and the nocturnal skink, *Sphenomorphus fasciolatus.* Thus the genus *Lerista* is well represented, and its species are a variable group. All have very elongate bodies, but they differ in limb and eye structure ; *L. bougainvilli* has short pentadactyl limbs ; *L. punctovittata* has only rudimentary limbs with one finger and two toes ; and *L. bipes* has only rudimentary hindlimbs with two toes. The above three species possess eyelids, but the remaining two species, the two fingered, three toed *L. lineata*, and three fingered, three toed *L. timidus*, both lack eyelids completely. The more heat tolerant forms in the Eyrean are heliotherms and they exploit a variety of microenvironments to avoid the summer surface heat. *Cryptoblepharus boutoni*, a small, flat, strong limbed species lives on trees and rocky outcrops, utilising the natural cracks and crevices in the vertical surfaces for shelter. The elongate strong limbed, pentadactyl, striped skinks belonging to the genus *Ctenotus* and the snake eyed skink *Morethia lineoocellatus* all burrow in loose sandy soil to escape the heat. One heliothermic species, the semi-aquatic northern water skink *Sphenomorphus quoyi* will not tolerate high body temperatures and is restricted to the Murray River corridor.

Seventeen species representing eight genera are found in the Bassian. Two of these species, the burrowing thigmotherm *Lerista bougainvilli* and heliotherm *Ctenotus robustus,* also occur in the *Eyrean* and are restricted to the warm temperate zone. Another five species, including the two elongate weak limbed *Hemiergis* species, and the heliothermic four fingered skink *Carlia maccooeyi,* eastern water skink *Sphenomorphus tympanum* (warm temperate form) and coppertail skink *Ctenotus taeniolatum,* are found only in the warm temperate zone.

The remaining four species found in the warm temperate are shared with the cool temperate ; these are all *Leiolopisma* species, of which two, *L. delicata* and *L. mustelinum,* are thigmotherms and two, *L. guichenoti* and *L. trilineatum,* are heliotherms. These four species reproduce by oviparous means and all are restricted to open habitats where there is an abundance of ground cover, such as in heathlands, woodlands, or forest clearings. *Anotis maccoyi,* a small, elongate lizard with reduced pentadactyl limbs, is the only species restricted to the cool temperate zone. It is an ovoviviparous thigmotherm which lives in the litter layer of wet sclerophyll forests, and it maintains a low mean body temperature of about 70°F. during activity. Only five species occur in the cold temperate zone and all are shared with the cool temperate. All these species are viviparous heliotherms and they maintain mean body temperatures of 85° to 90°F. during activity by basking. Thus they are restricted to open habitats such as in forest clearings, along watercourses, in rocky or burnt areas, or in alpine woodlands and grasslands. Four of the species are ground dwelling forms, one of which (the southern water skink *Sphenomorphus tympanum,* cool temperate form) is largely restricted to watercourses. The fifth species, *Pseudemoia spenceri,* a small, flat, strong limbed skink, is a tree and rock dwelling form, and exploits the natural cracks and crevices in the vertical surfaces for basking sites and shelter. In appearance and habits *P. spenceri* strongly resembles the Eyrean skink *Cryptoblepharus boutoni,* and is often abundant on large dead eucalypt trees, especially in regenerating burnt forests.

Sub-family Scincinae (rock skinks and bluetongue lizards). The palatine bones are separated on the median line of the palate ; the pterygoid bones are widely separated ; and the nostril pierces the nasal or two adjacent plates, but never touches the rostral.

In Australia this sub-family is represented by two genera, *Egernia* and *Tiliqua*, which include the largest species of skinks. Scincinid lizards belonging to the genus *Egernia* (rock skinks) have a uniform row of fine cylindrical recurved teeth. Their bodies are stout with well developed pentadactyl limbs and relatively short tails (never much longer than the head and body combined) that are broad and flat at the base and taper to a point. The scales are keeled, but in some species (e.g., *E. whitei*) the keels are not obvious, while in others (e.g., *E. cunninghami*) they form well developed spines. The bluetongue lizards belonging to the genus *Tiliqua* have conical teeth which are enlarged in the centre of the jaw. They have elongate thickset bodies with poorly developed pentadactyl limbs. The tails are short (never as long as the combined length of the head and body), flattened at the base, and usually taper to a point, but in one species, the shingleback or stumpy tail lizard *T. rugosa* the tail has been reduced to a rounded stump. The scales are smooth in all species except *T. rugosa* where they are enlarged and rough, so the skin has the texture of a pine cone.

All species of scincinid lizards are pentadactyl and the digits are cylindrical and equipped with claws. Scincinid lizards are capable of caudal autotomy, but most species, especially those with short tails, seem loath to carry out this practice. The ear opening is always obvious in scincinid lizards, and the eyes are always provided with eyelids. Threat displays in *Egernia* species may only involve a lateral lashing of the tail followed by an attempt to bite. In *Tiliqua* species, however, threats usually involve inflating the body cavity with air, side-on posturing with the mouth held wide open exposing the blue pigmented tongue, and violent hissing.

Unlike the lygosomid skinks, scincinids have a uniform mode of reproduction : they are all viviparous. The number of young produced ranges from one to sixteen, but is usually about five.

The scincinid lizards tolerate high body temperatures ; all species are heliothermic ; and they have apparently descended from a heliothermic group as they will not voluntarily allow wide variations in body temperature. During activity the species maintain mean body temperatures from 91° to 95°F. by basking in the sun.

Seven species of skinks belonging to the genus *Egernia* are known to occur in Victoria. Three species are found in the Eyrean. To avoid the surface heat, one species, *E. inornata,* constructs a burrow ; the second species, *E. striolata*, is a tree and rock dwelling form ; while the third species, *E. cunninghami*, which intrudes from the Bassian, is found only on the larger rocky outcrops and these latter two species use the natural cracks and crevices in their respective habitats for shelter. Four species are found in the warm temperate Bassian. One, the rock dwelling *E. cunninghami*, which also occurs in the Eyrean, is restricted to the warm temperate in the Bassian. A second species, *E. luctuosa*, is known only from five swampy localities in the warm temperate, where it constructs burrows. The two remaining warm temperate species, the black rock skink *E. saxatilis* and White's skink *E. whitei,* also occur in the cool temperate and both utilise rocky outcrops and fallen logs for basking sites, and in this way manage to penetrate the forests. *E. whitei* also occurs in the cold temperate zone where it is limited to the open habitats in the lower woodlands.

Five species of skinks belonging to the genus *Tiliqua* occur in Victoria, and all are ground dwelling forms. Three species occur in the Eyrean and one, the western bluetongue *T. occipitalis,* is restricted to this zone, but the other two species, the shingleback lizard *T. rugosa* and common bluetongue *T. scincoides,* also occur in the Bassian where they are restricted to the warm temperate zone. The latter species (*T. scincoides*) may reach 2 ft in length and is Victoria's largest skink. The three species of *Tiliqua* mentioned so far occupy relatively superficial microenvironments under the surface litter or rocks during their winter hibernation. The two remaining Victorian species occupy open habitats, but utilise deep microenvironments and this could help explain their success in the cool and cold temperate zones. The oak skink *T. casuarinae* is found in the warm, cool and cold temperate zones of eastern Victoria and is rather rare. The southern bluetongue *T. nigrolutea* is restricted to the cool temperate zone where it is common.

Family Varanidae (goannas or monitor lizards). The skull is slender with a very long snout ; the upper temporal arch is present ; the posterior region of the external nares (nostrils) are broadly open and contact the frontals ; the nasal bones are fused and very elongate, forming part of the internariel bar ; the parietal foramen is present ; and the orbit (eye socket) is open as the jugal does not contact the postorbital bone. The teeth have a pleurodont attachment to the jaw and they are long and curved, with the sharp points directed to the rear.

In goannas, the slender head attaches to an elongate neck that is covered by loose, folded skin. In the throat (gular) region this loose skin can be inflated with air. The body is slender and rather flattened, and the limbs are always well developed, most species being capable of running and climbing at high speeds. All goannas have pentadactyl limbs ; the digits are cylindrical and equipped with long claws. Goannas have a tough, leathery, loosely folded skin which is typically covered by small non-overlapping (juxtaposed) scales. The whip-like tail is longer than the combined length of the head and body, and it tapers uniformly from a thick muscular base to a point. In many species the tail is laterally compressed. Goannas do not practise caudal autotomy, and if the tail should be broken, it cannot be regenerated. The tongue of a goanna, like that of a snake, is long and thin with a deep anterior split that makes it bifurcate (forked). When not in use the tongue retracts into a basal sheath. Hearing is well developed, and the tympanum is visible externally. The eye has not been modified or specialised ; eyelids are present ; and the pupil is round. Threat displays involve inflating the body with air, especially in the throat (gular) region, posturing, violent tail lashing, and hissing. Where the threat fails goannas will resort to savage clawing and biting. The sexes are not easy to differentiate.

Goannas are uniform in their mode of reproduction ; all are oviparous ; and they lay up to thirty elongate soft shelled eggs, although the exact number varies with the size of the individual and the species. Goannas tolerate very high body temperatures, and all are heliothermic. During activity they maintain mean body temperatures of about 100°F.

Only two species of goannas occur in Victoria, and both belong to the genus *Varanus*. The sand goanna *V. gouldii* is restricted to the Eyrean, where it constructs a tunnel in sandy soil to escape the summer heat. The second species, the lace lizard *V. varius*, uses hollows in standing and fallen trees for shelter, and it occurs in both the Eyrean and warm temperate Bassian. This latter species is Victoria's largest lizard ; specimens measuring more than 7 ft 6 inches still occur in remote areas of east Gippsland.

Sub-Order OPHIDIA (*snakes*)

The two halves of the lower jaw (mandibles) are loosely united in front by a ligament, and the bones of the upper and lower jaws are not solidly fused. In the skull, the upper temporal arch is missing, leaving the quadrate bone (which articulates to the lower jaw) loosely connected to the braincase ; anteriorly the brain cavity is enclosed by the frontal and parietal bones ; the maxillary and palatal bones (palatines, ectopterygoids, and pterygoids) are only loosely attached to the skull proper ; the bones of the nasal region have some freedom from the posterior part of the skull ; the lacrimal, postfrontal, squamosal, jugal, and quadrato-jugal bones are absent ; and the rod-like stapes terminates at the quadrate bone. Thus the skull has been reduced and is highly flexible ; all of the above modifications help the snake to greatly distend its mouth and swallow its prey whole. In the skull the parietal foramen (third eye aperture) is always absent. The teeth have an acrodont attachment to the jaw, and they are long and recurved, terminating in a sharp rearwards directed point. Teeth are present primitively on the pre-maxillary, maxillary, dentary, palatine, and pterygoid bones.

Snakes have very elongate bodies, a consequence of extension of the vertebral column by an increase in the number of vertebrae, which range from 140 to 435. Limbs and pectoral girdles are absent from all species and remnants of the pelvic girdle are found in only two families, the Typhlopidae and Boidae. External ear openings and the middle ear are other structures missing in all snakes, and as a consequence snakes are probably only able to pick up vibrations transmitted through the ground. Eyelids are also missing in all species of snakes. Further features which help to distinguish members of the sub-order OPHIDIA from the sub-order LACERTILIA include the lack of a eustachian tube, a sternum, and a urinary bladder. In all snakes, except members of the Typhlopidae, there is an undivided row of enlarged ventral scales used for locomotion, each scale being connected directly to a pair of ribs by ligaments and to the backbone by skeletal muscle. Elongation of the body has caused a change in the shape and symmetry of the internal organs (viscera), they have elongated and come to lie in a longitudinal series rather than next to one another. In the case of the paired organs (lungs, kidneys, gonads, etc.), the right organ lies anterior to the left partner and sometimes the function of the left organ is reduced; for example, in primitive snakes the left lung is small, but in advanced groups it is absent altogether. In snakes the tail is relatively short, always less than half the combined length of the head and body. Snakes do not practise caudal autotomy, and the tail cannot be regenerated if it is broken. The tongue (like that of goannas) is long, thin and bifurcate (forked). While the snake is active, the tongue is constantly projected through a small notch in the front of the upper lip. It flickers over the substrate and through the air, then is retracted into the mouth where the ends are inserted into the two lobes of Jacobson's organ. In this way information about the "tastes" and "smells" of the environment are conveyed to the brain, and these combined senses are well developed in snakes. Snakes are always covered by a thick skin with shiny, overlapping (imbricate) scales.

Family Boidae (boa constrictors, pythons, and anacondas). In boids the skull is not highly modified; the pterygoid extends to the quadrate bone; the prefrontals are sutured to the nasals; the nasals and related elements (premaxillae, septo-maxillae, and vomers) are flexibly movable on the braincase; large supratemporals are present; the quadrate bone is not inclined backward or enlarged dorsally; the stapes are long and contact the quadrates; the elongate maxilla contacts the premaxilla and also broadly contacts the palatine and ectopterygoid bones; and the teeth are long, strongly recurved, and solid.

Sub-family Pythoninae (pythons). This sub-family is recognised mainly on skull characters; a supraorbital is present; the internal process of the palatine is long; the prefrontals are not in contact; and there are teeth on the premaxillary, maxillary, palatine, pterygoid, and dentary bones.

Pythons feed on large active vertebrates (mainly birds and mammals) but have no venom with which to subdue and kill their prey. For this reason they constrict their prey after capture by throwing several tight body coils around the victim and holding it this way until it suffocates and can be swallowed. In pythons the posterior margin of the head is flattened causing it to stand out from the neck. The body is thickset, very muscular, and rounded in outline. There are vestiges of the pelvic girdle and hind limbs, the latter being visible externally as small claw-like spurs on either side of the cloacal vent. The spurs are longer in the males, and they are used in courtship. During courtship the male vibrates his spurs on the female's body, this apparently stimulates her and helps her to locate the cloacal region of the male so copulation can occur. Pythons have very short, muscular, and prehensile tails. The head shields are small and often asymetrical; there are many scales round mid-body (these range from 35 to 65); and the ventral body scales are narrow, never more than half the body width. Pythons are rarely active in sunshine and the eye is adapted to shaded habitats; the pupil fills the eye in the dark, but narrows to a vertical slit in the light. Many species of pythons (e.g., *Morelia argus argus* and *M. argus variegata*) have heat (infra-red) sensitive pits on the lips which help them detect "warm blooded" prey (i.e., endothermic mammals and birds) in the dark. The left lung is well developed, though smaller than the right lung. Apart from biting, pythons lack threat displays.

All the Australian pythons are oviparous; they lay from 15 to 100 large, elongate, soft shelled eggs; and in several species the female is known to actively assist the incubation of the eggs. Some overseas species are ovoviviparous. Pythons are thigmotherms and most appear to be nocturnal in their habits. After feeding, many species have limited periods of basking in the early morning and late afternoon, apparently to facilitate rapid digestion.

Only two pythons occur in Victoria; both belong to the same genus and species, but they are subspecifically distinct. The carpet python, *Morelia argus variegata*, is found mainly in the red gum woodlands and rocky cliffs of the Eyrean Murray River corridor. The diamond python, *M. argus argus*, is a coastal species, and is known only from the warm temperate Bassian coastal woodlands in the extreme east of Victoria. Pythons are probably limited in the Bassian by their thigmothermic habits and oviparous mode of reproduction.

Family Elapidae (front-fanged venomous snakes). In the absence of the world's other major terrestrial family of venomous front-fanged snakes (the family Viperidae, represented in other continents by the vipers, pit vipers, and rattlesnakes), the elapid snakes have radiated into almost every habitat in Australia. The Elapidae are also represented in other continents by such forms as the cobras, coral snakes, mambas and kraits, but they are most numerous in Australia where there are over sixty species including all the dangerous terrestrial snakes.

