1

PHYSICAL ENVIRONMENT

Molluscs of Victoria

Introduction

The molluscs are soft bodied animals without internal bony structure and typically have an external shell that protects the body. The body has no external appendages and their means of movement is by a flat muscular plate called a foot. The actual shape and method of use of this foot is variously modified in the major groups or classes of molluscs.

They are commonly called " Shellfish ", which is a suitable descriptive name, but unfortunately often used in a wider sense to include the crabs and crayfish and even sea urchins, etc.—animals which are far removed in body organisation from the molluscs and whose " shells " are in fact not shells at all, but the calcium reinforced external layer of the body.

The typical mollusc has an elongated body with a head region with eyes, one or two pairs of tentacles, and a mouth leading into the digestive tract. There is no brain but nerve ganglia co-ordinate the body functions. The mouth is furnished with jaws and a long ribbon composed of horizontal rows of rasping teeth, called the radula. The number, shape, and size of the radula teeth vary considerably in the various families. Herbivorous molluscs, such as the land snails, have a radula formed of rows of many similar small teeth which when magnified remind one of the carpenter's rasp. On the other hand, each row of teeth of the radula of the carnivorous Octopus consists of a few large, sharp, and variously cusped teeth suitable for tearing the flesh of its victims.

Behind the head the molluscan body is sac-like without appendages. In the more primitive forms the alimentary canal is a straight tube consisting of stomach and intestines and with a large digestive gland or liver. However, this primitive form is modified in most groups and in the snails the entire visceral mass becomes twisted into a hump on the animal's back.

The shell is typically large enough to enclose the whole body and is coiled to conform to the spiral of the visceral mass. It is secreted by the outer skin or mantle of the animal and is laid down in three parts. The outer two are secreted by the cells on the borders of the mantle, and the shell lining layer, which may or may not be pearly (nacreous), is laid down by the external cells of the entire mantle. The minute embryonic shell is formed very early in the mollusc's life and as the animal grows, the cells of the edge of the mantle add to the lip and the surface of the mantle lines the additional area with the inner calcareous layer to conform to the older portion of the shell.

Molluscs usually have separate sexes but in some forms the male and female organs are both carried in the one animal which is said to be hermaphrodite. Eggs are produced and these may hatch either into miniature adults or, in many marine forms, as free swimming larvae (veliger) which float and swim in the water before settling down to grow into the more sedentary adult.

Classification

Classification is a man-made device to assemble the knowledge of the natural world in some sort of order. Aristotle was one of the earliest thinkers to attempt the classification of natural objects, but it was not until the 17th century that the Swedish naturalist, Carl Linnaeus, worked out the system for the animal and plant kingdoms upon which all modern classification is based. He divided the animal kingdom into a number of major groups or phyla ; within each phylum he made smaller groups or genera ; and within each genus he grouped species of animals that he considered related. Since Linnaeus's time increased knowledge and understanding have enabled many additions and alterations to be made to his original classification but the foundation was his.

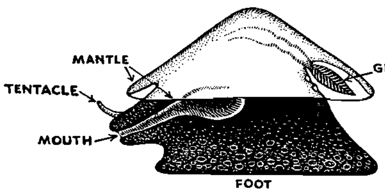
The Mollusca is a phylum or major group of the animal kingdom and it is divided into six sub-groups or classes based on the differences of external and internal anatomy of the animals placed within them.

Ancestral molluscs had long been known as fossils in rocks laid down in the Cambrian sea. Then, in 1956, the Danish deep-sea research vessel " Galathea " dredged living specimens from the ocean deeps off the West Coast of Mexico thus allowing zoologists to study them in the flesh. As already known from the Cambrian fossils, they are limpet-like animals with a single cap-shaped shell covering a rounded body with a head. The undersurface of the body has a long muscular plate or foot which is used for locomotion and attachment. The upper surface of the body is covered by the mantle which secretes the shell. Lying between the foot and the mantle on each side of the body there are five gills. The internal anatomy is typically molluscan.

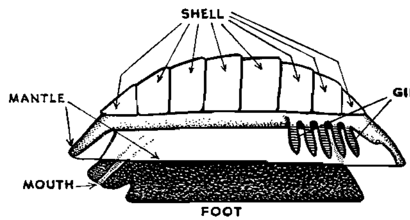
The fossil mollusc known from the Cambrian had been considered distinct from the remainder of the molluscs and the " Galathea's " discovery enabled them to be classified in a separate class—**MONOPLACOPHORA.** As zoologists considered the " Galathea " discovery to have certain special features distinct from the fossils it was given a special generic name *Neopolina* and a species name *galathea.* Since its discovery further deep dredging in other parts of the ocean has produced a number of animals all of which bear the generic name *Neopolina* but with different species names to indicate that they show constant small differences from the original " Galathea " specimens.

Classes of Molluscs

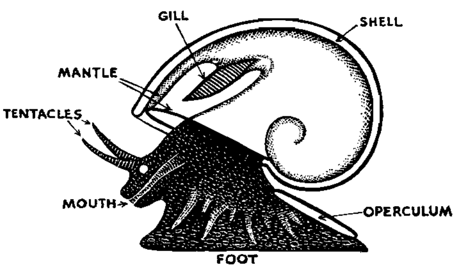
Apart from the **MONOPLACOPHORA** there are five classes of living molluscs and these classes have, in some instances, been given several names by different authors. However, zoologists have agreed that unless it must be rejected for some very pressing and valid reason,



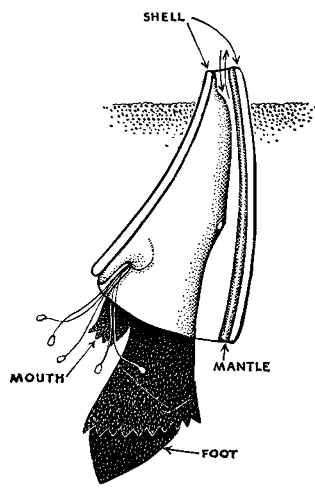
Monoplacophora



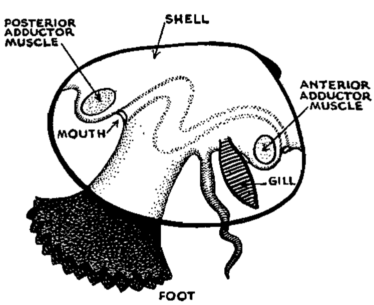
Amphineura



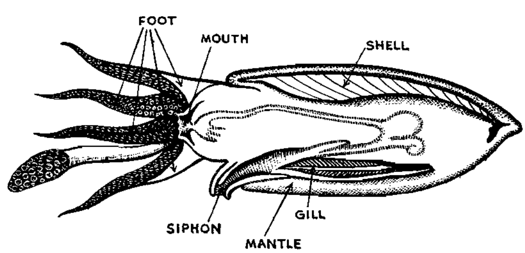
Gastropoda



Scaphopoda



Bivalvia



Cephalopoda

FIGURE 1.—Diagrams of Molluscs.

the name first given to an animal or group of animals is the official one. Thus, the correct name will be used as the heading for each class in this article, but the other names which have been applied to it will be listed in brackets to help correlate the information here with other books on molluscs.

Most molluscs are bottom dwellers either crawling on the surface or burrowing into the substrate. So the form of the foot is very important and each class has at some time been given a name which refers to this particular organ. Thus a number of the names are applied to the classes ending with the word " poda " or foot.

Class **AMPHINEURA** (Loricata). The common name for these animals is Chitons or Coat-of-Mail shells. They are a very uniform group of bottom dwellers with eight parts or interlocking valves forming the flat plate-like shell that covers the back of the elongated body of the animal. The valves are of three types, the head or anterior valve, six central or median valves, and the tail or posterior valve. The valve sculpture and colour pattern varies from species to species. The valves are held together by a leathery girdle which surrounds them and in which their lateral edges (insertion plates) are imbedded. The upper surface of the girdle may be covered with scales, calcareous spines, spicules, hairy processes or a combination of two such coverings. The shell with the girdle completely covers the dorsal surface of the animal.

At the anterior there is a small head with a mouth, tentacles, and usually, eyes and from it stretches along the undersurface a muscular foot on which the animal crawls and which is also suctorial so it can attach itself to any firm surface.

The series of gills lie in a groove on each side between the foot and the girdle. The anus and reproductive organs open into this groove or mantle cavity, the former at the posterior. The sexes are separate, the products of reproduction are discharged into the water where fertilisation takes place. The young have a free swimming veliger stage which, after a varying length of time metamorphoses into a miniature adult.

The class **AMPHINEURA** is divided into two sub-classes, **POLYPLACOPHORA** [Loricata, Crepipoda (creeping footed)] and the **APLACOPHORA.** The latter is a very specialised deep water group, members of which have lost their shell and become worm-like in form. They are not recorded from southern Australia and so do not concern us. The Polyplacophora are the true chitons and most of them occur on rock surfaces from mid-tide level down to several fathoms. A few are mud dwellers while others are specialised for life attached to the stems of sea grasses and a very few species have been found at great depths in the ocean.

The chitons are a comparatively small and uniform herbivorous class which has been divided into two Orders, the **Lepidopleurida** and the **Chitonida**; most Victorian species belong in the latter group. There are a number of families, members of which are separated from each other by the slits on the insertion plates and the scales and spicules on the girdle.

Class **GASTROPODA** (Stomach Foot) (Univalvia). Snails and slugs are the largest and most varied class of molluscs, members of which have adapted themselves to almost every type of habitat both on land and in the sea. Thus we find snails living over most of the earth's surface from deserts to swamp, streams and lakes, as well as in trees. Marine forms inhabit all sections of the ocean.

The typical gastropod has an elongate body with a well developed head with tentacles and eyes which may be sessile or stalked and a mouth. The ventral surface of the body has a muscular foot running its entire length. The organs—digestive, reproductive, etc.—are coiled into a spiral, on the dorsal surface, which is enclosed in, and is protected by, the shell. The entire body may be withdrawn into the last whorl of the shell and in many marine and some land snails the opening can be sealed with a horny or calcareous plug (operculum) which is attached to the posterior dorsal surface of the body.