The skull has been reduced and highly modified to make it more flexible, increase the jaw gape and provide a biting apparatus. In the skull, the pterygoid reaches the quadrate; the prefrontals and nasals are widely separated; elements of the nasal region articulate freely with the anterior end of the braincase; supratemporals are present and moveable; the quadrate is elongate, enlarged dorsally, and slants strongly backwards, increasing the jaw gape; the stapes are long and reach the quadrates; the parietal and frontal do not meet below the orbit; the maxilla articulates movably with the prefrontal; the pterygo-palatine bar is free of the braincase; and the maxilla is flexibly connected to it via the ectopterygoid which extends posteriorly to the pterygoid.

The elapid snakes have a characteristic dentition and arrangement of the maxillary and palatal bones. The premaxilla is small and toothless, but teeth are well developed on the maxilla, palatine, pterygoid, and dentary. The maxilla is flat, short and wide, and deeply eroded on the inner margin. Each maxilla bears one or two large, permanently erect, poison fangs with a deeply grooved or enclosed poison channel opening just behind the tip of the fang. Behind each fang lie several developing replacement fangs, and there is a short row of small solid teeth on the posterior end of the maxilla.

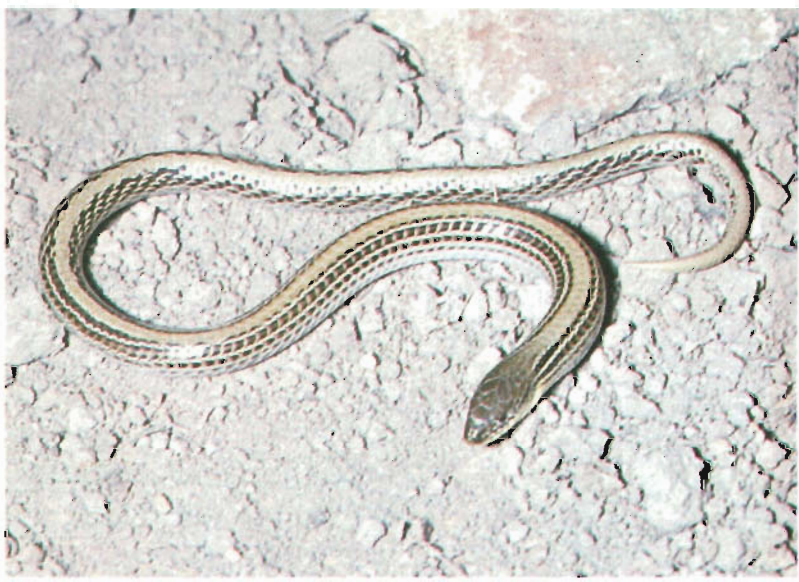
Sub-family Elapinae (front-fanged venomous snakes). The members of this sub-family are characterised by a short maxillary bone and a uniform row of teeth on the dentary bone in the lower jaw (mandible). Elapid snakes feed mainly on vertebrates (frogs, lizards, birds, and small mammals) and they have evolved a potent venom to subdue and kill their prey. An injecting apparatus has evolved in association with the venom.

Limnodynastes dorsalis (Leptodactylidae)
J. A. Owen

Amphibians and Reptiles

Tiliqua rugosa (Scincidae : Scincinae)
E. R. Rotherham

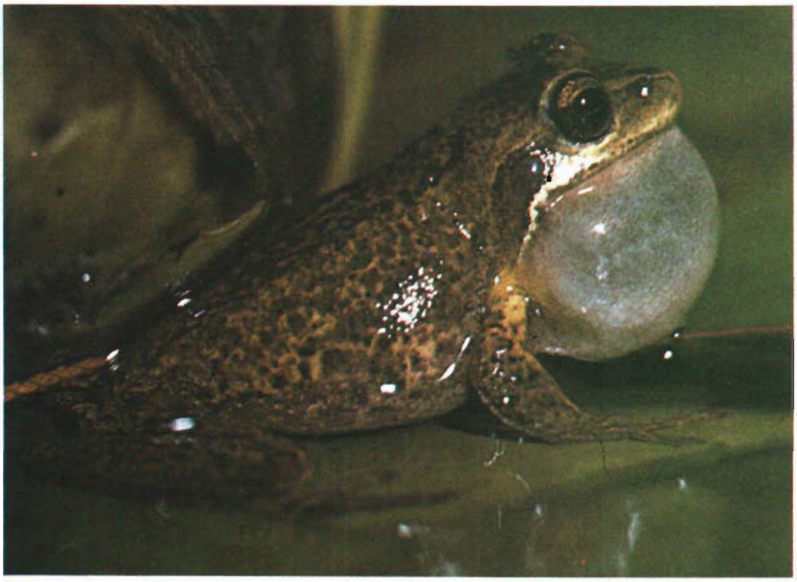
Typhlops australis (Typhlopidae)
E. R. Rotherham



Delma impar (Pygopodidae)
J. A. Owen

Morelia argus variegata
(Boidae : Pythoninae)
E. R. Rotherham

Hyla phyllochroa (Hylidae)
G. C. Adams



Hyla ewingi (Hylidae)
J. A. Owen

Philoria frosti (Leptodactylidae)
M. J. Littlejohn

Physignathus lesueuri (Agamidae)
J. A. Owen

Leiolopisma mustelinum
(Scincidae : Lygosominae)
E. R. Rotherham

Sphenomorphus tympanum
(Scincidae : Lygosominae)
J. A. Owen

Varanus gouldii (Varanidae)
P. A. Rawlinson

Uperoleia marmorata (Leptodactylidae)
M. J. Littlejohn

Heleioporus australiacus (Leptodactylidae)
A. A. Martin

Neobatrachus centralis (Leptodactylidae)
M. J. Littlejohn

Phyllodactylus marmoratus (Gekkonidae)
E. R. Rotherham

Vermicella annulata (Elapidae)
E. R. Rotherham

Chelodina longicollis (Chelyidae)
J. A. Owen

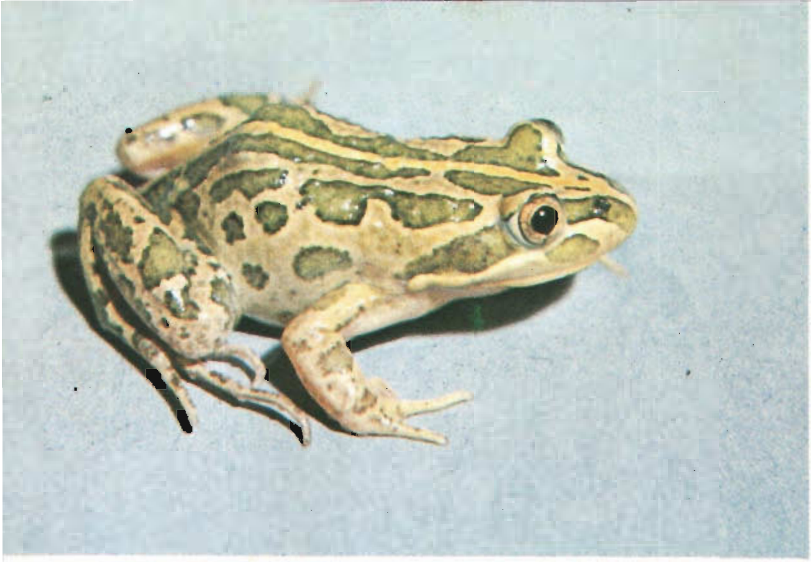
Denisonia superba (Elapidae)
E. R. Rotherham

Mixophyes balbus (Leptodactylidae)
M. J. Littlejohn

Egernia saxatilis
(Scincidae : Scincinae)
E. R. Rotherham

Crinia victoriana (Leptodactylidae)
J. A. Owen

Pseudophryne dendyi (Leptodactylidae)
M. J. Littlejohn



Limnodynastes tasmaniensis (Leptodactylidae)
M. J. Littlejohn

Crinia signifera (Leptodactylidae)
M. J. Littlejohn

Hyla aurea aurea (Hylidae)
M. J. Littlejohn

A pair of modified salivary glands in the cheeks manufacture and store the venom. Voluntary muscles are attached to the glands and when they contract, venom is forced into the venom ducts that run inside the upper lip to the maxillary bones. Here the ducts open into cavities above the fangs, and the venom passes into the venom channels of the fangs. Thus when the snake bites its prey, and the fangs are embedded, venom is injected directly into the body tissue of the victim. After envenomation is accomplished, the elapid snake does not release its grip, but hangs on until the prey is dead and can be swallowed.

Elapid snake venoms are rich in neurotoxins that destroy the function of the nerve endings. Death usually results from suffocation following rapid failure of the nervous system. Thus the venom is highly potent, and the elapid snakes include in their ranks the world's most deadly species. The venom of the Australian tiger snake, *Notechis scutatus*, is one of the most lethal animal toxins known, and is certainly the most powerful found in any terrestrial vertebrate. Fortunately the volume of venom injected is often small, and the injecting apparatus is not as efficient as that in viperid snakes which have long folding fangs.

The head in elapid snakes is usually flattened, but it does not stand out distinctly from the neck. Most species are capable of moving at high speeds and their bodies are slender, and flattened ventrally to provide as much traction as possible. The short, fat death adder, *Acanthophis antarcticus*, is the most notable exception to this rule; as a consequence of its build it is only capable of slow movements on the surface. In elapids there is no internal or external evidence of the pelvic girdle or hind limbs, and the tail is short and cylindrical, tapering more or less uniformly to a point. The head shields are large and symmetrical; there are few scales round mid-body (these range from 15 to 23); and the ventral body scales are wide (always more than the full body width). In most elapids the eye is unmodified with a round pupil, but in some nocturnal forms it may be oval shaped. The left lung is absent in elapid snakes. Threat displays are well developed in most species and usually involve inflating the body with air, violent hissing, posturing, and flattening or compressing parts of the body. If the threat fails, the snake may bite and inject venom, but defence is a function of the venom apparatus which is only secondary to that of killing their prey.

Elapid snakes do not have a uniform mode of reproduction; there are oviparous, ovoviviparous, and viviparous (placental) forms. However, in Australia most species are viviparous and the only well represented group where all species are oviparous is the genus *Demansia*. The number of young produced varies greatly with litters ranging from four to 120.

It is also impossible to generalise about the habits of members of this family. There are many thigmothermic forms, and the heliotherms are poor at temperature regulation as their elongate bodies make it difficult to expose all sections uniformly to sunshine. Also, all the body contacts the substrate, so conductive heat transfers are rapid. Thus heliothermy is probably not as advantageous to snakes as it is to lizards.

Twenty-three species of elapid snakes representing ten genera are known to occur in Victoria. Sixteen species are found in the Eyrean.

The species belonging to the genera *Acanthophis, Aspidomorphus, Brachyaspis, Denisonia, Rhynchoelaps,* and *Vermicella* are small thigmothermic snakes that burrow into loose soil or under litter for shelter from the surface heat. The remaining species found in the Eyrean are large heliothermic snakes and they utilise a variety of shelters such as under logs and rocks or in burrows dug by other animals. These latter species include the thin whip snake, *Demansia psammophis,* which may reach 4 ft 6 inches in length; the hooded brown snake, *Demansia nuchalis,* which reaches 6 ft in length; and the brown snake, *Demansia textilis,* taipan, *Oxyuranus scutellatus,* and mulga snake, *Pseudechis australis,* all of which have been known to exceed 7 ft 6 inches in length. The record of the taipan, *O. scutellatus,* from Victoria is based on two specimens in the National Museum of Victoria said to have been collected at the junction of the Murray and Darling Rivers. This locality is doubtful, and the specimens could have come from an area to the north as taipans have recently been recorded from the Coopers Creek area in South Australia. Two heliothermic species, the tiger snake *Notechis scutatus* and black snake *Pseudechis porphyriacus,* that are well represented in the warm temperate Bassian, are found in the Eyrean where they are restricted to the Murray River corridor. Five species are found in the warm temperate Bassian and two of these, the little whip snake *Denisonia flagellum* and the small eyed snake *Denisonia nigrescens,* are thigmotherms and both are restricted to the warm temperate. The three heliotherms, the brown snake *Demansia textilis,* tiger snake *Notechis scutatus,* and black snake *Pseudechis porphyriacus,* are also found in the Eyrean or the Murray River corridor. Only four species are found in the cool temperate Bassian, and all are heliotherms and viviparous: one species, the tiger snake *Notechis scutatus,* is shared with the warm temperate; one species, the lowlands copperhead *Denisonia superba* (lowlands form) is restricted to the cool temperate; and the remaining two species, the white lipped snake *Denisonia coronoides,* and highlands copperhead *Denisonia superba* (highlands form), are shared with the cold temperate where they are restricted to the lower woodlands.

Family Typhlopidae (blind snakes or worm snakes). This group of small burrowing snakes is unique in that the cranial bones are solidly united and the jaws are not adapted to give a wide gape. In the skull the pterygoids fail to reach the quadrate; the ectopterygoids are reduced or absent; the prefrontals and nasals contact and are solidly united; elements of the rostral (snout) region are fused and form a burrowing organ that is solidly attached to the braincase; supratemporals are absent; the quadrate is short and flat with a dorsal process, and slants forward ventrally; the stapes are absent; the supraorbital and postorbital bones are absent, so the orbit is open. In the upper jaw, the premaxilla is widely separated from the maxilla, and the maxilla is shortened and movably attached to the skull. In the lower jaw, the dentary is greatly reduced and a coronoid is present. The dentition is very reduced, and the premaxilla, palatine and pterygoid bones are toothless. The maxilla bears a few solid teeth in a transverse row, and the dentary may bear one tooth or be toothless.

Sub-family Typhlopinae (blind snakes or worm snakes). In the lower jaw, the dentary is strongly reduced and toothless, and the splenial is present and reaches the anterior end of the jaw. The hyoid apparatus is Y-shaped and a reduced pelvic girdle (consisting of a single bone) is present.

Blind snakes feed on small, soft bodied invertebrates such as termites. Thus they have no need to subdue their prey before swallowing, and they are neither venomous nor have any special abilities (such as constricting) for incapacitating other animals. As the name " worm snakes " infers, these reptiles bear a superficial resemblance to earthworms. The head is short and blunt, with a shovel shaped snout adapted for digging. Below the rim of the snout lies the small mouth. The head passes imperceptibly into the neck which is indistinguishable from the body and tail as all are round in section and of the same diameter. The tail is extremely short and blunt, and terminates in a small downward directed spine that is used to anchor the snake when it is pushing through loose soil. The head shields are large, highly polished, and symmetrical ; while the neck, body, and tail are covered by flat highly polished scales which are in 16 to 24 rows at mid-body. Blind snakes lack the enlarged undivided ventral scales that are characteristic of other snakes. The eyes are very reduced and only visible externally as small black spots under the translucent head shields, this feature giving rise to the name " blind snakes ". The left lung is absent. Probably because of their cryptic habits, blind snakes have no threat displays and will not bite.

Blind snakes have been poorly studied in the past, and the mode of reproduction is known for only a few species ; however, it is possible to state that they are basically oviparous and recorded litter sizes range from two to fifteen. Dissection of a female belonging to an overseas species revealed fourteen fully developed embryos, so there may be ovoviviparous and even viviparous species.

All blind snakes are burrowing thigmotherms and their extreme adaptations would probably prevent any other mode of existence. They only move about on the surface at night or when heavy rains flush them from the soil.