The typical shell is a cone coiled round a central axis as a spiral. This central axis is called the columella and at the anterior end of the shell forms the inner lip of the mouth opening. It may be drawn out to form, with the anterior edge of the mouth, a canal (anterior canal) sheathing the proboscis. If, as in some species, there is a notch between the outer lip and the body-whorl, this is called the posterior canal. The shape of the spiral of shells varies considerably as also does the form of the mouth ; the latter may be small and round, or if the body-whorl is large, it may extend for the whole length of the shell. The lip may be thickened or sharp and may or may not be indented with teeth. At the apex of the spiral is the embryonic shell (protoconch) and it often has a different form and ornament from the adult shell.

The snail-like form has been variously modified in several major sections of gastropods. The coil of the shell may be comparatively small with the body whorl very much enlarged as in the family HALIOTIDAE (Abalones–Mutton fish or Ear Shells) or it may be almost or completely obliterated as in the limpets with their flat or conical-shaped shell. The slugs, both marine and land forms, have completely lost their external coiled shell though some forms retain a small vestigial shell beneath the mantle. The shell-less marine slugs (Nudibranchiata) are variable in form and colour.

As well as the typical coiling of the shell and visceral mass, all gastropods have some time in their ancestral history (phylogeny) undergone *torsion*, a very important event in gastropod history. It is a process by which the organs are twisted through a 180° arc in relation to the head and foot and the mantle cavity is brought to the front of the body. The larval gastropod has the asymmetrical retractor muscle attached to the shell on the right side ; with the twisting at torsion, this muscle pulls the bulky visceral mass over to the left side of the animal in a ventral position and the mantle cavity at the same time is moved to the right, until it opens forward in a vertical position. Everything behind the neck is thus reversed in position. The value of torsion to the animal has been argued by different authors, but a recent suggestion points to the following advantages : it allows the sense organs of the head to make small adjustments of position ; the gills are bathed by undisturbed water from the front of the animal ; and the sense organ (osphradium) over the gills samples the environment into which the animal is moving.

As a result of torsion the anus lies in front and the animal cannot grow longer ; as compensation for this the viscera began to bulge in a dorsal hump which was most compactly disposed of in a spiral. Hence the visceral spiral is covered by a spiral shell. In the sub-class Opisthobranchiata (sea-slugs, etc.) the shell and mantle cavity are reduced or lost and with them torsion and spiral coiling have disappeared. The body is reorganised bilaterally in the form of a slug. In the terrestrial gastropods, the gill is replaced by a vascular lung still situated in the mantle cavity.

The gastropods are the largest class of Mollusca and show such great diversity of structure and adaption that they cannot be fitted into neat patterns of classification. They have been divided into three primary divisions or sub-classes **PROSOBRANCHIATA, OPISTHOBRANCHIATA,** and **PULMONATA.** Each of these are again divided into orders, families, genera, and species.

The Prosobranchiata are the most numerous and diverse. Its members have become adapted to live on land and in fresh water as well as in the sea, but most of them are marine and the first of the three orders. **Archaeogastropoda,** as its name implies, contains the most primitive living gastropods, all of which are marine and mostly herbivorous grazers, although a few species live on sponges and some are detritus feeders. Most members of the order are of medium to large size and are intertidal or shallow water dwellers and so are generally well known. There are ten families of which the HALIOTIDAE or Ear Shells, the two families of limpets ACMAEIDAE and PATELLIDAE, and the TROCHIDAE and TURBINIDAE are the most common and easily recognised. The TURBINIDAE and TROCHIDAE both have spiral shells but are easily separated from each other as the TROCHIDAE have a circular horny operculum while in the TURBINIDAE it is thick and calcareous.

The **Mesogastropoda** show great diversity of form and its members have attempted every adaption produced by the more specialised opisthobranchs and pulmonates. There are forty families of which only a few can be mentioned. The LITTORINIDAE are unspecialised with a top-shaped spiral shell, many of its members adapted for life at and above high tide where desiccation and changes of temperature are at their maximum. The long slender spiral shell of such families as the CERITHIIDAE and TURRITELLIDAE are adapted for life on sandy or muddy bottoms where they obtain their food by scavenging or feeding on soft bodied animals in the substrate. One family of slender spired shells, the EULIMIDAE, are ectoparasites on Echinoderms, starfish, sea urchins, etc., as is one genus *Thyca* of the limpet-shaped family CAPULIDAE which lives on star-fish. The large and most specialised members are the carnivorous families CYMATIIDAE or Rock Whelks and the CASSIDIDAE or Helmet Shells.

Two families have become pelagic : the IANTHINIDAE or Violet Snails construct a buoyant raft of a tough transparent bubble-like secretion from the foot and attach themselves to it or they may ride attached to the raft-like siphonophore *Velella* on which they feed. The members of super-family HETEROPODA are also planktonic but instead of floating have become adapted for rapid swimming. The NEOGASTROPODA are specialised carnivorous forms which inhabit both rocky shores and soft sediments into which they burrow. The MURICIDAE (Murex) whose members are mostly rock dwellers show great diversity of shell shape and ornament. The family BUCCINIDAE is one of the largest families in number of species and actual size, its members showing great diversity of form. The tropical family VOLUTIDAE is represented in Victorian waters by several species living in deeper waters of Bass Strait including the False Baler.

In the **OPISTHOBRANCHIATA** the shell and mantle cavity have become greatly reduced or lost. Torsion and coiling disappear in the more specialised forms, the body is reorganised bilaterally into the slug-like form.

There are three distinct forms of Opisthobranchs : the burrowers which retain a thin external shell, the naked and flattened slug-like forms which are often beautifully coloured either to blend with their environment or flash a warning to would-be predators, and the swimmers or sea butterflies (PTEROPODA).

The sub-class **PULMONATA** have the mantle cavity modified into a lung and most of the land and fresh water molluscs belong here. The order **Basommatophora** has the eyes at the base of the tentacles. It contains the aquatic pulmonates, both fresh water and marine, the marine representatives being confined to one family SIPHONARIIDAE, limpet-like and entirely intertidal. The fresh-water forms are more diverse and comprise both snail-like and limpet-like forms. The order **Stylommatophora** has two forms of tentacles with the eyes carried at the tip of one pair. They are almost wholly terrestrial with a large number of snail-like species varying from the minute to large size as well as slugs of several distinctive types.

Class **SCAPHOPODA** (Wedge Foot). Tusk shells are a small and very uniform group of sand burrowers. The shell tapers like a tall conical tube but with an opening at both ends—hence the name " tusk shell ". The shell lies obliquely in the sand with the broad end containing the head and foot at the bottom. The foot is wedge shaped and can be extended and plunged into the sand to draw the animal by contraction. The simple head has several bunches of slender retractile tentacles which explore the surrounding sand for foraminifera, very small molluscs, etc., which adhere to their expanded tips and on which the tusk shells feed. The mouth is furnished with a strong radula.

The mantle forms a complete tube and both the inhalent and exhalent currents pass through the narrow posterior end, and respiration takes place through transverse folds in the lining of the mantle. There is no gill. The sexes are separate ; reproductive products are discharged into the water where fertilisation takes place.

A number of species of tusk shells are found in southern Australian waters but because they occur only below low water and usually in several fathoms they are rarely collected and then only by dredges and grabs. There are two families of tusk shells : the DENTALIIDAE with a shell tapering uniformly from the broad anterior end to the narrow posterior apex, with at least a portion of the shell sculptured, and the second family SIPHONODENTALIIDAE which has the shell inflated near the middle and the mouth end contracted.

Class **BIVALVIA** [Lamellibranchiata ; Pelecypoda (pelecy = wedge, poda = foot)]. The typical bivalve has two symmetrical shell valves joined along the dorsal line by the ligament, an elastic connecting strip formed of uncalcified conchiolin, the organic substance of the shell. The valves are held together by two muscles, the anterior and posterior adductor muscles ; when these relax, the shell is opened by the elasticity of the ligament. The ligament usually lies slightly behind, but may occur in front of the earliest or embryonic part of the shell called the protoconch or umbo. It may be placed on the dorsal side of the hinge and therefore be visible on the outside of the shell when it is said to be external or it may be placed on the ventral side when it is said to be internal. The shell usually develops interlocking teeth along the hinge line, which prevent fore and aft movement of the valves.

The shell valves enclose the much modified animal which has completely lost the head, the buccal mass, and the radula. The gills have been developed as aids to feeding in addition to their respiratory function. The cilia (small hairs) of the gills draw into the large mantle cavity a powerful water current and the fine food particles contained in it are strained out by the cilia and are carried forward to the mouth.

Most bivalves are sedentary. Many forms have a gland either behind or at the base of the foot which produces tough threads of tanned protein, the byssus, which is used to anchor the animal to the substratum for long periods or permanently. Others are firmly cemented as, for example, oysters. The foot is wedge-shaped and muscular and can be elongated and thrust forward to aid the animal in locomotion. In burrowing forms it is thrust forward into the sediments and then contracted to haul the animal after it. In bivalves, the mantle flaps enclose the whole body and secrete the right and left shell valves, respectively. The mantle is attached to the shell valves near the margins along a line called the pallial line.

In the less specialised forms the mantle cavity is wide open and the water current enters in front and passes out behind. The higher forms and in particular burrowers the mantle margins become fused to a greater or lesser extent as the intake and intrusion of the water current is posterior. The inhalent passes through a ventral and the exhalent current through a dorsal opening in the fused mantle edge. The lips of these apertures elongate with increased depth of burrowing and develop a muscular system that enables them to be elongated or contracted. They are then termed siphons and the line of attachment of the mantle to the shell is embayed where they are attached to the shell. This embayment is called the pallial sinus and its shape varies from species to species but is constant in each individual species and is often used as a diagnostic feature in classification.

The basic pattern of the bivalves is very distinct though their form and habit are diverse and their classification has always posed difficulties to the zoologist. Originally two main bases of classification were used, employing the form of either the gills or the hinge. Neither is entirely satisfactory and later workers tried a combination of the two structures but still did not altogether achieve a satisfactory arrangement. Recent workers have tried to blend evidence from many characteristics both anatomical and ecological with the result that three major lines of development are postulated.

The first or so-called normal branch contains the least specialised members of the class. Most of its members lie freely at or near the surface though a number burrow actively in sand or mud. The members of this branch comprise part of the sub-class **EULAMELLIBRANCHIA,** in particular the orders **Schizodonta** and **Heterodonta.** In the former are placed the very interesting family TRIGONIIDAE and the several families of fresh water mussels. Trigoniidae is mainly a fossil family with its only recent representatives living in temperate Australian seas, one species *Neotrigonia margaritacea* being found in Westernport Bay. The order Heterodonta is a large one containing many families whose members are common intertidal and shallow water inhabitants of sandy and muddy situations. These are " typical " bivalves : the Heart Cockles (CARDIIDAE), Venus Shells (VENERIDAE), Trough Shells (MACTRIDAE), Wedge Shells and Pipi (DONACIDAE), and Tellins (TELLINIDAE).

The second or sessile branch are the oldest in the sense of their history in geological time with their ancestry in the Palaeozoic and Mesozoic. These are the orders **Taxodonta** and **Anisomyaria,** and the former order contains the comb-toothed families of Arca shells (ARCIDAE), and Dog Cockles (GLYCYMERIDAE). The **Anisomyaria** contains the Marine Mussels (MYTILIDAE), the Scallops and Pectins, etc., (PECTINIDAE), and the Oysters (OSTREIDAE), to mention the most usually seen families.

The third group, is the deep-burrowing branch, many of whose members have become modified for deep penetration of the substrate with the sacrifice of mobility. It is here that the specialised orders **Adapedonta** and **Anomalodesmata** are placed. The first of these orders contains the various families of sand and rock borers and the wood boring family TEREDINIDAE which has great economic importance due to its members' destruction of wharf piling and other wooden structures. The **Anomalodesmata** contain such interesting and specialised burrowers as the Watering Pot Shells (CLAVAGELLIDAE) and the Rock Shells (CLEIDOTHAERIDAE) which do not burrow but cement themselves to stones and rocks or even other shells, the cementing valve so growing on to the substrate as to reproduce its contours exactly. The White Rock Shell *Cleidothaerus albidus* (Lamarck) is common in Westernport and Port Phillip Bays.

Class **CEPHALOPODA** (cephalo = head, poda = foot). Octopus, Cuttlefish, and Squids are the most highly evolved molluscs with the ability to move rapidly. The body is elongated dorso-ventrally, the head with well developed eyes, mouth, and tentacles is situated on the ventral side, as opposed to the blunt or pointed dorsal surface. The name of the class was given to describe the modification of the foot into two organs. The prehensile tentacles are situated round the head so that the mouth lies in their centre. The number varies in the different orders ; Pearly Nautilus has a large number of tentacles while the Octopus has eight approximately equally developed arms and the Squids and Cuttlefish eight short and two long tentacular arms.

The second organ is the funnel which lies behind the head on the posterior side of the animal and controls the exit of water from the mantle cavity and enables the animal to produce a strong jet which is used as a means of locomotion.

The shell in most modern cephalopods is either internal or lost but like their extinct ancestors, the Nautilus has a last external shell coiled in a plane spiral. As the animal which occupies only the last portion of the shell grows and enlarges the shell it divides the earlier part by septae into chambers which are filled with gas to give the animal buoyancy, the animal itself only occupying the last chamber.

In modern cephalopods without an external shell the visceral hump is covered by the muscular mantle. The body is streamlined in squids and cuttlefish and in the former the dorsal surface ends in a pair of fins, in the latter the fins run along the sides of the body. The two gills are situated in the mantle cavity, the water current that bathes them being produced by the contraction of the muscular mantle. The expulsion of this current is controlled by the funnel which on contraction of the mantle produces a stream of such force that jet propulsion has become the characteristic means of locomotion. In some forms, particularly from deep water, swimming may be by pulsation of a web running between the arms.

Almost all cephalopods, with the exception of *Nautilus,* have an ink sac which produces a melanoid pigment. This sac is a diverticulum of the rectum just inside the anus and on stimulation it releases a dense cloud of " ink " which is used as a smoke screen and so enables the animal to dart away unnoticed.

In Victoria, there are only a few commonly seen cephalopods, though a number of others are recorded as intermittent visitors to these shores. This is mainly due to the majority of squids and cuttlefish being open ocean pelagic species which wash ashore occasionally and are not normally collected unless special methods are used. Octopods and some cuttlefish are bottom shallow water dwellers and these are observed regularly by visitors to beaches and hooked by fishermen operating in shallow water.

Seven families are represented by the common Victorian species as follows:

SPIRULIDAE. The sole member of this family is the Ram's Horn Shell —a small open ocean creature with a coiled external shell hanging free at the posterior end of the body and held in position by two mantle flaps. The animal is never seen on Victorian shores but the fragile white shells are washed up in large numbers on ocean beaches from time to time.

SEPIIDAE or Cuttlefish are like the Spirula best known to the beachcomber by the flat calcareous internal shell which, on the death and disintegration of the animal, floats away and is often washed ashore. The shells or cuttlebones of a number of species are continually washed on to Victorian ocean beaches. The largest and commonest species *Sepia apama* Gray, 1849 is often taken alive by seine nets or close in shore by rod and line fishermen and is used and sold as bait. It has a broad strong " bone " which is common on many beaches even within Port Phillip. The animal is distinguished by the narrow fin which runs the length of the body on each side.

LOLIGINIDAE. The Calamaries are elongate open ocean species and some grow to a large size. The internal shell is reduced to a chitonous pen which helps to support the body. Two species are fished commercially in Victoria, the Southern Calamary *Sepioteuthis australis* Quoy and Gaimard, 1833 with the fin at the posterior end of the body and Etheridge's squid *Loligo etheridgei* Berry, 1918 in which the tail fin extends approximately two-thirds of the way up the body.

OMNASTREPHIDAE or Squids also have a chitonous pen but are distinguished from the calamaries in having the fins extending the length of the body on either side. Gould's squid, *Nototodarus gouldi* (McCoy, 1888), the commonest Victorian species, is fished in Bass Strait. It has a narrow spoon-shaped pen.

OCTOPODIDAE. There are five common Octopus in Victorian waters including the small blue and gold spotted species *Hapalochlaena maculosa* (Hoyle, 1883) which is notorious because of its very potent and curious venom. It is an inshore species living under stone and in the dead shells of oyster and scallops.

ARGONAUTIDAE or Paper Nautilus are octopus-like animals. The dorsal arms of the larger female have expanded glandular membranes at their extremities which secrete and hold a delicate calcareous shell in which she deposits and carries her eggs. Paper Nautilus are all pelagic species but the common Paper Nautilus *Argonauta nodosa* Solander, 1786 is blown ashore in large numbers along the Victorian coast from time to time.

Ecology of Molluscs

The molluscs are inhabitants of all types of environments from the mountain tops to the depths of the sea. Thus they can be classified by their ecology into the inhabitants of the three major habitat types—land, fresh water, and marine—as well as on their body structure.

The various classes as already described show unequal preferences for each of these habitats. The Chitons, Tusk Shells, and Cephalopods are all marine, the Bivalves are marine and fresh water, and the Gastropods are found in all three types of environment and have become equally well adapted to each of them.

Terrestrial Molluscs

All molluscs were originally marine so the terrestrial environment has necessitated the greatest degree of modification which required that the mantle become modified for use as a lung to breathe air and absorb oxygen from it. Such modifications have arisen not only in the sub-class **PULMONATA** but also in a number of Prosobranch families with the result that there are many lines of land operculate snails of the order **Mesogastropoda.**

The terrestrial pulmonates are a fairly uniform group which do not vary greatly in appearance from the picture conjured up by the term " Land Snail or Garden Snail." This is an animal with a coiled shell, usually but not always, in shades of brown and a typical snail-like head bearing a pair of tentacles and two eyes which may be stalked. The shape of the coiled shell varies considerably from the conical to the planorbital (flat spiral) or may be reduced to an internal plate or be absent altogether in the slugs.

The best known land snail to most people is the garden snail *Helix aspersa* Müller, 1774 which is not a native of Victoria but was introduced, probably with garden plants, from England many years ago. Conditions suited it and it has spread throughout the urban areas of southern Australia and become a pest in most gardens.

There have been several other introductions of snails and slugs not only from Britain but from southern Europe as well. In fact all the slugs found in Victoria are introduced, there being no true slugs native to Victoria. Perhaps the most successful of all these introductions is the white snail or coast snail *Theba pisana* (Müller, 1774) which has established itself from west of Wilson's Promontory along the whole coast line to Geraldton in Western Australia. In many districts it is a pest denuding the coastal vegetation and occurring in such quantity on pastures that sheep will not graze.

The native land snails, unlike the introduced species, disappear with the advances of civilisation and are only found in areas where the native vegetation has not been greatly disturbed. The majority of Victorian species are very small snails of the family ENDODONTIDAE, most being less than $\frac{1}{4}$ inch in diameter. These small snails are inhabitants of bushland living among decaying leaves, under logs and stones, and such material as affords them shelter. Because of their small size and cryptic nature, these snails are rarely observed.