Eight species representing one genus, *Typhlops*, are known to occur in Victoria, and all are restricted to the Eyrean. They avoid the surface heat by burrowing in loose soil. It is probable that they actively thermoregulate during the day by moving up and down in the soil layers, following the optimal temperature. Blind snakes are probably excluded from the Bassian by their thigmothermic habits and their oviparous mode of reproduction.

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GEOGRAPHICAL FEATURES

Area and boundaries

Victoria is situated at the south-eastern extremity of the Australian continent, of which it occupies about a thirty-fourth part and covers about 87,884 square miles or 56,245,760 acres.

The following table shows the area of Victoria in relation to that of Australia :

AREA OF AUSTRALIAN STATES

State or Territory	Area	Percentage of total area
	sq miles	
Western Australia	975,920	32·88
Queensland	667,000	22·47
Northern Territory	520,280	17·53
South Australia	380,070	12·81
New South Wales	309,433	10·43
Victoria	**87,884**	**2·96**
Tasmania	26,383	0·89
Australian Capital Territory	939	0·03
Total Australia	2,967,909	100·00

Victoria is bounded on the north and north-east by New South Wales, from which it is separated by the Murray River and a boundary about 110 miles long running north-westerly from Cape Howe to the nearest source of the Murray River, being a point known as The Springs, on Forest Hill. All the waters of the Murray River are in New South Wales, the State boundary being the left bank of the stream. The total length of the New South Wales boundary is about 1,175 miles.

On the west the State is bounded by South Australia and on the south by the Indian Ocean and Bass Strait. Its greatest length from east to west is about 493 miles, its greatest breadth about 290 miles, and its extent of coastline 980 miles, including the length around Port Phillip Bay 164 miles, Western Port 90 miles, and Corner Inlet 50 miles. Great Britain, inclusive of the Isle of Man and the Channel Islands, contains 88,119 square miles, and is therefore slightly larger than Victoria.

The most southerly point of Wilsons Promontory, in latitude 39 deg 8 min S., longitude 146 deg 22½ min E., is the southernmost point of Victoria and likewise of the Australian continent ; the northernmost point is where the western boundary of the State meets the Murray, latitude 34 deg 2 min

S., longitude 140 deg 58 min E.; the point furthest east is Cape Howe, situated in latitude 37 deg 31 min S., longitude 149 deg 59 min E. The westerly boundary lies upon the meridian 140 deg 58 min E., and extends from latitude 34 deg 2 min S. to latitude 38 deg 4 min S.—a distance of 280 miles.

Physical divisions

This article should be read in conjunction with the articles on geographical features, area, and climate.

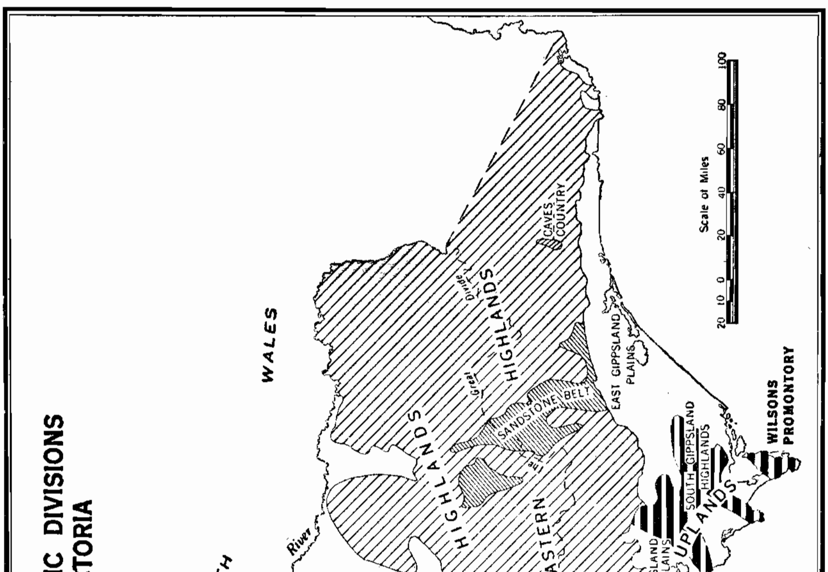

FIGURE 1.

The chief physical divisions of Victoria are shown on the map (Figure 1). Each of these divisions has certain physical features which distinguish it from the others as a result of the influence of elevation, geological structure, climate, and soils. The following divisions are recognised :

1. *Murray Basin Plains :*
    - (*a*) The Mallee
    - (*b*) The Murray Valley
    - (*c*) The Wimmera
    - (*d*) The Northern District Plains
2. *Central Highlands :*
    - A. The Eastern Highlands, within which
        - (*a*) the Sandstone Belt and
        - (*b*) the Caves Country may be distinguished from the remainder
    - B. The Western Highlands :
        - (*a*) The Midlands
        - (*b*) The Grampians
        - (*c*) The Dundas Highlands
3. *Western District Plains :*
    - (*a*) The Volcanic Plains
    - (*b*) The Coastal Plains
4. *Gippsland Plains :*
    - (*a*) The East Gippsland Plains
    - (*b*) The West Gippsland Plains
5. *Southern Uplands :*
    - (*a*) The Otway Ranges
    - (*b*) The Barabool Hills
    - (*c*) The Mornington Peninsula
    - (*d*) The South Gippsland Highlands
    - (*e*) Wilsons Promontory

Murray Basin Plains

These plains include the Mallee, the Wimmera, the Northern District Plains, and the Murray Valley itself. The most noticeable distinguishing features of the Mallee are the soils, vegetation, and topography. It is not a perfect plain, but exhibits broad low ridges and depressions which appear to be due to folding and faulting of the rocks. Sand ridges trending due east and west are an indication of a former more arid climate, but they are now fixed by vegetation. When cleared, the sand distributes itself irregularly without forming new ridges. There is evidence of a succession of former wet and dry periods in the Mallee, but at the present time all the streams that enter it lose so much water by evaporation and percolation that they fail to reach the Murray and terminate in shallow lakes, many of which are salt. The Murray Valley itself is cut into the higher Mallee land and is subject to periodic flooding by the river.

The Northern District Plains are formed from the combined flood plains of rivers flowing to the Murray, with an average gradient of between 3 and 5 ft to the mile, the surface being almost perfectly flat except where small residual hills of granite rise above the alluvium as at Pyramid Hill.

The Wimmera lies between the Western Highlands and the Mallee and is also composed mainly of river plains, except to the north of the Glenelg where old abandoned river channels contain a succession of small lakes. Most of the lakes of the Murray Basin Plains have crescentic loam ridges (lunettes) on their eastern shores.

Central Highlands

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear beyond the Dundas Highlands near the South Australian border. They were formed by up-warping and faulting. The Eastern Highlands differ from the Western in their greater average elevation, with peaks such as Bogong, Feathertop, and Hotham rising above 6,000 ft, while the Western Highlands are generally lower, the peaks reaching above 3,000 ft, and the valleys being broader. Also, in the Eastern Highlands patches of Older Volcanic rocks occur, whereas in the Western the volcanic rocks belong mainly to the Newer Volcanic Series. Several well known volcanic mountains are still preserved, Mounts Buninyong and Warrenheip near Ballarat being examples.

Because of the great variety of geological formations in the Central Highlands and the effects of elevation and deep dissection by streams, the features of the country are very varied and there are many striking mountains and gorges. The severe winter climate, with heavy snow on the higher land, is also a special feature of the Eastern Highlands. Included in the area are several high plains such as those near Bogong and the Snowy Plains. Caves are well known in the limestone around Buchan.

In the Western Highlands the Grampians, with their striking serrate ridges of sandstone, may be compared with the belt of sandstones stretching from Mansfield to Briagolong in the east.

The Dundas Highlands are a dome which has been dissected by the Glenelg and its tributaries, the rocks being capped by ancient laterite soils which form tablelands with scarps at their edges.

Western District Plains

Many of the surface features of the Western District Plains are a result of volcanic activity, very large areas being covered with basalt flows of the Newer Volcanic Series above which prominent mountains rise, many of them with a central crater lake. Some of the youngest flows preserve original surface irregularities practically unmodified by erosion, thus forming the regions known as " Stony Rises ".

The coastal plains of the Western District are for the most part sandy, the soils being derived from Tertiary and Pleistocene sedimentary deposits, which in places attain a thickness of some 5,000 ft, and yield considerable quantities of artesian water.

Gippsland Plains

Continuing the east-west belt of plains on the eastern side of the drowned area represented by Port Phillip Bay and Western Port are the Gippsland Plains. These are underlain by marine and non-marine Tertiary and Pleistocene sedimentary deposits, including the thick seams of brown coal of the Latrobe Valley. A notable feature is the Ninety Mile Beach and the lakes and swamps that lie on its landward side. This beach is an offshore bar on which aeolian sand ridges have accumulated.

Southern Uplands

Lying to the south of the plains above mentioned is a group of uplifted blocks for which faulting is mainly responsible, these constituting the Southern Uplands. The Otway Ranges and the South Gippsland Highlands are composed of fresh water Mesozoic and Tertiary sediments with Older Volcanic basalts in South Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites. The Sorrento Peninsula is entirely composed of Pleistocene calcareous dune ridges which have been responsible for practically blocking the entrance to Port Phillip Bay.

Physical environment and land use

The Central Highland Zone (see Figure 1) is the dominant physiographic region of Victoria. The greatest importance of these Highlands is their influence on the drainage pattern of the State. They act as a drainage division and catchment areas between the long north and north-west flowing rivers which are part of the Murray System and the shorter south flowing rivers.

The Highlands are divided into two parts by the 1,200 ft Kilmore Gap, a natural gateway for transport routes leading north from Melbourne.

Eastern Highlands

To the east, the Eastern Highlands form a broad, rugged region of deeply dissected high plateaux with elevations of up to 6,000 ft. They form a barrier to east-moving air masses, giving rise to heavy orographic rainfall of over 50 inches a year in the higher parts. This is the wettest part of the State, and is the coldest region in winter with substantial snowfalls at higher elevations, a factor enabling the development of skiing resorts at locations such as Mt Buffalo, Mt Buller, Mt Hotham, and Falls Creek. Because of the elevation, this is also the coolest part of the State in summer. The rugged topography and dense forest cover of the Eastern Highlands makes them rather inaccessible and of little agricultural potential, so that they are the only large area of Victoria that is very sparsely settled and almost devoid of transport routes. However, the foothill zone adjoining the East Gippsland Plains is an important forestry area, while the lower slopes and valleys are used for grazing, particularly of cattle. High alpine grassland areas in the north-east, such as the Bogong High Plains, are used for summer grazing, this area being one of the rare cases of a transhumance farming economy in Australia. The high run-off and steep stream gradients have made the Eastern Highlands important for water storage and hydro-electricity generation at Kiewa, Eildon, and Rubicon.

Western Highlands

West of the Kilmore gap, the Western Highlands are much lower than those to the east. These Highlands culminate in the west in a series of block mountains, of which the Grampians and the Dundas Highlands form the final western outlines of the Highland Zone. Stream gradients are more gentle than in the Eastern Highlands, so that hydro-electricity potential is low. However, the Rocklands Dam and the Eppalock and Cairn Curran Reservoirs are important storages for water supply to farms of the northern plains of Victoria.

The Western Highlands, because of their lower elevation, have a lower rainfall than the Eastern Highlands, and they do not act as a barrier to settlement and transport. The reasonably reliable rainfall of 20 inches to 30 inches a year, cool winters, warm summers, rolling topography, open dry sclerophyll forest and grasslands, and moderately fertile, although thin, volcanic soils offer an environment suitable for sheep grazing for wool and fat lambs, fodder cropping, dairying, and potato growing. Early settlement of the area was stimulated by the gold discoveries of the 1850s and 1860s in the Ballarat and Bendigo districts, and these two cities have developed as important regional centres. Castlemaine, Maryborough, and Clunes are additional service centres.

Murray Basin Plains

North of the Central Highland Zone are the flat Murray Basin Plains (see Figure 1). The western section is comprised of the Mallee–Wimmera Plain, characterised by areas of east-west running sand ridges, grey-brown and solonised Mallee soils, and some areas of sandy wastelands. Rainfall is around 20 inches a year in the southern Wimmera, but it decreases to under 10 inches a year in the north-western Mallee, which is the driest area of the State. As well as being low, rainfall is erratic and unreliable in the Mallee–Wimmera, but the warm winters and hot summers ensure a year round growing season where water is available. Early farms were too small, and over-cropping led to widespread crop failures and soil erosion. Since the 1930s farming here has become more stable as a result of the provision of adequate and assured water supplies from the Mallee–Wimmera Stock and Domestic Water Supply System, larger farms of over 1,000 acres, crop rotations, the development of a crop-livestock farming pattern, the use of superphosphate and growing of legumes to maintain soil fertility, and soil conservation practices. The winter rainfall maximum and dry summer harvesting period, the good rail and road network and bulk handling facilities, and scientific farming techniques have enabled the Wimmera to become a region of high-yielding wheat and mixed farms. The drier areas of the Mallee are characterised more by larger sheep properties.

Of great significance in the Mallee are the irrigation areas of the Mildura–Merbein–Red Cliffs and Swan Hill districts, with close settlement farming growing vines and fruits. Mildura, Ouyen, Swan Hill, Horsham, Warracknabeal, and St Arnaud are the main regional centres of the Mallee–Wimmera Plains.

The Northern District Plains form the narrower eastern section of the Murray Basin Plains. Here rainfall increases from 15 inches a year in the western part to over 30 inches a year in the eastern part of the plain adjoining the Eastern Highlands. Rainfall is more reliable than in the Mallee–Wimmera District. However, there is generally a summer water deficiency which restricts pasture growth, so that the Northern District Plains are characterised by extensive grazing and mixed wheat-sheep farms. Recently there has been increasing emphasis on " ley " farming (i.e., rotation of crops and pastures) in order to increase carrying capacities and productivity. The higher, eastern section of the Northern District Plains with more reliable rainfall is one of the best sheep and cattle grazing areas in the State.

There is a marked contrast in the Northern District Plains between the " dry " farming areas and those closely settled irrigation areas of the Murray and its tributaries, especially in the Kerang, Echuca–Rochester, Kyabram–Shepparton, and Cobram–Yarrawonga areas using water from the Loddon, Campaspe, Goulburn, and Murray Rivers, respectively. Fruits, vegetables, hops, and tobacco growing with local specialisations, and dairying based on improved pastures are the main activities in the irrigated districts. Shepparton has become an important centre for canned and frozen fruits and vegetables. These areas are also important as suppliers for the metropolitan fresh fruit and vegetable market.

In the Northern District Plains Shepparton, Wangaratta, and Benalla are large and expanding regional centres with manufacturing industries, while Echuca, Rochester, Kyabram, and Wodonga are smaller service centres with a small range of urban functions.

Coastal Region

South of the Central Highland Zone, coastal Victoria is readily divided into three regions.

The first of these is Port Phillip Bay and environs, bounded by the You Yang Range and Keilor Plain in the west, the Central Highlands in the north, the Dandenong Range and West Gippsland Plain in the east, and the Mornington Peninsula in the south-east. Melbourne, Geelong, and the developing Western Port provide port facilities in this region. This region is dominated by the urban areas of Melbourne, which is the hub of the State's transport system, and Geelong. The urban areas are surrounded by intensively farmed rural landscapes in which market gardening is important in addition to cattle and sheep fattening, dairying, and fodder cropping. The bayside beach resorts and the seaside resorts of the Mornington Peninsula are the centre of an important tourist industry.

The second region of coastal Victoria is the extensive volcanic plain stretching westwards from the Port Phillip region. This is possibly the best agricultural region in Victoria. The rolling surface is characterised by volcanic plains and cones, lakes, and stony rises, with rich but shallow volcanic soils. Rainfall is above 20 inches a year in all areas, with a slight winter-spring maximum, and temperatures are warm in summer and mild in winter so that year round pasture growth and cropping are possible. Western District farms produce cattle, sheep for wool and fat lambs, fodder crops, and potatoes. This is also an important dairying district. Rural population densities, along with those of the West Gippsland dairying country, are second highest in the State after the northern irrigation districts. Colac, Warrnambool, Portland, Hamilton, and Camperdown are the main regional centres. Portland has recently developed modern port facilities.

South of the Western District Plains lie the Otway Ranges, a sparsely populated region of rugged scenery and very high rainfall. The coastline between Anglesea and Apollo Bay has a number of popular tourist resorts.

The third region of coastal Victoria is Gippsland. Immediately east of the Bay are the West Gippsland Plains, which are sandy in their western section where large areas of swamp have been drained for market gardening. The South Gippsland Highlands, a sparsely populated area of little agricultural potential, is bounded by the West Gippsland Plain and to the east by a fault trough stretching from Warragul to the Latrobe Valley (included in East Gippsland Plains in Figure 1). The fault trough with its rolling hills, 30 inch rainfall, and year round pasture, is among the best dairying country on the Australian mainland, supplying the metropolitan wholemilk market. The Latrobe Valley towns have experienced rapid post-war development as a result of the brown coal mining operations in the Yallourn-Morwell area.

East of the Latrobe Valley, rainfall decreases to below 30 inches a year between Traralgon and the Gippsland Lakes. Here the coastline is characterised by sand dunes and lagoons, backed by the riverine plains of the Latrobe, Macalister, Avon, and Mitchell Rivers. The relatively low rainfall necessitates irrigation for cropping. Irrigated farming in the Sale–Maffra, Bairnsdale, and (further east) Orbost districts is based on maize, bean, potato, and fodder growing. Elsewhere the main land use is cattle and sheep grazing.

The plains narrow east of Lakes Entrance when the coastline becomes one of alternating river valleys and hilly headlands where the Eastern Highlands protrude south to the sea. Forestry is the main activity here, with some grazing and fodder cropping in the valleys and foothills. Tourism is important in the area around Lakes Entrance, which is also a fishing port. Gippsland is linked with Melbourne by the Princes Highway and by rail as far east as Orbost.

Mountain regions

The mountainous regions of Victoria comprise the Central Highlands and a belt known as the Southern Uplands lying to the south and separated from the Central Highlands by plains.

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear near the South Australian border. In the eastern sector patches of Older Volcanic rocks occur and peaks rise more than 6,000 ft, while in the western sector the volcanic rocks belong mainly to the Newer Volcanic Series and the peaks reach 3,000 ft.

The Highlands descend to plains on their southern and northern flanks. On the south are the Western District Plains and the Gippsland Plains, and beyond these again rises a group of uplifted blocks constituting the Southern Uplands. The Otway Ranges and the hills of South Gippsland are composed of fresh water Mesozoic sediments and Tertiary sands and clays with Older Volcanic rocks in South Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites.

By 1875 the mountainous areas of the State were embraced by a geodetic survey which had been started in 1856. This was the first major survey, although isolated surveys had been carried out as early as 1844. Further surveys were carried out by the Australian Survey Corps during the Second World War, and by the Department of Lands and Survey in the post-war years. Most recent values for some of the highest mountains in Victoria are Mt Bogong, 6,516 ft; Mt Feathertop, 6,307 ft; Mt Nelse, 6,181 ft; Mt Fainter, 6,157 ft; Mt Loch, 6,152 ft; Mt Hotham, 6,108 ft; Mt Niggerhead, 6,048 ft; Mt McKay, 6,045 ft; Mt Cobberas, 6,030 ft; Mt Cope, 6,026 ft; Mt Spion Kopje, 6,025 ft; and Mt Buller, 5,919 ft.

Further reference, 1962

Erosion and sedimentation on the coastline

Over an appreciable period of time all coastlines change. Earth movements, world-wide rises and falls of sea level, and volcanic eruptions cause traumatic alterations to shorelines; but the constant erosion and sedimentation which can be observed along any stretch of coast is the continuing process of change. Marine erosion is caused almost entirely by breaking waves, while lesser contributors to the process are the activities of wind on its own, rivers, and man.

Wave action

Winds passing over the surface of the ocean generate waves which travel to generally distant shores. Although the wave form moves, only in the shallows is there a forward movement of the water particles, and here the wave picks up sand, pebbles and other detritus, with which it batters cliffs or the shallow seabed.

Waves tend to swing so that the crest is parallel to the shore, but under strong cross winds will strike the shore obliquely. Eroded material is carried out to sea by the backwash, and where the wave action is oblique the effect of each wave is to move the material a short distance laterally. The combined result of many waves is to produce a movement along the shore in the direction of the prevailing moderate to strong winds. This is known as long shore drift. On the other hand, storm waves will carry the material into deeper water, where the drift affects them less.

Both actions can be seasonal, storm waves being often more common in winter, and the prevailing winds having different directions in winter and summer. In Port Phillip Bay long shore drift is from south to north in summer, and reverses in winter. For most of the Victorian coast drift is predominantly from west to east. Waves thus both erode and move material until it is deposited in sheltered bays or formed into ridges offshore.

Eroding coastlines

The rate of erosion will depend largely on the force of the waves and the hardness of the shoreline being attacked. Where the coastline material is sand dune, soft sandstone, or clays, erosion occurs fairly uniformly through the battering action of detritus-armed storm waves and the scouring action of water alone. This is seen at Anglesea, at Peterborough, between Barwon Heads and Lonsdale Bight, between Dromana and Sorrento, near Kilcunda, along the Ninety Mile Beach, and east of Marlo.

In harder rocks, the erosion is governed largely by joint planes and faults. As well as the abrasive action in the wave zone, waves can compress water and air in the joint crevices, the resulting high pressures splitting off great blocks. This type of erosion is found in the jointed granite at Cape Woolamai and Wilsons Promontory; in the layered basalt at Flinders and Cape Schanck; and in the layered mudstones and sandstones along the Otway Peninsula, near San Remo, and south-east from Warrnambool.

Differing resistance to erosion produces irregularities. Where horizontal soft and hard bands alternate the soft layers are eroded, leaving the hard strata as ledges. Typical examples are at Broken Head near Port Campbell, at Barwon Head, and at Kilcunda. Weaknesses along the strata may cause erosion behind the headland, resulting in rock stacks and natural arches; the area east of Port Campbell provides a spectacular example. The effect of variation along the line of the coast is to leave the harder areas as promontories—numerous examples of which are found between Frankston and Dromana.

In the erosion of a partially submerged slope, undercutting in the wave zone and the subsequent disintegration of overlying strata by storm waves and weathering results in a wave cut platform at the foot of the cliff. This has occurred at Apollo Bay, along the Otway coastline, between Portsea and Cape Schanck, at Mount Martha and Mornington, at Olivers Hill, and at Kilcunda. In most cases the eroded materials are deposited on the seaward side of the slope, thus widening the platform.

The appearance of the eroding coastline depends on the relative speeds of wave erosion and atmospheric weathering. Where the materials are soft, weathering is rapid, and the natural angle of repose is reached quickly, giving a line of smoothly curving cliffs, marked by landslips. Where wave attack is the more rapid, and the material is soft, the cliff becomes almost vertical—as at Port Campbell, Anglesea, and Mentone; but where the rock is hard with vertical joints, the vertical cliffs are irregular as in the granite cliffs at Cape Woolamai. Where the strata slope towards the sea, the cliff face may coincide with the bedding planes, and where the slope is towards the land, a stepped appearance results.

Advancing coastlines

The detritus from marine erosion and material discharged into the sea by rivers and streams is moved by wave action and is deposited ultimately in sheltered locations.

Where the coast slopes gently, the deposition of material beyond the breaking zone of the waves forms an offshore bar. Continuing addition to this constructs an offshore ridge, with a lagoon left between the ridge and the original coastline. The Ninety Mile Beach is a prominent example, and here the typical shallowing of the lagoon is being carried out by erosion products of the streams discharging into it.

The process of long shore drift can be interrupted by a protruberance from the general line of the coast, with a build up on the "upstream" side, and depending on the resistance to the movement, advance of the coastline may follow. Where the direction of longshore drift is not constant, a bar may form on both sides of the obstruction. This has happened at Wilsons Promontory, where the main granitic mass is connected to the mainland by an extensive sand tongue, and at Cape Woolamai, where the same action has connected the Cape to Phillip Island. In each case an underwater ridge provided the initial obstruction. The same tendency is obvious opposite Gabo Island, where bars from the west and east have formed a cuspate foreland extending towards the island.

In sheltered areas which are not subject to high energy wave force, there is deposition of sediments from wave, tidal, and stream action. With the growth of plants which are capable of existing in brackish water, the scouring action of long shore drift and tides is impeded, and the process of siltation accelerates. Parts of Port Phillip Bay, the northern end of Western Port, and Corner Inlet provide good examples of this type of advancing coast.

Where rivers discharge into the sea, the action of waves is to form a bar across the mouth. This impedes the discharge of the detritus carried by the river, and a build-up occurs. If there is a strong continuous stream flow a delta will result. No Victorian river is in this category, so bars which are more or less continuous have formed across the mouths of most streams, including the Snowy River at Marlo, the composite river system at Lakes Entrance, the Hopkins River at Warrnambool, and the Glenelg River at Nelson. In times of high flow the stream breaches the bar, the position of the breach being determined by the direction of the long shore drift. The majority of Victorian streams which discharge into open sea have their mouths deflected eastward, and those in Port Phillip Bay generally northward, as can be seen at Balcombe Creek at Mount Martha.

Human agency

The natural processes of erosion and siltation are, overall, almost balancing; but in any particular area the effect of either may be to "interfere" with man's use of that area. The erosion of either private land or popularly used Crown land leads to a demand for its protection, and where retaining walls are constructed for this purpose the material for natural accretion at some point is cut off and erosion will commence at some other point. Numerous examples of this are found around Port Phillip Bay.

The need for ports and small boat harbours, and for adequate channels leading into them, causes the construction of breakwaters and training walls which interfere with the natural action of waves, causing siltation in the shadow of breakwaters, and denudation of beaches adjacent to them. At Apollo Bay, Queenscliff, Port Fairy, Lakes Entrance, and the channels leading to Melbourne and Geelong, dredging is needed to maintain access; and siltation is evident at St Kilda, Brighton, Sandringham, and Port Welshpool.

Construction of dams for water supply, or the diversion of streams for flood control eliminates or reduces the flushing action of streams in flood, with consequent loss of channels at the mouth, and possibly increased siltation. The Werribee, Barwon, and Yarra Rivers are examples of the former; Mordialloc Creek, Patterson River, and Kananook Creek of the latter.

Conclusion

The joint processes of erosion and sedimentation are primarily the result of wave action. The profile of the resulting coastline will depend on the nature of the rocks which form the coast, the slope of the bed, and the intensity of the wave forces. To this, rivers and man contribute to a lesser extent, and a thorough understanding of the processes is needed before an area is developed for any particular use.

Hydrography of Coast, 1966; Coastal Physiography, 1967; Plant Ecology of Coast, 1968; Marine Animal Ecology, 1969; Marine Algae of the Victorian Coast, 1970

Rivers

Stream flows

Water is a limited resource and a major factor in the development of the State. Hence a knowledge of its water resources is essential to their optimum use. Tabular data giving the mean, maximum, and minimum flows at selected gauging stations are published periodically by the State Rivers and Water Supply Commission in their *River Gaugings.* The data in the table below have been extracted from the latest published volume containing records of 175 gauging stations to 1965.

An average value such as the mean annual flow is a useful relative single measure of magnitude, but variability is equally important. Another crude measure of such variability is given by the tabulated values of the maximum and minimum annual flows; however, the difference between these extremes, termed the " range ", will increase with increasing length of record.

The following table shows the main river basins of Victoria and flows of the main streams :

VICTORIA—SCHEDULE OF MAIN STREAM FLOWS

Div.	Basin	Stream	Site of gauging station	Catchment area (square miles)	Year gauged from	Annual flows in '000 acre ft			
						Mean	No. of years	Max.	Min.
IV. Murray-Darling Division	1	Murray	Jingellic	2,520	1890	1,933	76	4,978	549
		Mitta	Tallandoon	1,840	1935	1,063	30	2,613	316
		Mitta	Tallangatta	2,000	1886	1,147	49	3,460	203
	2	Kiewa	Kiewa	450	1886	518	80	1,684	144
	3	Ovens	Wangaratta	2,250	1941	1,308	25	3,367	271
	4	Broken	Goorambat	740	1887	205	79	887	15·5
	5	Goulburn	Murchison	4,140	1882	1,795	84	6,139	516
	6	Campaspe	Elmore	1,240	1886	192	78	667	0·6
	7	Loddon	Laanecoorie	1,610	1891	205	75	660	8·9
	8	Avoca	Coonooer	1,000	1890	63	76	321	3·8
	15	Wimmera	Horsham	1,570	1889	104	77	479	0
II. South East Coast Division	22	Snowy	Jarrahmond	5,000	1907	1,682	42	3,254	766
	23	Tambo	Bruthen	1,030	(*a*) 1906	179	29	575	50
	24	Mitchell	Glenaladale	1,530	1938	764	28	1,779	325
	25	Thomson	Cowwarr	420	1901	325	50	553	142
	25	Macalister	Glenmaggie	730	1919	477	47	1,277	181
	26	Latrobe	Rosedale	1,600	(*b*) 1901	777	51	2,634	362
	28	Bunyip	Bunyip	268	(*c*) 1908	124	47	246	56
	29	Yarra	Warrandyte	899	1892	685	48	1,215	265
	30	Maribyrnong	Keilor	500	(*d*) 1908	91	35	266	3
	31	Werribee	Melton	446	(*e*) 1917	68	49	259	5·3
	32	Moorabool	Batesford	430	(*f*) 1908	58	16	149	2·5
	33	Barwon	Winchelsea	370	(*g*) 1922	115	33	412	25
	35	Carlisle	Carlisle	30	(*h*) 1930	32	31	71	14·5
	36	Hopkins	Wickliffe	540	(*i*) 1921	28	34	103	1·4
	38	Glenelg	Balmoral	606	(*j*) 1889	117	60	439	2·5

Source : *River Gaugings to 1965*, State Rivers and Water Supply Commission.

Note	Years excluded in estimating mean	Note	Years excluded in estimating mean
(*a*)	1924–25 to 1937–38	(*f*)	1921–22 to 1945–46
(*b*)	1919–20 to 1936–37	(*g*)	1933–34 to 1943–44
(*c*)	1951–52	(*h*)	1943–44 to 1946–47
(*d*)	1933–34 to 1955–56	(*i*)	1933–34 to 1943–44
(*e*)	1952–53	(*j*)	1933–34 to 1938–39

Catchment and lengths

Other characteristics relating to streams are the size of the catchment and the lengths of the rivers. Areas of gauged catchments are given in *River Gaugings*, and the lengths of 230 rivers are tabulated on pages 31 to 35 of the *Victorian Year Book* 1963.

Catchments may be regarded as the hydrologically effective part of a " basin ", or the area from which there is " run-off " to the stream. Thus, the whole of any area may be subdivided into basins, but parts of some basins may be regarded as non-effective, being either too flat or the rainfall too small to contribute to normal stream flows. There is little or no contribution in the north-west of the State where the annual rainfall is less than 18 inches to 20 inches. Above this amount, roughly half the rainfall appears as stream flow.