But there are a few larger species which are readily apparent to observers in their environment. The largest and commonest are two carnivorous species which inhabit the wetter areas of the Dividing Range. They both belong to the genus *Paraphanta* and have black, flatly coiled shells. The eastern species, found in the Dandenong and Warburton Ranges, is slightly the larger with a shell approximately $1\frac{1}{2}$ in across and a grey animal with a rose coloured foot. The western species, found in the Otways, has a shell 1 to $1\frac{1}{4}$ in in diameter and the animal is grey. Two other snails found with *Paraphanta* are the related species *Helicarion* and *Cystopelta*—the former with a much reduced horny shell and the latter without a shell at all. In eastern Victoria the large tropical rain forest genus *Hedleyella* is represented by the conical brown snail—*H. kershawi* (Brazier, 1871) found mostly in the drier and higher forest country and in particular in Murray pine stands.

The drier lower forest country is the home of the Hairy Shelled Snail *Chloritis victoriae* Cox, 1868 and the carnivorous *Strangesta* species belonging to the family PARAPHANTIDAE. Undisturbed grasslands, both coastal and inland, are often inhabited by the species *Austrosuccinea australis* (Ferussac, 1821) which has a horn coloured conical right hand spiral shell. These snails are gregarious, occurring in large numbers in suitable conditions.

Fresh-water Molluscs

The members of two classes of molluscs, bivalves and gastropods, have adapted themselves to the fresh-water environment. Most of the gastropods belong to the pulmonate order **Basommatophora** and have returned to the aquatic existence. The Pulmonate lung is an ideal organ for both aerial and aquatic respiration and so many members, who are to a certain degree amphibious, live in the water but come to the surface at regular intervals to recharge the air breathing lung.

Most Australian species exhibit this intermediate state which enables them to survive in semi-arid summer conditions when smaller water courses and pools dry up.

There are a number of very small aquatic gastropods including fresh water limpets which are rarely seen. Amongst the larger species there are several members of the genus *Physastra* which have the typical snail like animal with a head bearing a pair of thin tentacles. The shell has a left hand spiral which immediately distinguishes this group of snails from the LIMNAEIDAE.

This latter family has great economic importance as most of its members are intermediate hosts for parasitic flat worms or flukes. The liver fluke of sheep *Fasciolaria hepatica,* one of the worst scourges of the industry, has as its intermediate host the very wide spread and variable species *Limnaea tomentosa* Pfeiffer, (1855) which occurs throughout eastern Australia, Tasmania, and New Zealand, but has not been recorded west of the Nullarbor Plain. This shell is approximately one-half inch in length and oval in shape. A second and larger species is *Limnaea lessoni* Deshayes, 1830 with an inflated shell. This latter species prefers stagnant or slow running water and is economically unimportant as it is not a host for liver fluke.

In the Murray River in north-western Victoria there are two species of the Prosobranch family, VIVIPARIDAE, a truly aquatic family whose members retain their gill. As the family name implies, these snails are ovoviviparous, brooding the eggs in the mantle cavity until they hatch and the young emerge from the mother as miniature adults.

Several families are represented by the fresh-water bivalves. Most species are small and insignificant. All the large species belong to the family MUTELIDAE, one of the three families grouped in the super-family UNIONACAE. The commonest Victorian species is *Velesunio ambiguus* (Smith, 1881) a large rounded mussel growing to about 3½ in with a blue-black periostracum or outer skin. It is common throughout the streams and swamps of Victoria and was used extensively by the aborigines for food.

Marine Molluscs

The molluscs originated in the sea and, as one would expect, the greater proportion of them lives in the sea, the majority of members of all the classes being marine and the cephalopods, chitons, and tusk shells exclusively so. In fact, they have colonised the sea from the ocean depths to the splash zone above high tide mark. Naturally with such a wide variety of conditions operating the animals have become adapted to live in one particular habitat. Thus the marine environment can be divided into a number of ecological units based on bottom type, depth, etc.

Intertidal

The intertidal zone affords the greatest amount of variation in environment within a limited space. As the tide rises and recedes no two horizontal strips are exactly alike and the animals inhabiting it have become very sensitive to the changes. Each species has adapted itself to a particular intertidal level. Animals living at or near high tide level must be able to withstand desiccation or protect themselves in some way from dehydration, while those at the lower tidal limit are usually uncovered for only a few minutes at each low tide. As a result of this there are changes of species every few inches from the high tide line down the shore.

Rock Platforms

The fauna and flora of rock platforms have been studied very intensively by biologists and the knowledge so gained has enabled the classification of the shoreline to be made into climatic zones. The Victorian shoreline falls within the temperate zone but is particularly interesting as three ecological Provinces meet within its area. These are the temperate eastern Peronian, similar western Flindersian, and the cool temperate Maugerian. Because all these Provinces are within the temperate most of the species have a horizontal range over the whole area. However, there is also a limited number of species that have become so selective that they are confined to a smaller area where conditions which are suited to their narrower range of adaptability operate. The deciding factor in most instances appears to be temperature. Sea temperature is not necessarily a reflection of atmospheric temperature but is also influenced by depth of water, proximity to land, and warm and cold currents.

The highest zone of a typical rock platform is the Splash Zone above high tide which is only wetted by the spray from waves breaking on the shore. The vertical extent of the Splash Zone varies with the contour of the shore and the degree of wave action to which it is subject. A locality of high cliffs and ocean swell may receive spray as high as 80 ft above high tide mark, while in a sheltered bay the spray may not reach more than 2 or 3 ft even under storm conditions. In this zone the animals have to withstand drying for considerable periods and at certain times of the day will be subject to the heat of the sun as well. Two species of mollusc are adapted to these conditions, the Banded and the Checked Australwink, *Melarapha unifasciata* (Gray, 1826) and *M. praetermissa* (May, 1908). A third species, the Tubercled Noddiwink, *Nodilittorina pyramidalis* (Quoy and Gaimard, 1833) of the Peronian Province just reaches Victorian shores at Mallacoota.

At high tide mark another littorid, the Striped-mouth Conniwink, *Bembicium nanum* (Lamarck, 1833) is found on open ocean platforms, but in more sheltered bays and inlets the Black-mouthed Conniwink, *B. melanostoma* (Gmelin, 1791) replaces it.

Above mid-tide level there are several gastropods : the Ribbed Top Shell *Austrocochlea constricta* (Lamarck, 1822) can withstand the full exposure of sun and wind on an exposed platform but the Wavy Top Shell, *A. concamerata* (Wood, 1828) and the Black Nerite Crow *Melanerita melanotragus* (A. E. Smith, 1884) tend to find partial shelter in cracks and crevices during low tide. Scattered with these and ranging up into the *Bembicium* are found the Siphon Shell *Siphonaria diemenensis* Quoy and Gaimard, 1833.

At approximately mid-tide level on Victorian open ocean platforms there are sheets of the ribbed mussel *Brachidontes rostratus* (Dunker, 1857). This mussel likes the surge and splash of the waves of the ocean so it does not occur to any extent in the bays and inlets, and where the wave action is extreme it may be torn off the rock to which it is normally held by its byssus. At this level is found the Ribbed limpet *Patelloida alticostata* (Angas, 1865) easily distinguished by the black horizontal lines between the ribs. Also in the area, just above mid-tide level, the small Black Mussel *Modiolus pulax* (Lamarck, 1819) often establishes itself. It may occur in sheets but more often shows a preference for small shallow cracks particularly adjacent to sand or where small areas of sand have become washed on to the rock platform.

These mussels afford shelter for a number of other molluscs and a search among the clumps will reveal the limpets *Montfortula rugosa* (Quoy and Gaimard, 1834) and *Notoacmea alta* Oliver, 1926, and the small Southern Kellia *Kellia australis* (Lamarck, 1818), while the Dog Winkle *Dicathais textilosa* (Lamarck, 1822), the lineated Cominella *Cominella lineolata* Lamarck, 1809, and the Mussel Drill *Bedeva parvae* (Crosse, 1864) all feed upon them.

At the lower tidal level the Variegated Limpet *Cellana tramoserica* (Sowerby, 1825) and the Siphon Shells *Siphonaria funiculata* Reeve, 1856 and *S. tasmanica* T. Woods, 1876 occur, and the Turban Shell *Subninella undulata* (Solander, 1786) is often present though it usually prefers sheltered positions in cracks or amongst weeds. At low tide level the Scaley Limpet *Patelloida peroni* (Blainville, 1825) and the chitons *Poneroplax albida* Blainville, 1825 and *P. costata* Blainville, 1825 are found and just below low tide amongst the holdfasts of the giant seaweed *Durvillea potatorum* is found the Liver-coloured Limpet *Patelloida victoriana* Singleton, 1937. In positions of extreme exposure some of these molluscs may be absent because they are not able to remain attached to the surface when wave action is intense. In such places there may be only limpets, siphon shells, and chitons which can clamp down hard on the rock surface and allow the waves to wash over them.

In the rock pools which have water in them even at low tide and have a growth of algae that afford shelter there are often found single specimens of species that normally live below low tide level in deeper water off-shore. Also there are the regular rock pool inhabitants including the Checkered Top Shell *Austrocochlea odontis* (Wood, 1828) and Adelaide Top Shell, *A. adelaidae* (Philippi, 1849), the various species of Kelp Shells of the genera *Calliostoma, Clanculus*, etc. Such pools are also often inhabited by species of sea slugs of the Order **Nudibranchiata**; these parrots of the mollusc world are elusive creatures as their larval stages are free swimming and the adults have only a short life span so that a species found in a rock pool today may not be there on a visit a few weeks later.

So far the discussion has been confined to rock platforms with comparatively smooth surface, but in bays where the wave action is normally not too strong, the lower part of the platform towards low tide mark and beyond is often covered with rocks and boulders. These provide shelter for a wealth of animals that do not like to be exposed to the daylight and that require to be either in the water or in a very moist atmosphere. It is here that the various species of small cowries of the genus *Notocypraea* are found as well as many chitons, mostly of the family *Ischnochitonidae*. Cone shells *Floroconus anemone*

(Lamarck, 1810) are often abundant. As in the rock pools, there may be visitors from deeper water including nudibranchs of various species. Few bivalves occur on rock platforms but there are several species that like the shelter of such stones. These include the Hairy Ark *Barbatia pistachia* Lamarck, 1819, and the Milk Stone *Pullastra galactites* Lamarck, 1818. The small Southern Kellia *Kellia australis* which is common sheltering amongst the *Brachydontes rostrata* will also be found here.