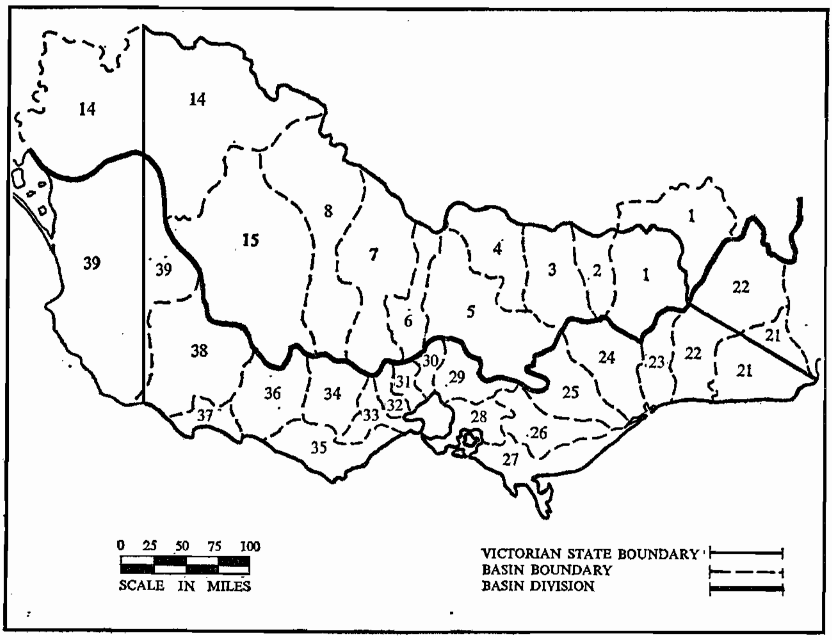

FIGURE 2. Relevant Basins of the two Divisions (South East Coast Division and Murray–Darling Division) which include Victoria and some adjacent areas. The Basins are numbered as shown on Map 3 (Sheet 2) in *Review of Australia's Water Resources,* published by Department of National Development, 1965.

SOUTH EAST COAST DIVISION

21. East Gippsland
22. Snowy River
23. Tambo River
24. Mitchell River
25. Thomson River
26. Latrobe River
27. South Gippsland
28. Bunyip River
29. Yarra River
30. Maribyrnong River
31. Werribee River
32. Moorabool River
33. Barwon River
34. Lake Corangamite
35. Otway
36. Hopkins River
37. Portland
38. Glenelg River
39. Millicent Coast

MURRAY–DARLING DIVISION

1. Upper Murray River
2. Kiewa River
3. Ovens River
4. Broken River
5. Goulburn River
6. Campaspe River
7. Loddon River
8. Avoca River
14. Mallee
15. Wimmera–Avon River

Total flow

The current estimate of mean annual flow is 17 mill. acre ft each year, about half of which flows into the Murray ; the other half flowing southward to the Victorian coast. The geographic distribution of flow is heavily weighted towards the eastern half where the total flow is about 14 mill. acre ft (with about 8 mill. acre ft in the north-east and 6 mill. acre ft in the south-east) and hence leaving 3 mill. acre ft in the western half.

Location of streams

The location of about 2,500 streams in Victoria may be obtained by referring to the *Alphabetical Index of Victorian Streams* compiled by the State Rivers and Water Supply Commission in 1960. Owing to the replication of names for some streams, there are over 2,900 names ; these have been obtained by examining Department of Crown Lands and Survey and Commonwealth Military Forces maps, so as to include names which have appeared on them. There are, in addition, many unnamed streams, those with locally known names, and those named on other maps or plans. No attempt was made in the Index to suggest a preferred name ; this is a function of the committee appointed under the *Survey Co-ordination Place Names Act* 1965.

Stream reserves

In 1881, under the then current Land Act, an Order in Council created permanent reserves along the banks of streams where they passed through Crown land. These are scheduled in the *Township and Parish Guide* reprinted by the Lands Department in 1955. This schedule indicates the location and width of reservations for 280 streams which (except for the Murray) are 1, 1½, or 2 chains wide on *each* bank of the stream. The areas thus reserved were not fully delineated until subsequently surveyed prior to alienation.

Further reference, 1963 ; Droughts, 1964

Floods

General

The natural history of unregulated rivers is largely the history of their floods and droughts. Rainfall intensity increases with decrease in latitude and consequently Victoria is less subject to floods than the northern States. The practical importance of floods is, however, largely related to the damage they do in occupied areas.

Flood damage usually occurs because of the occupation of flood plains, and once occupied there is a demand for protection which is commonly provided by levees. Such levees have been constructed along the major streams including the Murray, Snowy, and Goulburn, and also in urban areas occupying the flood plain of the Dandenong Creek. The objection to levees is that by restricting the flood plain, the flood level for a given discharge is increased, and if overtopping does occur, damage is more serious. Other flood mitigation measures used in Victoria, such as straightening the stream to increase the gradient and flow rate, have also been used on such streams as the Bunyip and the Yarra. Provision to prevent excessive scour may be necessary in some cases.

Lake level changes

Another form of flood damage that has occurred in the Western District is due to the increase in level of closed lakes flooding marginal land. This has been caused by a series of wet years since 1950 upsetting the normal balance between evaporation and inflow. In the decade since 1950 the winter rainfalls in the region of Lake Corangamite were 15 per cent above average, and the lake level rose 11 ft above its normal level of 380 ft to 391 ft to inundate about 20 square miles of adjacent land.

To reduce the inflow to this lake and hence the area flooded, a 28 mile channel, completed in 1959, diverts water to the Barwon River from the Cundare Pool. This pool, which was formed by building a low barrage across a shallow area at the head of the lake, acts as a temporary storage for the relatively fresh waters of the Woady Yaloak River which normally enter the lake.

The rate of diversion is governed by the level of the Cundare Pool and by the relative salinities of water in the pool and in the Barwon River. If the 60,000 acre ft diverted in 1960 had entered Lake Corangamite, the lake level would have been 9 inches above the maximum observed level. The level would have been almost as high again in late 1964—another very wet year—but for the diversion in the preceding five years of about 180,000 acre ft. These wet years have maintained the relatively high lake level.

Legislation has been passed to permit the Government to pay compensation on a special scale to landowners who may elect to surrender land up to 388 feet above sea level around Lake Corangamite, plus any higher land rendered inaccessible to the landowner by the initial surrender. The legislation also makes similar provision for the neighbouring Lakes Gnarpurt and Murdeduke.

Other floods

Owing to the tendency for major floods to overflow the banks and, in flat country, to pass down other channels which may not rejoin the main stream, it is often difficult to determine even the relative magnitude of major floods. The difficulty is magnified by the necessity for maintaining records of the level of the gauge in relation to a permanent datum, if a true comparison is to be made.

The year 1870 is regarded as the wettest that Victoria has experienced for over a century. As there were only thirteen rainfall stations whose records are available, the estimated average of 38 inches over the State is crude, but is 3 inches more than the next highest figure of 35 inches for 1956. River gauges in 1870 were practically restricted to the Murray, and consequently flood estimates on other streams are crude and can only be inferred from dubious evidence. Furthermore, subsequent to the 1870 floods, levees were constructed along the Goulburn and other streams and consequently heights of subsequent floods were augmented by the restrictions imposed.

In the north-east, floods occurred in the years 1906, 1916, 1917, and 1956. Although records of flood flows at gauging stations on the main streams have been published, such estimates are open to correction in the light of more recent evidence. Owing in part to under-estimation of earlier floods, the protection at the S.E.C. works at Yallourn was inadequate and the 1934 flood overflowed the banks of the Latrobe into the open cut at Yallourn. This flood was caused by a storm which is, on the basis of rainfall over large areas, the most severe that has been recorded within Victoria. An earlier storm of December 1893 which occurred over East Gippsland was heavier, but this also covered part of New South Wales.

Lakes

Lakes may be classified into two major groups : those without natural outlets which are called " closed " lakes and those with a natural overflow-channel which may be termed " open " lakes. For closed lakes to form, annual evaporation must exceed the rainfall : this is the case over most of Victoria.

Closed lakes occur mainly in the flat western part of the State. They fluctuate in capacity much more than open lakes and frequently become dry if the aridity is too high. Lake Tyrrell in the north-west is usually dry throughout the summer and can consequently be used for salt harvesting.

The level of water in an open lake is more stable because as the lake rises the outflow increases, thus " governing " the upper lake level and thus partially regulating streams emanating from it. This regulation enhances the economic value of the water resources of open lakes but Victoria does not possess any such large lake-regulated streams. However, there are small streams of this type in the Western District, such as Darlots Creek partly regulated by Lake Condah and Fiery Creek by Lake Bolac.

Salinity is often a factor which limits the use of lake water ; even the use of freshwater lakes is not extensive in Victoria due to the cost of pumping. The average salinity of closed lakes covers a wide range depending upon the geological conditions of the catchments and the water level.

Lake Corangamite is Victoria's largest lake. It can be regarded as a closed lake although during the wet period in the late 1950s it rose to within 4 ft of overflowing. The total salt content is about 16 mill. tons, giving the lake a salinity somewhat higher than seawater under average water level conditions.

The Gippsland Lakes are a group of shallow coastal lagoons in eastern Victoria, separated from the sea by broad sandy barriers bearing dune topography, and bordered on the ocean shore by the Ninety Mile Beach. A gap through the coastal dune barrier near Red Bluff, which was opened in 1899, provides an artificial entrance to the lakes from the sea. However, sea water entering this gap has increased the salinity of some lakes, which in turn has killed some of the bordering reed swamp and led to erosion. The Gippsland Lakes have been of value for commercial fishing and private angling and also attract many tourists. Coastal lagoons of this type rarely persist for more than a few thousand years and as deposition of sediment proceeds and bordering swamps encroach, the Lakes will gradually be transformed into a coastal plain.

A number of Victorian lakes and swamps have been converted to reservoirs. Waranga Reservoir is an example of this, as are Fyans Lake, Batyo Catyo, and Lake Whitton in the Wimmera. A good example of lake utilisation is the Torrumbarry irrigation system on the riverine Murray Plains near Kerang in north-west Victoria.

Further reference, 1965 ; Natural Resources Conservation League, 1965 ; Survey and Mapping, 1969

CLIMATE

Climate of Victoria

Victoria experiences a wide range of climatic conditions ranging from the hot summer of the Mallee to the winter blizzards of the snow covered Alps, and from the relatively dry wheat belt to the wet eastern elevated areas where many of Victoria's permanent streams spring.

Circulation patterns affecting Victoria

The predominating pattern which affects Victoria is an irregular succession of depressions and anticyclones. Although these systems generally move from west to east, this is not always the case. Systems can develop or degenerate *in situ*. Their speed of movement can vary considerably. They can remain quasi-stationary for even a week or more at a time.

The mean tracks of the depressions and anticyclones show a marked annual variation across the Australian region. In winter, due to the cold continent, anticyclones are centred over inland Australia, and a series of depressions over southern waters provide a persistent zonal flow across southern parts of the continent. However, on occasions when an anticyclone develops a ridge to southern waters and a depression intensifies east of Tasmania, a " cold outbreak " occurs. This brings cold and relatively dry air from southern waters rapidly across Victoria, giving windy, showery weather with some hail and snow. On other occasions, when an anticyclone moves slowly over Victoria, a prolonged spell of fine weather with frost and fog results.

During the spring, the average track of depressions and anticyclones shifts further south until in summer the average position for anticyclones is south of the continent. At this time of the year the troposphere is warmer, and therefore can hold more moisture. For this reason, rainfall during the summer months tends to be heavier. However, lifting agents in the form of cold fronts are weaker and are not as frequent as the succession of fronts that pass in winter and spring, and so rain days are less frequent in summer.

Heat wave conditions, which usually last between two and three days, and occasionally longer, are not infrequent in summer when a large anticyclone remains quasi-stationary over the Tasman Sea. Dry air from the hot interior of the continent is brought over south-eastern Australia, and hot gusty northerly winds strengthen with the approach of a southerly change. These changes vary in intensity and while some are dry, others may produce rain and thunderstorms.

During the autumn, the mean track of the anticyclones moves northwards and extremes of temperature become less frequent as the season progresses.

One of the greatest State-wide rain producing systems is a weak surface depression whose centre moves inland across the State and which extends upwards in the atmosphere to 20,000 ft and more. When warm moist air from the Indian Ocean has been advected across the continent in the higher levels of the atmosphere the presence of such a system can give very heavy rainfall. Not infrequently the " upper low " may be present without any indication at the surface. On occasions, these inland depressions are not closed systems, but are " troughs in the easterlies ", and when moisture is present these can also produce general rain. These are more common in the summer months, when moist, humid air from the Tasman Sea is brought over southern Victoria.

The heaviest rainfall in East Gippsland is produced by intense depressions to the east of Bass Strait. These may have come from the west and intensified in this area, or alternatively may have developed to the east of New South Wales or further north, and moved southwards along the coast.

The distribution of the average annual rainfall in Victoria is shown in the map on page 56.

Rainfall

Rainfall exhibits a wide variation across the State and although not markedly seasonal, most parts receive a slight maximum in the winter or spring months. The relatively dry summer season is a period of evaporation, which greatly reduces the effectiveness of the rainfall. Average annual totals range between 10 inches for the driest parts of the Mallee to over 60 inches for parts of the North-Eastern Highlands. An annual total exceeding 140 inches has been reported from Falls Creek in the north-east ; however, with the sparse population and inaccessibility of the highland localities, it is not practicable to obtain a representative set of observations from this area. Most areas south of the Divide receive an annual rainfall above 25 inches, with over 40 inches on the Central Highlands, Otway Ranges, and southern Gippsland. The wheat belt receives chiefly between 12 and 20 inches. With the exception of Gippsland, 60 to 65 per cent of the rain falls during the period May to October. This proportion decreases towards the east, until over Gippsland the distribution is fairly uniform with a warm season maximum in the far east. All parts of the State have on rare occasions been subjected to intense falls, and monthly totals exceeding three times the average have been recorded. Monthly totals exceeding 10 inches have been recorded rarely at most places on and south of the Divide, the chief exception being over the lowlands extending from Melbourne to the Central Western District. Occurrences are more frequent, but still unusual, over the north-east and East Gippsland and isolated parts such as the Otways. This event has rarely been recorded over the north-west of the State. The highest monthly total ever recorded in the State was a fall of 35·09 inches at Tanybryn in the Otway district in June 1962.

An estimate of the area distribution of average annual rainfall, and the actual distribution of rainfall in Victoria as shown by area for 1968 and 1969 are shown in the following table :

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (inches)	Area ('000 square miles)		
	Average	1968	1969
Under 10	. .	1·5	. .
10–15	19·7	8·8	2·9
15–20	13·4	16·6	26·1
20–25	15·7	17·1	13·4
25–30	15·8	15·9	10·0
30–40	14·2	14·8	17·7
Over 40	9·1	13·2	11·8

The average annual number of wet days (0·01 inches or more in 24 hours) is over 150 on the west coast and West Gippsland, and exceeds 200 over the Otway Ranges. The average number of wet days a year is reduced to 100 at a distance of approximately one hundred miles inland from the coast.

District rainfall

Mallee and Northern Country

These districts receive very little rain from western cold fronts, and rain is usually brought by depressions moving inland, " upper lows ", and thunderstorms. The amount received is highly variable from year to year. The average rainfall is fairly even through the year, except near the northern edge of the ranges where more rain falls in winter than in summer.