In sheltered bays and inlets the water may carry too much sediment or changes of salinity may be too great for some species while others have become so adapted to the surge of fierce wave action that they cannot live in calmer sheltered water. Thus we find that typical ocean platform species such as the blue mussel and some of the limpets and siphon shells do not occur in the more sheltered bays.

Sandy Beaches

The inhabitants of sandy beaches are entirely different from those of rock platforms and the number of different types of molluscs on any one beach is much smaller than on a rock platform. However, the number of individuals of a given species is usually much greater.

In places where wave action is extreme molluscs may not be able to live in the continually moving sand of the intertidal zone. On ocean beaches such as the Ninety Mile Beach the dominant mollusc is the Pipi *Plebidonax deltoidales* (Lamarck, 1818) and associated with it and feeding on it is the carnivorous flat Sand Snail *Conuber incei* (Philippi, 1851). In slightly more sheltered and less steeply shelving beaches such as those of Wilson's Promontory the above two species occur together with the Wedge Shell *Donacilla angusta* (Reeve, 1854) and the Lined Nassarius *Alectrion particeps* (Hedley, 1915). With increased shelter of bays and inlets a greater variety of bivalves is found living buried in the sand and associated rocks and living upon them are Sand Snails and Nassarius. Port Phillip and Westernport Bays have a wide variety of bivalves living at and below low tide level. The commonest species amongst the Eel Grass *Zostera* is the Ribbed Venerid *Katelysia rhytiphora* Lamy, 1937 while on more open sand *Katelysia scalarina* (Lamarck, 1818) is common and in areas of extreme shelter *K. rhytiphora,* and *K. peroni* (Lamarck, 1818), occur with the Smoked Venerid *Eumarcia fumigata* (Sowerby, 1853). The conical Sand Snail *Conuber conica* (Lamarck, 1822) preys on all these species as do the Nassarius or Dog Whelks *Parcanassa pauperata* (Lamarck, 1822), *P. burchardi* (Philippi, 1851), and *Tavaniotha optata* (Gould, 1850).

Mud Flats and Salt Marsh

Animals living on intertidal mud flats and salt marshes have to withstand extremes of temperature and salinity as well as cope with sediment, and only a comparatively few species have become capable of adapting themselves to these conditions. In periods of low tide and high temperature the sun will cause considerable evaporation and thus raise salinity and warm the water. In reverse, the temperature of such areas will fall very rapidly in periods of frost or low winter temperatures. Also, the salinity will drop in the rainy season or if flushes of fresh water enter from swollen streams.

In the tropics where the temperatures are not so extreme many animals can adapt themselves to salinity changes but in the cooler temperate waters only a comparatively few species of molluscs occur, but these are usually in considerable numbers.

Thus in Victorian waters the Black-mouthed Conniwink *Bembicium melanostoma* (Gmelin, 1791) occurs at high tide level and at a slightly lower level just below high tide the stunted estuarine form of the Ribbed Top Shell *Austrocochlea constricta* (Lamark, 1882). Both these species require a hard surface, however small, for attachment and both penetrate into the salt marsh climbing on to the stems of mangroves and *Salicornia*. In the true salt marsh several other gastropods of the family ELLOBIIDAE are found ; these are the Delicate and Meridion Air Breathers *Marinula zanthostoma* H. and A. Adams, 1854 and *M. meridionalis* (Brazier, 1877), and the Common Mangrove and the Groved Air Breather *Ophicardelus ornatus* (Ferussac, 1821) and *O. sulcatus* (H. and A. Adams, 1855). The Air Breathers *Salinator fragilis* (Lamarck, 1822) and *S. solida* (von Martens, 1878), though very similar in appearance have preferences in habitat. *S. solida* prefers places where fresh water from small streams or springs enters the salt marsh.

At, and just below low tide, the commonest mud flat species is the Southern Mud Whelk *Velacumantus australis* (Quoy and Gaimard, 1834) which occurs in countless numbers. Often associated with it is the smaller Common Mud Whelk *Zeacumantus diemenensis* (Quoy and Gaimard, 1834), and in the eastern part of the State, the Club Mud Whelk *Pyrazus ebeninus* (Bruguière, 1792) is common.

Several bivalves are found living beneath the surface of mud flats. These include the Double-rayed Razor and Donax-like Razor *Soletellina biradiata* (Wood, 1815) and *S. donacioides* Reeve, 1857. There are also some species of the family TELLINIDAE including the very beautiful ornamented Victorian decussated Tellin *Pseudocopagia victoriae* (Gatliff and Gabriel, 1914), and the Triangular Tellin *Homalina deltoidalis* (Lamarck, 1818), these latter species being very common on the mud flats of Port Melbourne and Swan Bay.

Benthic

The sea floor below low tide repeats the bottom types found intertidally and is more stable as it is not subject to such violent wave action or the effects of exposure twice a day. Thus the variety and number of different molluscs on each bottom type is greater and as varied. No more than a very few common or particularly interesting species from both bays and open ocean can be mentioned here.

The Victorian coast has a number of underwater rock platforms and reefs, both in the open bays and in Bass Strait. On and around these are found several large Gastropods including the Rock Whelks *Cabastana spengleri* Perry, 1811 and *C. waterhousei* A. Adams and Angas, 1864. These and the Tulip Shell *Pleuroploca australasia* (Perry, 1811) sometimes even come up to low tide level during the breeding season. Also found on underwater rock platforms are the several species of MURICIDAE including the two largest species, the Fronded Murex and Three-shaped Murex *Torvamurex denudatus* (Perry, 1811) and *Pterynotus triformis* (Reeve, 1845).

On shallow water sandy areas between rocks the two species of Pheasant Shell *Phasianella australis* Gmelin, 1788 and *P. ventricosa* Swainson, 1822 occur. On deeper water sandy areas the Wavy Volute *Amorena undulata* (Lamarck, 1804) is common and more rarely the Papilose Volute *Ericusa papillosa* Swainson, 1821, while in the deep waters of Bass Strait the False Baler *Mamillana mamilla* Gray, 1844 is dredged. In more recent years deeper water trawling has collected the large Beer Barrel Tun shell *Tonna cerevisina* Hedley, 1919. In a similar habitat the New Holland Spindle *Fusus novae-hollandiae* Reeve, 1848 and several Whelks of the family BUCCINIDAE are taken including *Austrosipho maxima* Tryon, 1881. The smaller species *A. grandis* Gray, 1839 occurs in shallower water and is taken in Westernport and Port Phillip Bays. Among the deep water bivalves one of the most spectacular is the Thorny Oyster *Spondylus tennelus* Reeve, 1856. Also, there are several species of Pectenidae which may be taken in considerable numbers including the Queen Scallop *Equichlamys bifrons* (Lamarck, 1819) and the Doughboy Scallop *Chlamys asperrimus* (Lamarck, 1819). Bivalves are even more prolific in sheltered shallower waters and many of them prefer the sandy mud or mud bottom of quieter water in bays and inlets.

In the areas of sandy mud in Westernport and Port Phillip Bays the commercial scallop *Pecten alba* Tate, 1886 is very abundant and where the sand gives way to mud, there is often associated with it the Mud Oyster *Ostrea angasi* Sowerby, 1871, which entirely replaces it in some areas. In sheltered areas with a mud bottom the Mud Ark *Anadara trapezia* Deshayes, 1840 is common in bottom Westernport and Port Phillip. Another shell with a preference for such conditions is the Trigonia *Neotrigonia margaritacea* (Lamarck, 1804), a very beautiful mollusc with beaded ribbed ornament on the exterior and delicate internal nacre. This mollusc is of particular interest as the Australian species are the only living representatives of a very ancient fossil family.

The large Fan Mussel *Atrina tasmanica* T. Woods, 1875 is an inhabitant of the sandy mud areas of the eastern entrance to Westernport Bay. This species grows to 10 in and is the largest bivalve of Victorian waters.

Pelagic Molluscs

The molluscs are represented in the open ocean mainly by the cephalopods and a few families of gastropods whose members are specially modified for a free swimming existence. The very beautiful Violet Snail *Ianthina janthina* Linnaeus, 1758 lives its life on the surface of the ocean but is at times blown ashore and stranded on beaches in large numbers. All the members of the super family HETEROPODA and some opisthobranchs lead a pelagic existence and like *Ianthina* are blown ashore from time to time. The pelagic cephalopods are vigorous swimmers and therefore are not at the mercy of wind and waves and are less frequently stranded unless injured or ill. There are records of the stranding of most known open ocean species including the Giant Squid *Architeuthis kirkii* Robson, 1887. Because of their lightness the internal shells of cuttlefish and heteropods float after the death and disintegration of the animal and often wash ashore. Usually

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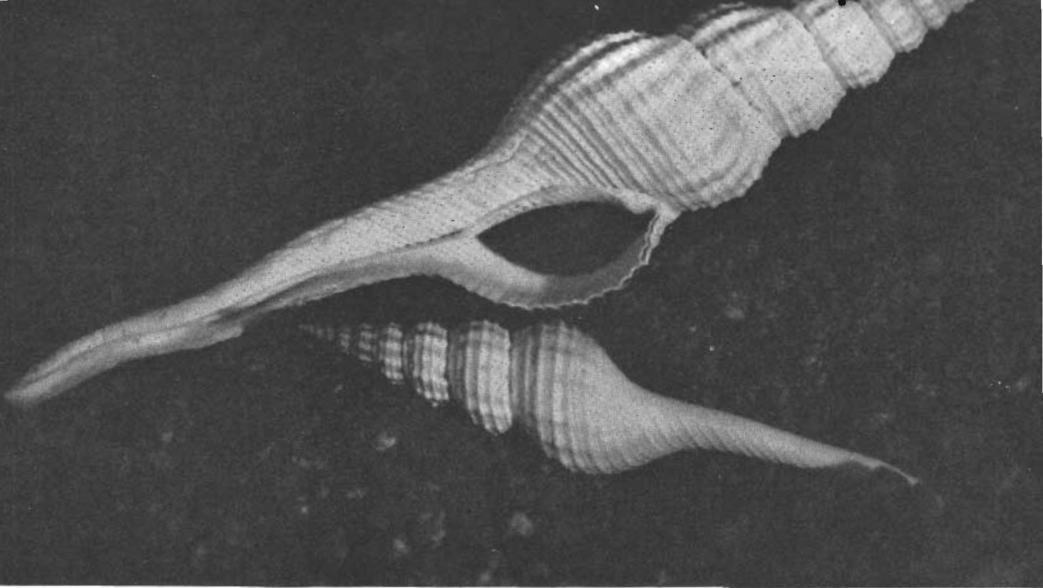
Roadnight Volute, *Pterospira roadnightae* (McCoy) is a rare volute dredged in deep water off the Victorian coast.

Molluscs of Victoria



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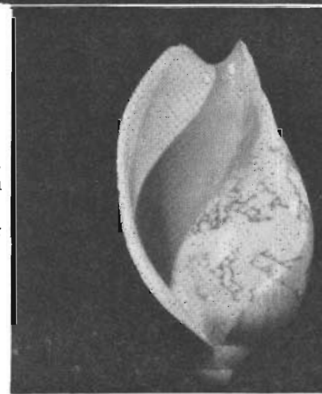
New Holland Spindle Shell, *Fusus novaehollandiae* (Reeve) is dredged from deeper water offshore along the Victorian coast.



False Baler Shell, *Mamillana mamilla* (Gray) is dredged from deeper water along the east coast of Victoria. Specimens can reach 12 inches in length.

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Spengler's Rock Whelk, *Cabastana spengleri* (Perry) (on left) and Waterhouse's Rock Whelk, *C. waterhousei* (Ads and Angas) (on right) live on reefs from just below low water to several fathoms in depth.

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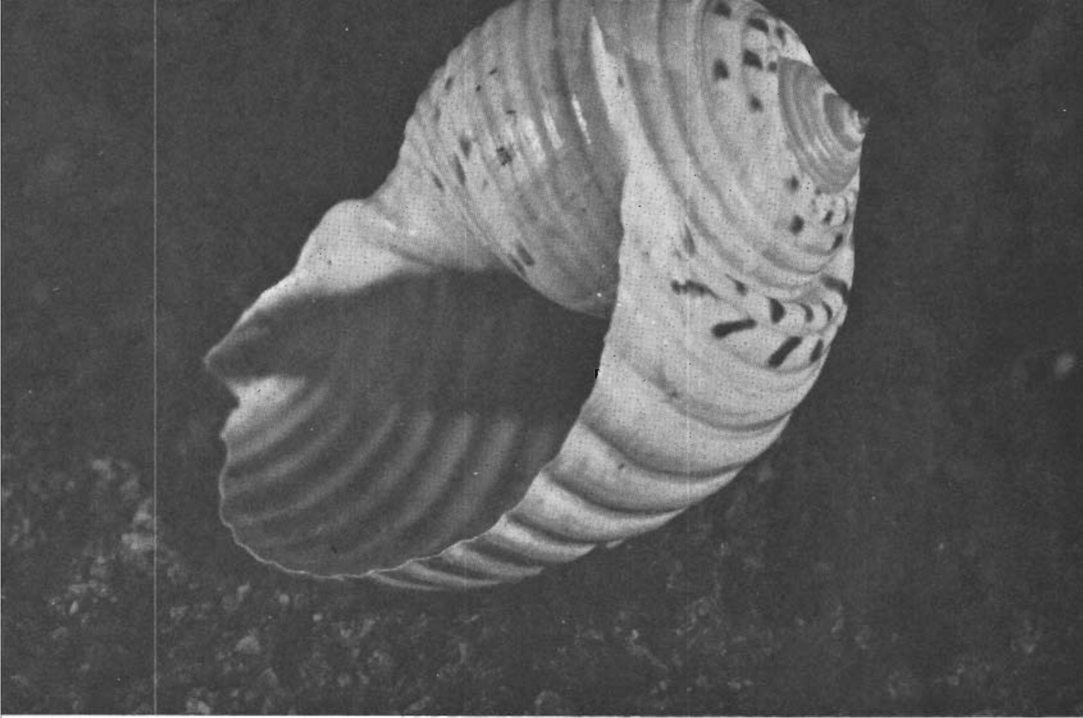

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Beer Barrel Tun, *Tonna cerevisina* Hedley is dredged in deep water off the east coast of Victoria.

Wonder Cowry, *Umbilia hesitata* Iredale is dredged in deeper water off the southern New South Wales coast and eastern coast of Victoria.

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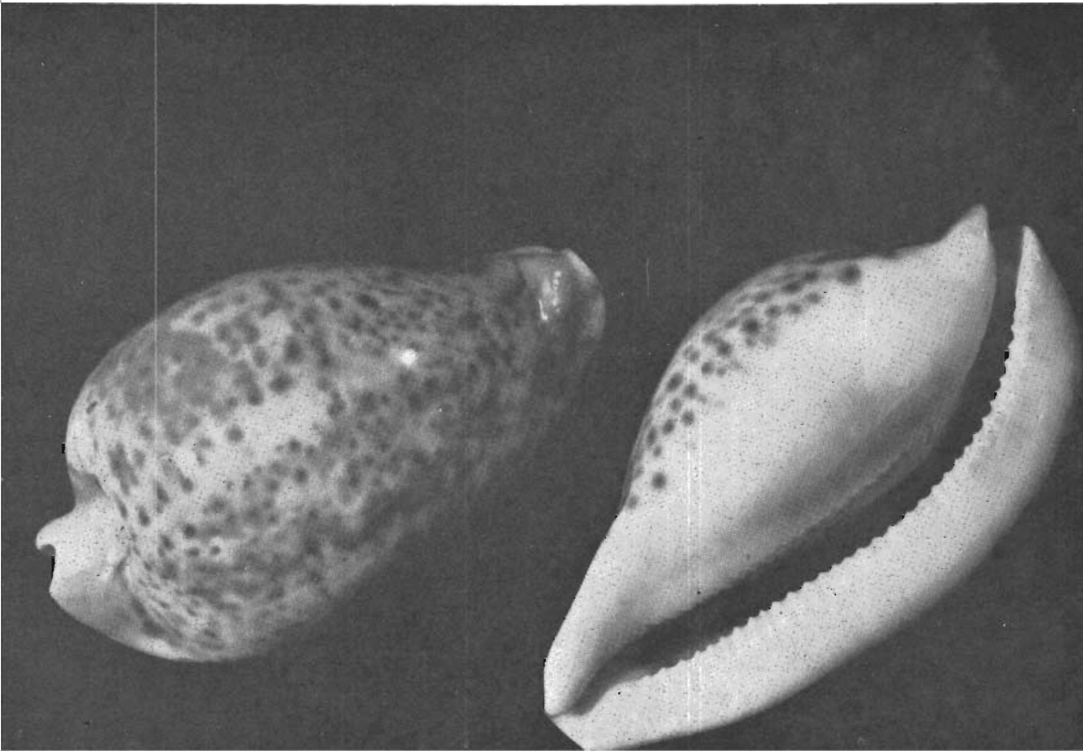

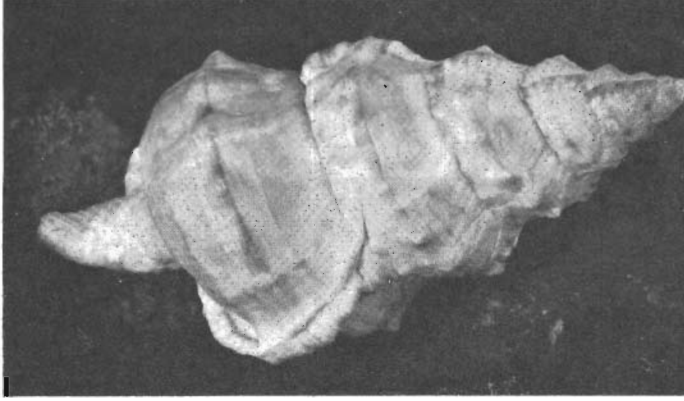

Australian Rock Whelk, *Mayena australasia* (Perry) lives on reefs and is found along the whole Victorian coast. This is the elongated deep water form *benthicola* Iredale.

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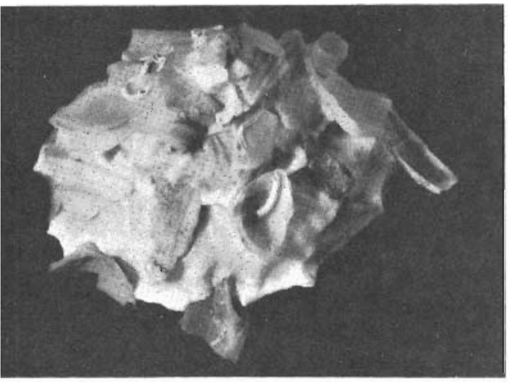

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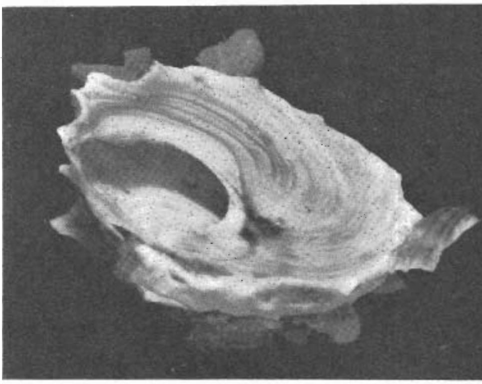
Carrier Shell, *Xenophora peroniana* (Iredale) (top view) builds fragments of other shells and small stones into its shell. It lives in deep water off the eastern coast of Victoria.