Wimmera

Rainfall in this district is more reliable than further to the north, as cold fronts bring showers, particularly in winter. The average rainfall shows a slight maximum in the winter months. This district includes part of the Grampians, which receive much higher rainfall than the plains.

Western and Central Districts

Rain may fall in these districts in a variety of situations and they have the most reliable rainfall in the State. Most rain comes with the westerly winds and cold fronts which predominate in winter and the average rainfall shows a winter maximum which is most marked along the west coast. The heaviest rain falls on the Otways, the Dandenongs, and the Upper Yarra Valley, while the plain to the west and south-west of Melbourne has relatively low rainfall due to the " rain shadow " of the Otway Ranges.

North Central

Most of this district consists of elevated country surrounding the Dividing Range and rainfall is heaviest on the higher parts, particularly towards the east. There is a well marked winter maximum in the yearly rainfall distribution.

North-eastern

The greater part of this district consists of ranges, some mountains being 6,000 ft in elevation, and rainfall on this higher country is generally heavy. The higher peaks lie under snow cover for most of the winter. A marked rain shadow area is evident near Omeo, which receives only half as much rain as the highlands to the north-west or north-east.

West Gippsland

The western part of this district has a very similar rainfall régime to the Western and Central Districts. The heaviest rain falls on the ranges of the Divide and the south Gippsland hills. Towards the east, however, a " rain shadow " is evident in the Sale–Maffra area. This eastern section receives some of its rain from east coast depressions.

East Gippsland

Depressions off the east coast bring most rain to this district, and such rainfall can be very heavy. The average rainfall shows a summer maximum. Fronts moving in a westerly stream bring very little rain, and with north-westerly winds in winter, the coastal section has the mildest weather in the State. Rain shadows are evident along the valleys of the Mitchell, Tambo, and Snowy Rivers while the heaviest rain falls on the surrounding highlands.

A description of the State's agricultural districts will be found on pages 270 to 274.

VICTORIA—RAINFALL IN DISTRICTS
(Inches)

Year	Districts							
	Mallee	Wimmera	Northern	North Central	North-eastern	Western	Central	Gippsland
1959	9·97	15·16	16·56	26·09	27·69	24·46	26·53	33·63
1960	18·08	24·75	22·70	38·45	40·16	36·01	34·98	37·26
1961	13·44	15·07	14·90	25·27	27·60	24·03	22·90	33·04
1962	11·29	17·69	18·85	27·77	33·78	25·99	26·07	31·41
1963	16·15	18·55	20·66	30·46	35·49	25·87	28·36	35·61
1964	16·14	25·02	20·93	34·40	40·27	38·69	35·40	37·99
1965	11·76	15·25	15·36	25·83	25·80	24·67	25·09	26·28
1966	12·48	16·47	20·28	31·97	41·26	29·35	32·08	38·97
1967	5·10	8·71	9·46	16·06	17·62	16·43	17·09	23·33
1968	13·68	19·68	20·93	34·66	39·51	33·54	28·84	34·04
1969	16·05	17·45	18·94	27·17	34·56	26·72	26·13	36·01
Average (*a*)	12·93	18·09	18·50	27·83	34·57	28·48	29·33	33·70

(*a*) Average for 53 years 1913 to 1965.

Rainfall reliability

It is not possible to give a complete description of rainfall at a place or in a district by using a single measurement. The common practice of quoting the annual average rainfall alone is quite inadequate in that it does not convey any idea of the extent of the variability likely to be encountered. Examination of rainfall figures over a period of years for any particular place indicates a wide variation from the average ; in fact, it is rare for any station to record the average rainfall in any particular year. Thus for a more complete picture of annual rainfall the variability or deviation from the average should be considered in conjunction with the average.

Rainfall variability assumes major importance in some agricultural areas. Even though the average rainfall may suggest a reasonable margin of safety for the growing of certain crops, this figure may be based on a few years of heavy rainfall combined with a larger number of years having rainfall below minimum requirements. Variability of rainfall is also important for water storage design, as a large number of relatively dry years would not be completely compensated by a few exceptionally wet years when surplus water could not be stored.

Although variability would give some indication of expected departures from normal over a number of years, variability cannot be presented as simply as average rainfall.

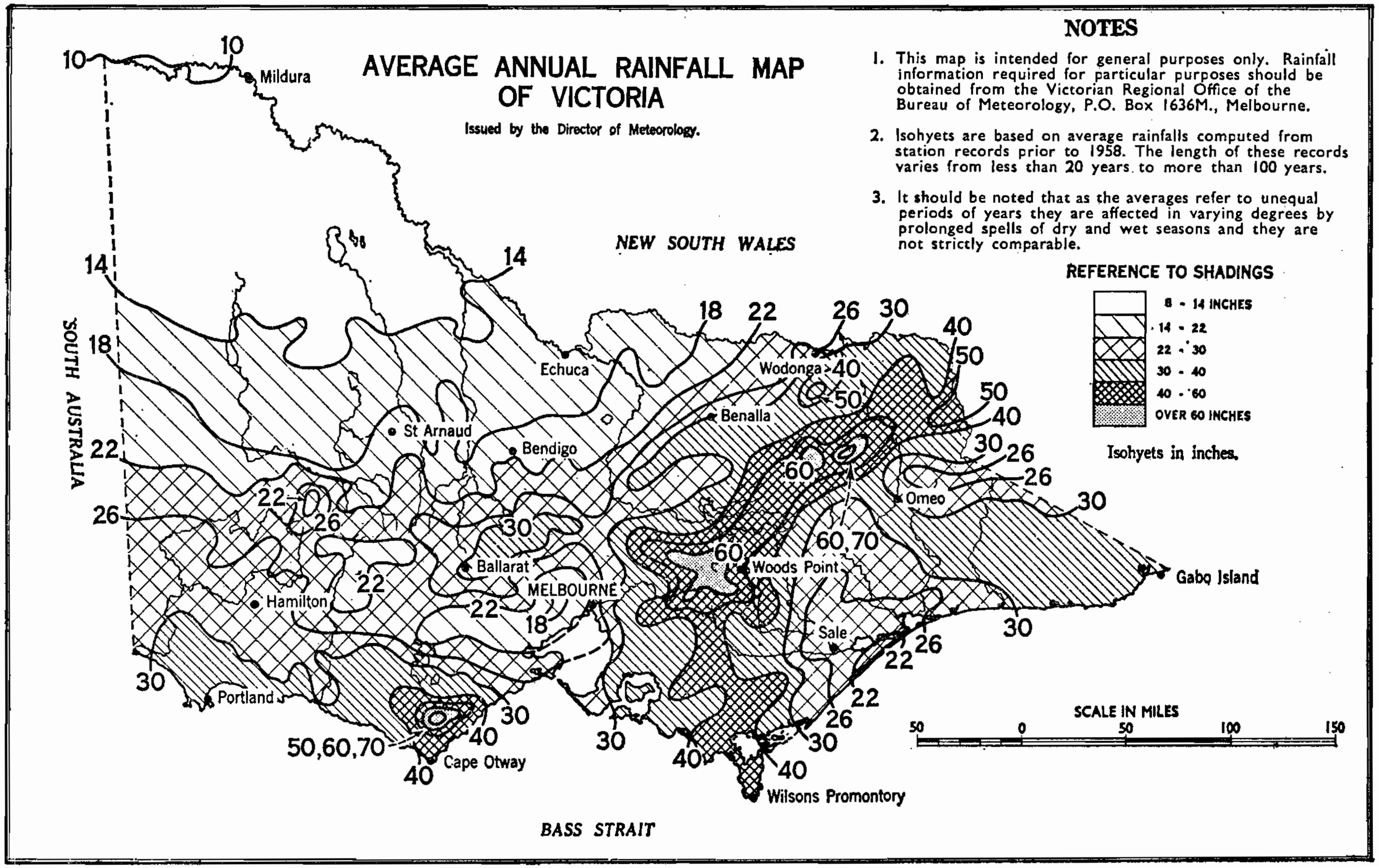
AVERAGE ANNUAL RAINFALL MAP
OF VICTORIA
Issued by the Director of Meteorology.
NOTES
1. This map is intended for general purposes only. Rainfall information required for particular purposes should be obtained from the Victorian Regional Office of the Bureau of Meteorology, P.O. Box 1636M., Melbourne.
2. Isohyets are based on average rainfalls computed from station records prior to 1958. The length of these records varies from less than 20 years to more than 100 years.
3. It should be noted that as the averages refer to unequal periods of years they are affected in varying degrees by prolonged spells of dry and wet seasons and they are not strictly comparable.
REFERENCE TO SHADINGS
8 - 14 INCHES
14 - 22
22 - 30
30 - 40
40 - 60
OVER 60 INCHES
Isohyets in inches.
SCALE IN MILES
50
0
50
100
150
NEW SOUTH WALES
SOUTH AUSTRALIA
BASS STRAIT
Mildura
Echuca
St Arnaud
Bendigo
Wodonga
Benalla
Omeo
Ballarat
MELBOURNE
Hamilton
Woods Point
Sale
Gabo Island
Portland
Cape Otway
Wilsons Promontory
50,60,70
60,70

FIGURE 3.

VICTORIA—DISTRICT MONTHLY RAINFALL : AVERAGE AND 1969

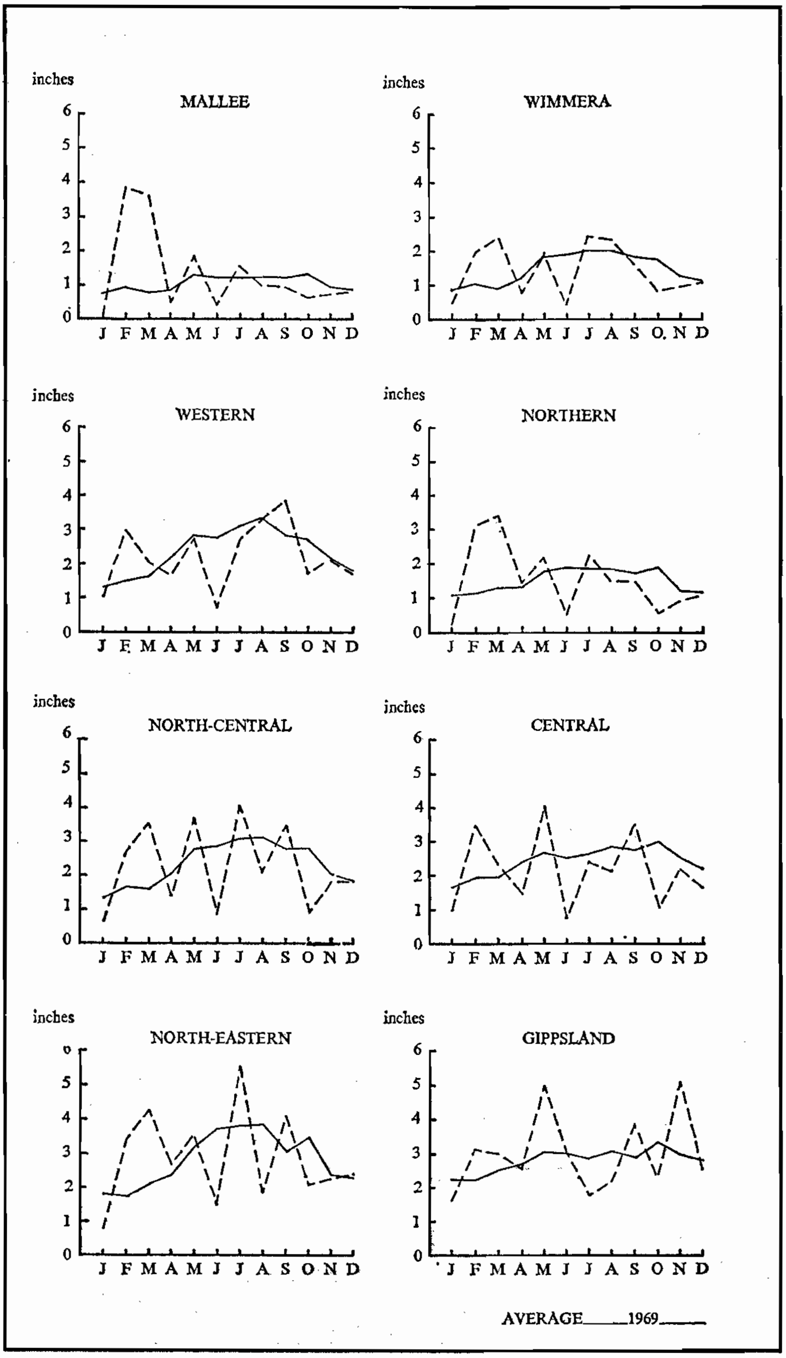

FIGURE 4.

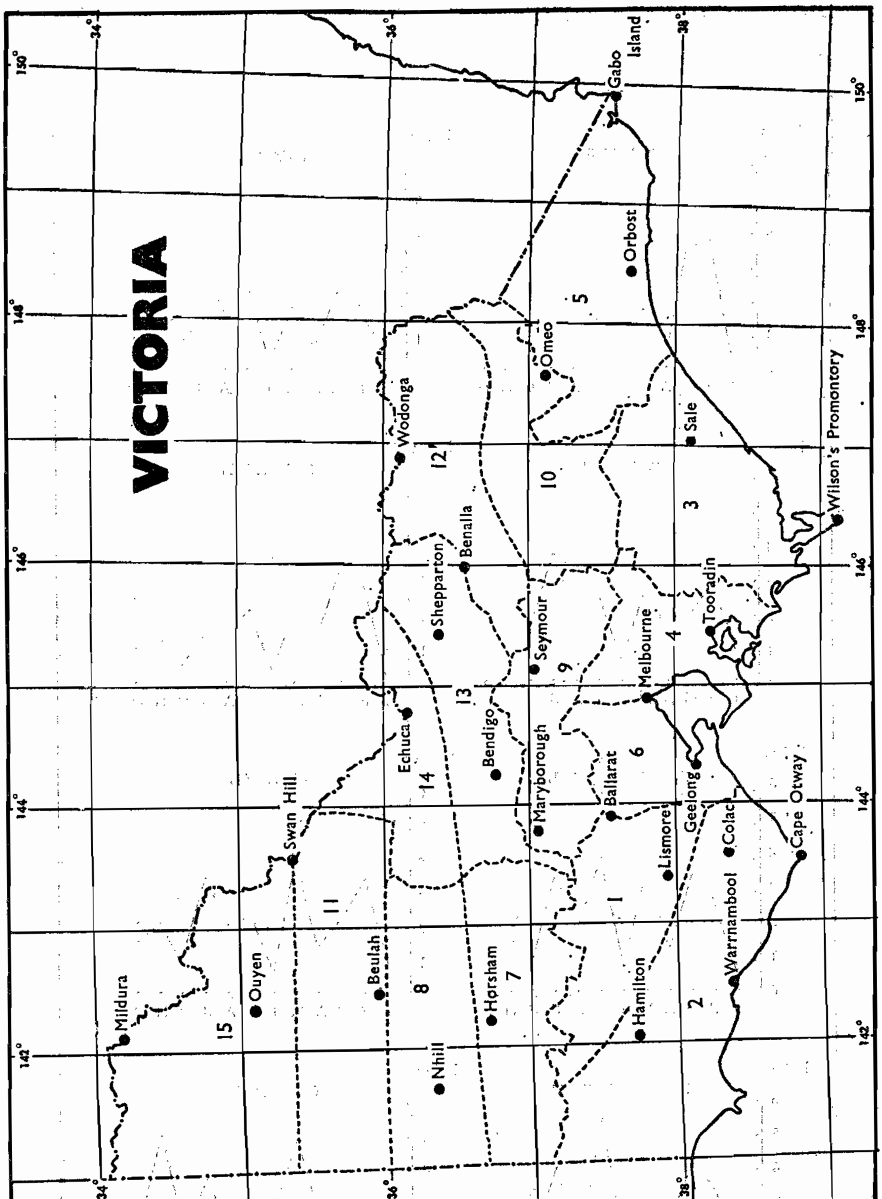

FIGURE 5. Relative rainfall variability based on district annual rainfall. Names of districts are shown in the table on page 59.