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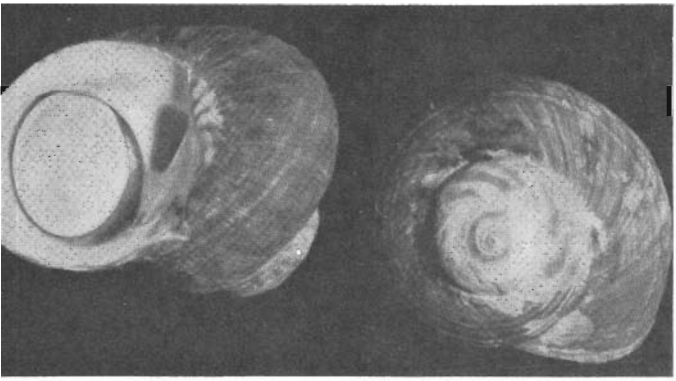
Carrier Shell, *Xenophora peroniana* (Iredale) (side view).



Warrener, *Subninella undulata* (Solander) is common on intertidal rock platform along the whole coast.

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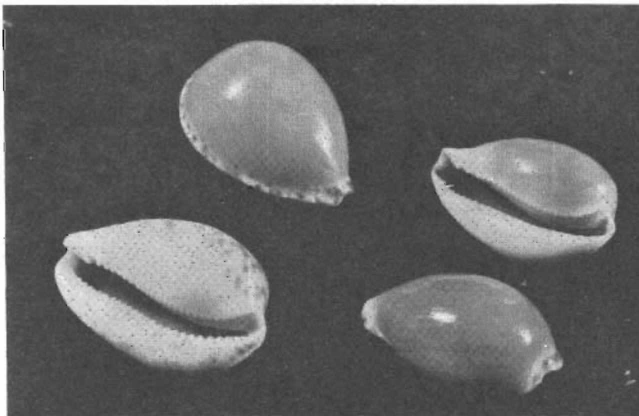

Brown Cowry, *Notocypraea angustata* (Gmelin) is common at low tide on rock platforms.

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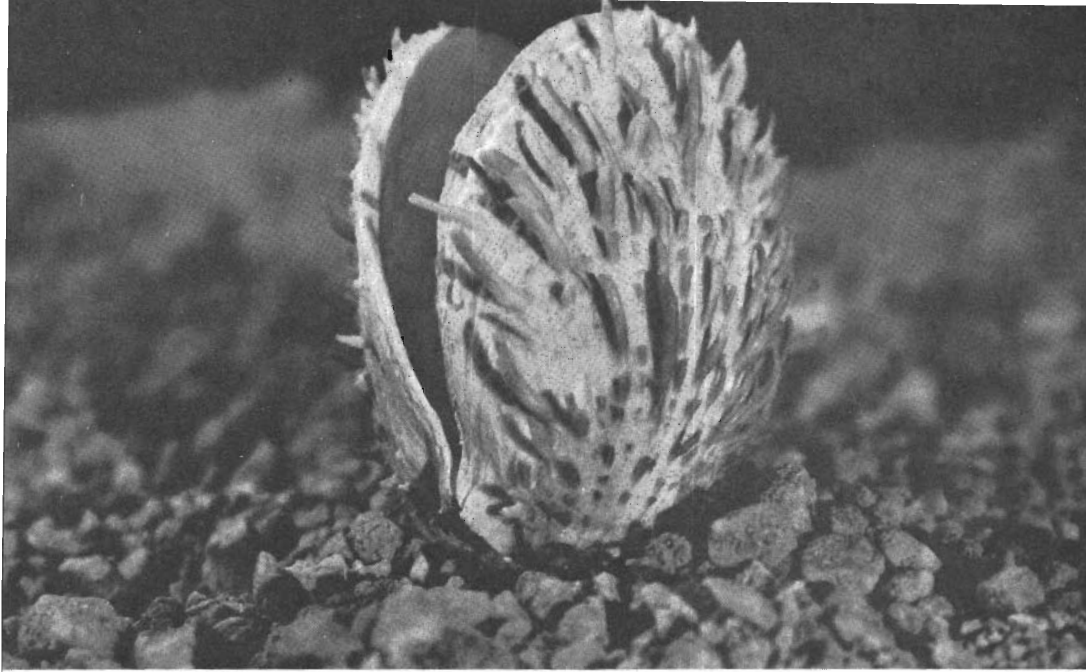

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Spiney Oyster, *Spondylus tenellus* (Reeve) is dredged from deeper water off the coast.

Mud Ark, *Anadara trapezia* (Deshayes) lives on a mud bottom in sheltered water and is common in Port Phillip and Westernport Bays and Corner Inlet.

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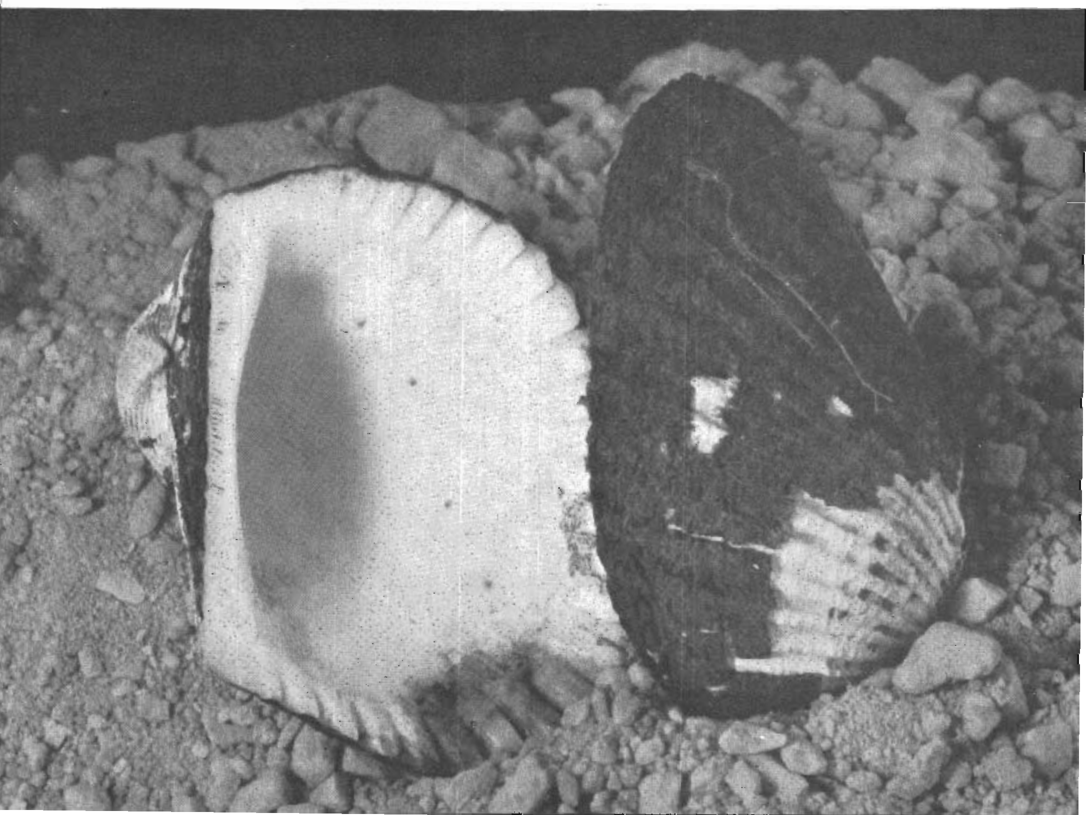

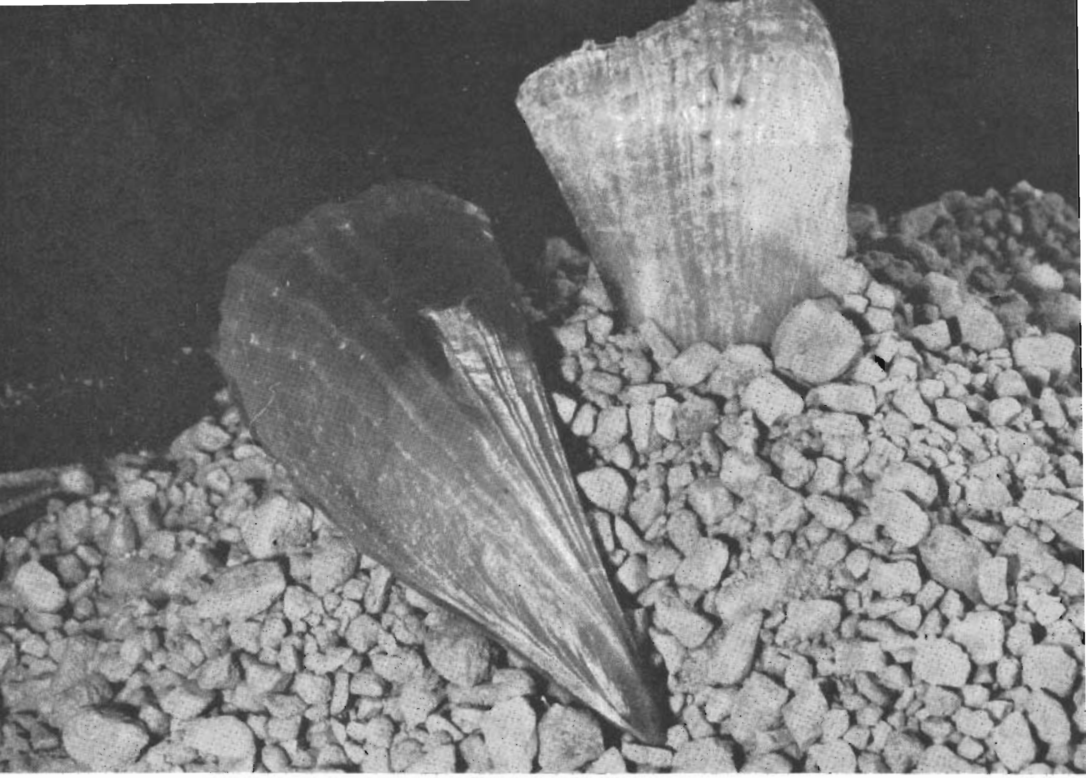

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Fan Mussel, *Atrina tasmanica* (Tenison Woods) lives amongst weed in sandy mud in Westernport Bay and at the southern end of Port Phillip Bay.