Several expressions may be used to measure variability, each of which may have a different magnitude. The simplest measure of variability is the range, i.e., the difference between the highest and lowest annual amounts recorded in a series of years. Annual rainfall in Victoria is assumed to have a " normal " statistical distribution. These distributions can be described fully by the average and the standard deviation. To compare one distribution with the other, the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{the average}} \times 100\right)$ has been used. The coefficient of variation has been calculated for the fifteen climatic regions of Victoria (see Figure 5) for the 53 years 1913 to 1965 and the results are tabulated below in order of rainfall reliability :

VICTORIA—ANNUAL RAINFALL VARIATION

District	Average annual rainfall (a)	Standard deviation	Coefficient of variation
	inches	inches	per cent
1. Western Plains	24·90	3·34	13·4
2. West Coast	30·34	4·64	15·3
3. West Gippsland	36·06	5·67	15·7
4. East Central	35·27	5·74	16·3
5. East Gippsland	30·20	5·25	17·4
6. West Central	23·89	4·41	18·5
7. Wimmera South	19·53	3·78	19·4
8. Wimmera North	16·30	3·37	20·7
9. North Central	27·83	6·07	21·8
10. Upper North-east	43·77	10·05	23·0
11. Mallee South	13·66	3·44	25·2
12. Lower North-east	30·27	7·68	25·4
13. Upper North	20·01	5·19	25·9
14. Lower North	16·86	4·65	27·6
15. Mallee North	11·86	3·36	28·3

(a) Average for 53 years 1913 to 1965.

The higher the value of the coefficient of variation of the rainfall of a district, the greater the departure from the average and hence the more unreliable the rainfall.

Droughts

The variability of annual rainfall is closely associated with the incidence of drought. Droughts are rare over areas of low rainfall variability and more common in areas where this index is high.

Since records have been taken, there have been numerous dry spells in various parts of Victoria, most of them of little consequence but many widespread and long enough to be classified as droughts. The severity of major droughts or dry spells is much lower in Gippsland and the Western District than in northern Victoria.

The earliest references to drought in Victoria appear to date from 1865 when a major drought occurred in Northern Victoria, and predominantly dry conditions prevailed in the Central District. Another dry spell of lesser intensity occurred in 1868.

The most severe and widespread drought recorded since white settlement in Australia occurred in the period 1897 to 1902. Victoria was most affected in the south in 1897–98 and particularly in the north in 1902.

The next major drought commenced about June 1913 and continued until April 1915 in the north and west and August 1916 in Gippsland. The worst period was from May to October 1914.

The period from 1937 to 1945 was marked by three major droughts. The first commenced in February 1937 and continued with a break in the succeeding spring and summer until January 1939, the effects being felt much more severely in northern districts than elsewhere. Good rains in 1939 were followed by another dry period from December 1939 to December 1940. The third drought of the period extended from 1943 to 1945 in which the worst period was from June to October 1944. The drought from 1967 to 1968 is described on pages 53 and 67 of the *Victorian Year Book* 1969 and other effects noted on pages 309 to 312 of the *Victorian Year Book* 1970.

Droughts of shorter duration and lower intensity occurred in 1888, in 1907–08 in Gippsland, and in the 1920s, particularly 1925, 1927, and 1929.

Readers are referred to the publication *Droughts in Australia,* Bulletin No. 43 of the Commonwealth Bureau of Meteorology, published in 1957, for a definitive treatment of the subject of droughts in Victoria.

1967–68 Drought, 1969

Floods

Floods have occurred in all districts, but they are more frequent in the wetter parts of the State such as the north-east and Gippsland. However, although a rarer event over the North-West Lowlands, they may result from less intense rainfall and continue longer because of the poor drainage in this section of the State. In many instances the frequency of flooding is increased by valley contours and damage is often greater because of the higher density of adjacent property and crops. (See also pages 49 to 51.)

Snow

Snow in Victoria is confined usually to the Great Dividing Range and the alpine massif, which at intervals during the winter and early spring months may be covered to a considerable extent, especially over the more elevated eastern section. Falls elsewhere are usually light and infrequent. Snow has been recorded in all districts except the Mallee, Wimmera, and Northern Country. The heaviest falls in Victoria are confined to sparsely populated areas and hence general community disorganisation is kept to a minimum. Snow has been recorded in all months on the higher Alps, but the main falls occur during the winter. The average duration of the snow season in the alpine area is from three to five months.

Temperatures

February is the hottest month of the year while January is only slightly cooler. Average maximum temperatures are under 75° F. along the coast and over elevated areas forming the Central Divide and North-Eastern Highlands. Apart from these latter areas, there is a steady increase towards the north, until, in the extreme north, an average of 90° F. is reached. Values decrease steadily with height, being under 70° F. in alpine areas above 3,000 ft and as low as 60° F. in the very highest localities.

Temperatures fall rapidly during the autumn months and then more slowly with the onset of winter. Average maximum temperatures are lowest in July; the distribution during this month again shows lowest values over elevated areas, but a significant feature is that apart from this orographically induced area, there is practically no variation across the State. Day temperatures along the coast average about 55° F. in July; much the same value is recorded over the wheat belt, and only a few degrees higher in the far north-west under conditions of few clouds and relatively high winter sunshine. The Alps experience blizzard conditions every year with minimum temperatures 10° F. to 20° F. less than at lowland stations.

Conditions of extreme summer heat may be experienced throughout the State except over the alpine area. Most inland places have recorded maxima over 110° F. with an all time extreme for the State of 123·5° F. at Mildura on 6 January 1906. Usually such days are the culmination of a period during which temperatures gradually rise, and relief comes sharply in the form of a cool change with rapid temperature drops of 30° F. at times. However, such relief does not always arrive so soon and periods of two or three days or even longer have been experienced when the maximum temperature exceeds 100° F. On rare occasions extreme heat may continue for as long as a week with little relief.

Night temperatures, as gauged by the average minimum temperature, are, like the maximum, highest in February. Values are below 50° F. over the elevated areas, but otherwise the range is chiefly 55° F. to 60° F. The highest night temperatures are recorded in the far north and along the coast. In mid-winter average July minima exceed 40° F. along the coast and at two or three places in the far north. The coldest point of the State is the north-east alpine section, where temperatures frequently fall below freezing point. Although three or four stations have been set up at different times in this area, none has a very long or satisfactory record. The lowest temperature on record so far is 9° F. at Hotham Heights (station height 5,776 ft) at an exposed location near a mountain. However, a minimum of minus 8° F. has been recorded at Charlotte Pass (station height 6,035 ft)—a high valley near Mt Kosciusko in New South Wales—and it is reasonable to expect that similar locations in Victoria would experience sub-zero temperatures (i.e., below 0° F.), although none has been recorded due to lack of observing stations.

Frosts

With the exception of the exposed coast, all parts of Victoria may experience frost, but frequencies are highest and occurrences usually more severe in elevated areas and valleys conducive to the pooling of cold air. All inland stations have recorded extreme screen temperatures less than 30° F., while at a large number of stations extremes stand at 25° F. or less. Thus frost may be expected each year over practically the whole of the State, but most of the occurrence is restricted to the winter season. Spring frosts may constitute a serious hazard to agriculture, and in some years a late frost may result in serious crop damage. Periods of frost lasting for more than three or four consecutive days are unusual.

Humidity

Generally, humidity in the lower atmosphere is much less over Victoria than in other eastern States. This is because the extreme south-east

VICTORIA—MEANS OF CLIMATIC ELEMENTS: SELECTED VICTORIAN TOWNS

Locality		Legend No. (a)	January	February	March	April	May	June	July	August	Sep.	October	Nov.	Dec.	Annual
MALLEE	Mildura	1	69	87	80	57	123	96	105	109	103	124	98	84	1,135
		2	89·6	88·0	83·4	73·9	65·7	61·9	59·0	62·6	68·2	74·9	81·4	85·3	74·5
		3	61·7	60·9	56·9	49·9	45·2	41·4	39·9	41·8	45·0	49·9	54·0	58·3	50·4
	Ouyen	1	75	90	77	81	126	123	120	129	128	143	99	98	1,289
		2	90·1	87·2	83·1	73·1	65·2	60·1	58·6	62·1	68·4	74·1	80·4	86·1	74·0
		3	58·8	58·3	54·4	48·1	44·5	41·1	39·7	41·1	43·7	47·8	52·1	55·8	48·8
WIMMERA	Horsham	1	83	103	97	129	184	203	179	188	178	170	130	114	1,758
		2	85·5	85·6	79·8	70·4	62·7	56·9	55·8	58·9	64·1	69·7	77·0	82·2	70·7
		3	55·9	56·1	52·4	47·2	43·3	40·3	38·9	40·3	42·3	45·4	49·8	53·5	47·1
	Nhill	1	79	91	86	117	162	192	178	184	171	159	116	111	1,646
		2	85·2	84·5	79·5	70·4	63·0	57·5	56·5	59·2	64·3	70·0	76·9	82·3	70·8
		3	55·0	55·3	51·6	46·7	43·0	39·9	38·1	39·4	41·7	44·9	48·8	53·0	46·5
WESTERN	Ballarat	1	137	188	182	220	265	253	278	300	289	270	220	210	2,812
		2	76·8	76·4	71·4	63·0	56·0	51·0	49·8	52·4	57·2	61·9	67·2	72·6	63·0
		3	51·0	52·4	49·8	45·5	42·5	39·6	38·2	39·1	41·0	43·5	45·8	49·0	44·8
	Hamilton	1	128	125	165	215	268	293	290	300	285	258	197	180	2,704
		2	78·0	77·8	73·2	65·5	59·2	54·7	53·4	55·6	59·6	63·6	69·0	73·9	65·3
		3	52·3	53·3	50·8	47·2	44·3	41·4	40·0	41·0	42·8	44·8	47·1	50·0	46·3
	Warrnambool	1	124	137	183	226	299	294	329	315	272	245	204	173	2,801
		2	71·3	71·4	69·5	65·0	60·5	56·7	55·6	57·0	59·8	62·8	65·8	68·8	63·7
		3	54·8	55·5	53·7	50·5	47·4	44·4	43·1	44·0	45·8	47·9	50·0	52·7	49·2
NORTHERN	Bendigo	1	125	128	141	155	211	243	219	219	208	203	146	129	2,127
		2	85·1	84·4	78·8	69·7	61·1	55·2	53·8	56·9	62·2	68·6	75·6	81·3	69·4
		3	57·2	57·7	54·1	48·4	43·6	40·7	38·7	39·9	42·8	46·5	50·6	54·4	47·9
	Echuca	1	98	105	127	130	164	180	159	165	153	170	119	112	1,682
		2	87·5	86·8	81·0	71·6	63·3	57·4	55·9	59·2	64·9	71·7	78·9	84·4	71·9
		3	59·5	59·4	55·5	49·1	44·1	41·0	39·4	41·0	43·8	48·1	52·5	56·8	49·2

North Central	Alexandra	1	159	143	197	204	251	289	283	294	260	279	222	192	2,773
		2	84·7	84·6	78·7	68·7	60·7	53·7	53·1	56·9	62·8	68·5	74·8	81·3	69·0
		3	52·1	53·0	48·8	43·3	39·6	37·2	36·5	37·3	40·0	42·9	46·5	50·0	43·9
	Kyneton	1	148	155	182	215	294	355	324	328	290	273	204	197	2,965
		2	81·1	80·3	74·6	65·0	57·1	51·2	49·9	52·9	58·9	64·6	71·4	77·0	65·3
		3	49·6	50·3	47·2	42·1	38·4	36·1	34·8	35·5	37·9	40·6	44·0	47·5	42·0
Central	Geelong	1	118	146	160	178	195	194	179	187	202	204	187	157	2,107
		2	77·0	76·7	73·8	67·5	61·8	57·3	56·4	58·7	62·5	66·7	70·5	73·9	66·9
		3	55·6	56·6	54·4	50·4	46·5	43·3	41·6	42·5	44·6	47·2	50·2	53·4	48·9
	Mornington	1	169	157	190	245	273	282	279	276	280	277	232	204	2,864
		2	76·6	76·4	73·5	66·3	60·8	56·0	54·6	56·5	60·6	64·3	68·4	73·2	65·6
		3	55·6	56·3	54·8	51·0	48·2	44·9	43·2	44·1	46·3	49·0	51·2	53·7	49·9
North-Eastern	Omeo	1	198	208	212	181	205	225	209	213	243	283	235	246	2,658
		2	79·3	78·5	73·6	65·6	57·5	51·3	50·2	53·9	59·6	65·3	71·4	76·3	65·2
		3	48·8	49·1	46·1	40·7	35·9	33·8	31·9	33·2	36·9	40·2	43·7	47·0	40·6
	Wangaratta	1	139	147	183	185	223	291	252	251	231	248	181	168	2,499
		2	87·7	87·0	81·0	71·6	63·3	56·5	54·8	58·1	63·8	69·9	77·8	84·0	71·3
		3	58·9	58·6	53·8	46·9	41·8	39·1	38·0	39·4	42·6	46·7	51·5	56·1	47·8
West Gippsland	Wilsons Promontory	1	195	187	277	342	431	480	446	452	379	372	287	249	4,097
		2	68·2	68·7	66·8	63·0	58·7	55·3	53·9	55·0	57·5	60·3	62·9	65·9	61·4
		3	56·6	58·1	56·9	54·4	51·3	48·3	46·6	46·7	47·7	49·4	51·7	54·4	51·8
	Yallourn	1	178	232	197	253	392	335	331	401	339	345	333	277	3,613
		2	76·9	74·6	72·3	65·2	58·0	54·6	52·9	55·2	59·8	63·5	67·3	71·8	64·3
		3	54·5	55·3	53·7	49·0	45·6	43·0	40·6	41·6	44·1	47·0	49·0	52·2	48·0
East Gippsland	Bairnsdale	1	240	198	252	201	205	219	199	188	223	273	248	265	2,711
		2	76·3	76·2	73·4	68·4	62·6	57·8	56·9	59·4	63·4	67·2	70·8	74·2	67·2
		3	53·9	54·6	52·1	47·2	42·7	39·6	38·3	39·6	42·7	46·0	49·1	52·2	46·5
	Orbost	1	269	236	265	282	276	327	267	233	270	312	260	300	3,297
		2	77·1	76·5	74·4	68·7	63·3	58·9	57·9	59·9	63·8	64·6	70·1	74·4	67·5
		3	54·6	55·3	52·9	48·3	43·9	41·0	39·1	40·0	42·5	46·4	49·6	52·6	47·2

(*a*) Legend : 1. Average monthly rainfall in points : 100 points = 1 inch. (For all years of record to 1968.)
2. Average daily maximum temperature (°F.) (For all years of record to 1966.)
3. Average daily minimum temperature (°F.) (For all years of record to 1966.)

of the continent is mostly beyond the reach of tropical and sub-tropical air masses. For several periods in the summer, however, air from the Tasman Sea has a trajectory over Bass Strait and other parts of the State, and it is then that the moisture content rises to show wet bulb temperatures above 65° F. The incidence of high humidity is important to the vine and fruit industry, tobacco growers, and wheat farmers.

Evaporation

Since 1967 the Class A Pan has been the standard evaporimeter used by the Bureau of Meteorology. This type is being progressively installed at evaporation recording stations in Victoria; there were thirty at the end of 1969.

Measurements of evaporation have been made with the Australian tank at about thirty stations, about half of which are owned by the Bureau of Meteorology. Results from these stations show that evaporation exceeds the average annual rainfall in inland areas, especially in the north and north-west, by about 40 inches. In all the highland areas and the Western District the discrepancy is much less marked, and in the Central District and the lowlands of East Gippsland annual evaporation exceeds annual rainfall by 8 to 15 inches. Evaporation is greatest in the summer months in all districts. In the three winter months, rainfall exceeds evaporation in many parts of Victoria, but not in the north and north-west.

Winds

The predominant wind stream over Victoria is of a general westerly origin, although it may arrive over the State from the north-west or south-west. There are wide variations from this general description, however, and many northerlies and southerlies occur. The latter is the prevailing direction from November to February with a moderate percentage of northerlies often associated with high temperatures. Easterly winds are least frequent over Victoria, but under special conditions can be associated with some of the worst weather experienced over the State. Wind varies from day to night, from season to season, and from place to place. Examples of the diurnal variation are the sea breeze, which brings relief on many hot days along the coastline, and the valley or katabatic breeze, which brings cold air down valleys during the night. The latter is well developed in many hilly areas of Victoria, being the result of differential cooling after sunset. It springs up during the night, often suddenly, and continues after sunrise until the land surfaces are sufficiently heated again. The sensitive equipment required to measure extreme wind gusts has been installed at only about five or six places in the State and to date the highest value recorded is just slightly over 102 mph at Point Henry near Geelong in 1962. There is no doubt, however, that similar gusts have been experienced in other parts of the State, although not in the vicinity of a recording anemometer. It is considered that any place in Victoria could feasibly experience at some time a local gust of 100 mph or more.

Thunderstorms

Thunderstorms occur far less frequently in Victoria and Tasmania than in the other two eastern States. They occur mainly in the summer months when there is adequate surface heating to provide energy for convection. On an average, more than twenty per year occur on the North-Eastern

Highlands and in parts of the Northern Country, but particularly in the north-east. Melbourne has an average of less than three per month from November to February. Isolated severe wind squalls and tornadoes sometimes occur in conjunction with thunderstorm conditions, but these destructive phenomena are comparatively rare. Hailstorms affect small areas in the summer months ; and showers of small hail are not uncommon during cold outbreaks in the winter and spring.

Computers in meteorology

Although both the solar system and the atmosphere behave in an ordered fashion, prediction of meteorological events is made very difficult by the sheer complexity of motion in the atmosphere. The meteorologist is concerned with the behaviour of a shallow layer of an uneven mixture of gases, held by gravity to a rotating sphere of irregular surface, heated by the sun and disturbed by the frequent change of phase of its water content. The equations describing the motions of the atmosphere are known, but two problems have to be overcome in their solution. One is to know the exact state of the atmosphere over the globe at the starting point. The other is to solve the complicated equations quickly enough to provide a useful prognostic pattern. This second problem is only just beginning to be overcome with the advent of the electronic computer.

The Commonwealth Bureau of Meteorology acquired its first computer in June 1968 and a second was installed in 1969. Coded versions of weather observations from hundreds of observing stations are fed directly into the computer. After checking for consistency these messages form the basis for portraying the current state of the atmosphere, i.e., the analysis charts. Further checks are applied by comparing observations from adjacent stations and also comparing observations taken at 3 hourly intervals from the one station. The analysed charts are drawn directly under computer control, each chart being drawn in 2·5 minutes.

At the same time the computer prepares prognostic charts, i.e., charts depicting the future state of the atmosphere. The prognostic charts are built up from a large number of evenly spaced grid points, and the relevant equations must be solved for each grid point separately, and for each of several levels in the atmosphere.

The operation of a World Meteorological Centre in Melbourne calls for the handling of weather information from other national centres and the exchange of this information between the three world centres in Washington, Moscow, and Melbourne. The computer is thus used to process weather information from the whole of the Southern Hemisphere.

In addition to keeping up with the current weather, the computer carries out tasks involving past weather data, and the preparation of routine climatological bulletins and summaries. Much of its time is taken up with tasks for research projects.

As further technological advances are made in the capacity and speed of computers and in data gathering techniques more sophisticated equations will be used for predicting the future state of the atmosphere.

One other complicating factor is that the equations are non-linear and have to be simulated on the computer. The success of this depends on the mathematical methods used in solving the equations.

The step from the prognostic charts to the actual forecast in terms of weather is the final difficult step. It will be some time before all the processes required here can be written in terms of mathematics. This is because the purely scientific problems associated with the small scale disturbances, such as turbulence, have not yet been solved.

Agricultural Meteorology, 1964; Maritime Meteorology, 1966; Aeronautical Meteorology, 1967; Meteorology in Fire Prevention, 1968; Meteorological Services for Commerce and Industry, 1969; Meteorological Observations, 1970

Climate of Melbourne

Temperature

The proximity of Port Phillip Bay bears a direct influence on the local climate of the metropolis. The hottest months in Melbourne are normally January and February when the average is just over 78°F. Inland, Watsonia has an average of 81°F., while along the Bay, Aspendale and Black Rock, subject to any sea breeze, have an average of 77°F. This difference does not persist throughout the year, however, and in July average maxima at most stations are within 1°F. of one another at approximately 55°F. The hottest day on record in Melbourne was 13 January 1939, when the temperature reached 114·1°F. which is the second highest temperature ever recorded in an Australian capital city. In Melbourne, the average number of days per year with maxima over 100°F. is about four, but there have been years with up to twelve and also a few years with no occurrences. The average annual number of days over 90°F. is approximately nineteen.

Nights are coldest at places a considerable distance from the sea, and away from the city where buildings may maintain the air at a slightly higher temperature. The lowest temperature ever recorded in the city was 27°F. on 21 July 1869, and likewise, the highest minimum ever recorded was 87°F. on 1 February 1902.

In Melbourne, the overnight temperature remains above 70°F. on only about two nights a year and this frequency is the same for nights on which the air temperature falls below 32°F. Minima below 30°F. have been experienced during the months of May to August, while even as late as October extremes have been down to 32°F. During the summer minima have never been below 40°F.

Wide variations in the frequencies of occurrences of low air temperatures are noted across the metropolitan area. For example, there are approximately ten annual occurrences of 36°F. or under around the bayside, but frequencies increase to over twenty in the outer suburbs and probably to over thirty a year in the more frost susceptible areas. The average frost free period is about 200 days in the outer northern and eastern suburbs, gradually increasing to over 250 days towards the city, and approaches 300 days along parts of the bayside.

Rainfall

The range of rainfall from month to month in the city is quite small, the annual average being 25·82 inches over 143 days. From January to August, monthly averages are within a few points of 2 inches; then a rise occurs to a maximum of 2·66 inches in October. Rainfall is relatively steady during the winter months when the extreme range is from half an inch to 7 inches, but variability increases towards the warmer months. In the latter period totals range between practically zero and over 8 inches. The number of wet days, defined as days on which a point or more of rain falls, exhibits marked seasonal variation ranging between a minimum of eight in January and a maximum of fifteen each in July and August. This is in spite of approximately the same total rainfall during each month and indicates the higher intensity of the summer rains. The relatively high number of wet days in winter gives a superficial impression of a wet winter in Melbourne which is not borne out by an examination of total rainfall.

The average rainfall varies considerably over the Melbourne metropolitan area. The western suburbs are relatively dry and Deer Park has an average annual rainfall of 19·10 inches. Rainfall increases towards the east, and at Mitcham averages 35·48 inches a year. The rainfall is greater still on the Dandenong Ranges and at Sassafras the annual average is 53·93 inches.

The highest number of wet days ever recorded in any one month in the city is twenty-seven in August 1939. On the other hand, there has been only one rainless month in the history of the Melbourne records—April 1923. On occasions, each month from January to May has recorded three wet days or less. The longest wet spell ever recorded was eighteen days and the longest dry spell forty days. Over 3 inches of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to April. Only twice has a fall above 2 inches during 24 hours been recorded in the cooler months.

Fogs

Fogs occur on an average of four or five mornings each month in May, June, and July, and average twenty days for the year. The highest number ever recorded in a month was twenty in June 1937.

Cloud and sunshine

Cloudiness varies between a minimum in the summer months and a maximum in the winter, but the range like the rainfall is not great compared with many other parts of Australia. The number of clear days or nearly clear days averages two to three each month from May to August, but increases to a maximum of six to seven in January and February. The total number for the year averages forty-seven. The high winter cloudiness and shorter days have a depressing effect on sunshine in winter and average daily totals of three to four hours during this period are the lowest of all capital cities. There is a steady rise towards the warmer months as the days become longer and cloudiness decreases. An average of over eight hours a day is received in January; however, the decreasing length of the day is again apparent in February, since the sunshine is then less in spite of a fractional decrease in cloudiness. The total possible monthly sunshine hours at Melbourne range between 465 hours in December and 289 in June under cloudless conditions. The average monthly hours, expressed as a percentage of the possible, range between 55 per cent for January and February to 34 per cent in June.

Wind

Wind exhibits a wide degree of variation, both diurnally, such as results from a sea breeze, etc., and as a result of the incidence of storms. The speed is usually lowest during the night and early hours of the morning just prior to sunrise, but increases during the day especially when strong surface heating induces turbulence into the wind streams, and usually reaches a maximum during the afternoon. The greatest mean wind speed at Melbourne for a 24 hour period was 22·8 mph, while means exceeding 20 mph are on record for each winter month. These are mean values ; the wind is never steady. Continual oscillations take place ranging from lulls, during which the speed may drop to or near zero, to strong surges which may contain an extreme gust, lasting for a period of a few seconds only, up to or even over 60 mph. At Melbourne, gusts exceeding 60 mph have been registered during every month with a few near or over 70 mph, and an extreme of 74 mph on 18 February 1951. At Essendon a wind gust over 90 mph has been measured.

There have been occurrences of thunderstorms in all months ; the frequency is greatest during November to February. The greatest number of thunderstorms occurring in a year was twenty-five. This figure was recorded for both 1928 and 1932.

Hail and snow

Hailstorms have occurred in every month of the year ; the most probable time of occurrence is from August to November. The highest number of hailstorms in a year was seventeen in 1923, and the greatest number in a month occurred in November of that year when seven hailstorms were reported. Snow has occasionally fallen in the city and suburbs ; the heaviest snow storm on record occurred on 31 August 1849. Streets and housetops were covered with several inches of snow, reported to be 1 ft deep at places. When thawing set in, floods in Elizabeth and Swanston Streets stopped traffic, causing accidents, some of which were fatal. One report of the event indicates that the terrified state of the Aboriginals suggested they had never seen snow before.

The means of the climatic elements for the seasons in Melbourne computed from all available official records are given in the following table :

MELBOURNE—MEANS OF CLIMATIC ELEMENTS

Meteorological elements	Spring	Summer	Autumn	Winter
Mean atmospheric pressure (millibar)	1015·1	1013·1	1018·3	1018·3
Mean temperature of air in shade (° F.)	57·8	66·7	59·5	50·1
Mean daily range of temperature of air in shade (° F.)	18·7	21·1	17·4	14·0
Mean relative humidity at 9 a.m. (saturation=100)	63	60	72	80
Mean rainfall (inches)	7·30	6·00	6·65	5·87
Mean number of days of rain	40	25	34	44
Mean amount of evaporation (inches)	10·28	17·34	8·13	3·79
Mean daily amount of cloudiness (Scale 0 to 8) (*a*)	4·9	4·2	4·8	5·2
Mean daily hours of sunshine	5·9	7·7	5·2	3·9
Mean number of days of fog	1·5	0·6	6·5	11·7

(*a*) Scale 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1965 to 1969. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological elements	1965	1966	1967	1968	1969
Mean atmospheric pressure (millibars)	1017·3	1017·2	1018·1	1014·5	1017·5
Temperature of air in shade (° F.)—					
Mean	59·3	59·3	59·5	60·2	59·5
Mean daily maximum	67·8	67·5	68·1	68·2	67·4
Mean daily minimum	50·9	51·1	50·9	52·1	51·5
Absolute maximum	106·9	102·8	105·2	110·6	101·6
Absolute minimum	32·4	32·9	34·2	35·2	30·5
Mean terrestrial minimum temperature (° F.)	47·9	48·4	48·6	49·6	49·6
Number of days maximum 100° F. and over	7	5	5	8	3
Number of days minimum 36° F. and under	10	7	4	3	3
Rainfall (inches)	23·24	26·81	13·06	20·96	24·60
Number of wet days	122	157	106	141	137
Total amount of evaporation (inches) (*a*)	44·87	47·08	55·15	59·56	56·60
Mean relative humidity (saturation = 100)	62	63	63	58	65
Mean daily amount of cloudiness (Scale 0 to 8) (*b*)	4·4	4·8	4·4	4·8	4·7
Mean daily hours of sunshine (*c*)	6·2	6·0	6·5	6·4	5·8
Mean daily wind speed (mph)	7·2	6·9	5·9	6·2	7·2
Number of days of wind gusts 39 mph and over	62	47	46	79	41
Number of days of fog	21	6	24	3	7
Number of days of thunder	9	6	3	12	8

(*a*) Since 1967 evaporation has been measured by Class A Pan.

(*b*) Scale 0 = clear, 8 = overcast.

(*c*) For 1968 and 1969 sunshine has been measured at Laverton.

Victorian weather summary 1969

January rainfall was below average throughout the State and combined with above average temperatures the conditions were favourable for bushfires. Numerous outbreaks did occur, but most were on a small scale—one notable exception was on 8 January when high temperatures and very strong winds caused eighty major fires which resulted in extensive property damage and loss of life.

The weather during February and March was mild but wet. In the Mallee and northern country February was the wettest on record and the two month totals in this area were the highest on record for any time of the year. Melbourne had its wettest February for 18 years and on 3 February a severe thunderstorm caused flash flooding of suburban drains. Fogs and frosts were prevalent in coastal and mountain regions in March.

April was cool and dry in most of the State although high rainfall in East Gippsland gave rise to floods on the Thomson River on 17 April—the first flood for the season. During May the weather continued cool although rainfall was above normal except in the north-east ranges and along the western border. Melbourne experienced its wettest May for 27 years and the second wettest on record. Minor flooding occurred in the last two weeks in East Gippsland and the first snow fell on 21 May. Fogs and frost were again quite widespread and Essendon Airport was closed for nearly 2 hours on 13 May because of thick fog.

In contrast to May, June was mild and dry except in the far east where moderate flooding occurred during the first week. Melbourne had its driest June for 111 years and this was the second driest on record. July and August continued mild and dry. The mean maximum temperature for July in Melbourne was the highest on record and the rainfall total for August was the lowest for 19 years. The August mean minimum temperature for Melbourne was the highest since 1911. Fogs and frosts were prevalent during the winter months.

The spring months were cool. In September Melbourne's mean temperature was the lowest since 1905. Rainfall in this month was only slightly above normal. October and November were mostly dry, although thunderstorms occurred on several occasions in October with frontal passages. Heavy rainfall in the last week of November brought totals close to normal; flooding occurred in Gippsland on 8, 16, and 29 November, and on 28 November further snow fell on the highlands.

December continued cool with almost average rainfall. On 11 December severe thunderstorms were reported from all parts of the State and in Melbourne severe damage in the suburbs resulted from local wind squalls in excess of 80 knots and hailstones up to 1 inch in diameter. Minor flooding occurred in the beginning of the month in Gippsland.