Commercial Scallop, *Pecten alba* Tate is dredged in Port Phillip and Westernport Bays and also from deeper water offshore.

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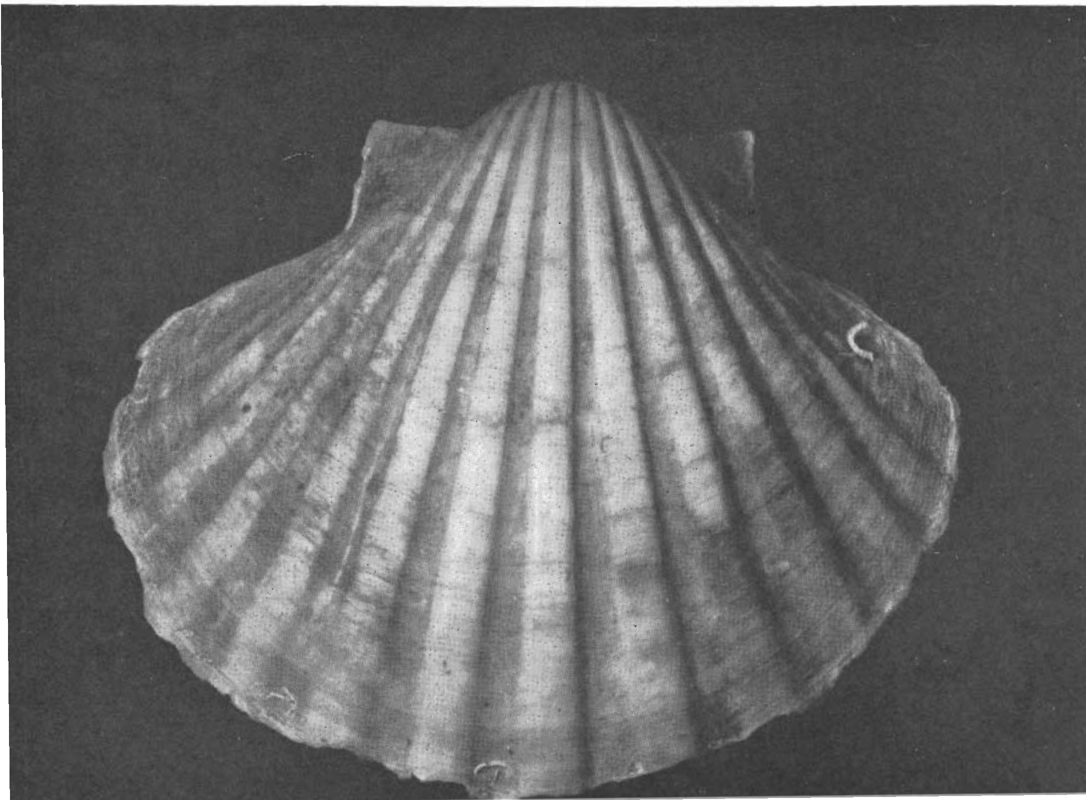

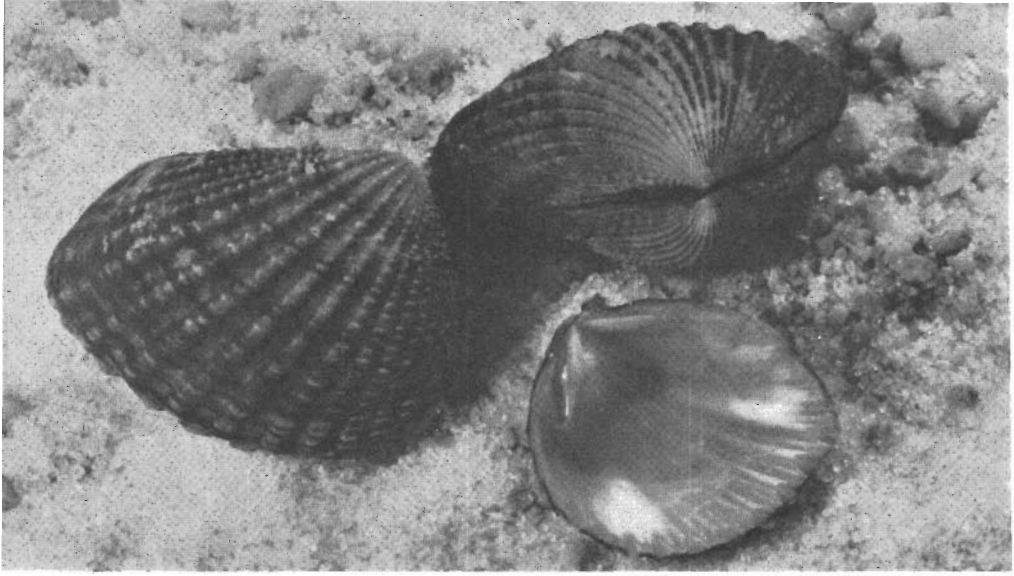

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Trigonia or Brooch Shell, *Neotrigonia margaritacea* (Lamarck) lives in mud and is found in Westernport Bay and along the Victorian coast.

Faintly Frilled Venerid, *Bassina pachyphylla* (Jonas) lives in sand in shallow water and is found offshore along most of the Victorian coast.

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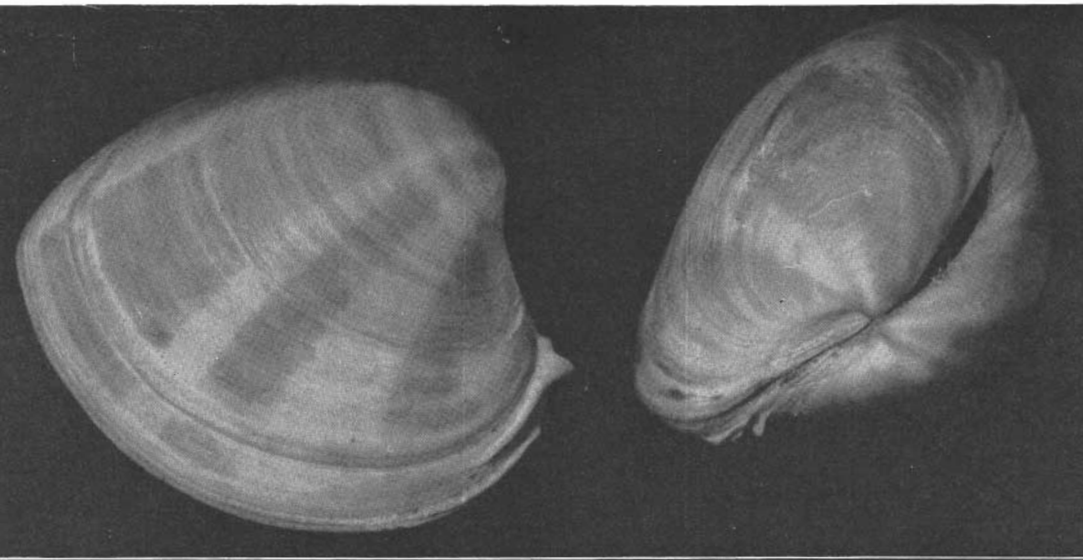

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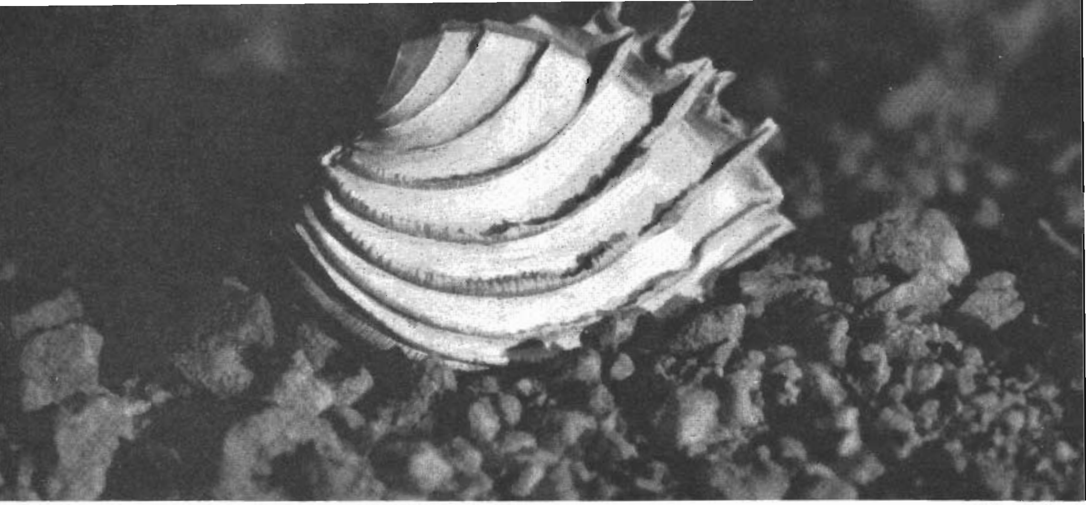
Pipi, *Plebidonax deltoides* (Lamarck) lives in sand just above low tide and is an inhabitant of most of Victoria's ocean beaches.



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Frilled Venerid, *Callanaitis disjecta* (Perry) lives in sandy mud and is taken in shallow water on the eastern side of Port Phillip Bay and in Westernport Bay.

Paper Nautilus, *Argonauta nodosa* Solander is an inhabitant of the open ocean but from time to time winds drive it ashore. The shell is the egg case secreted by the female to carry her eggs.

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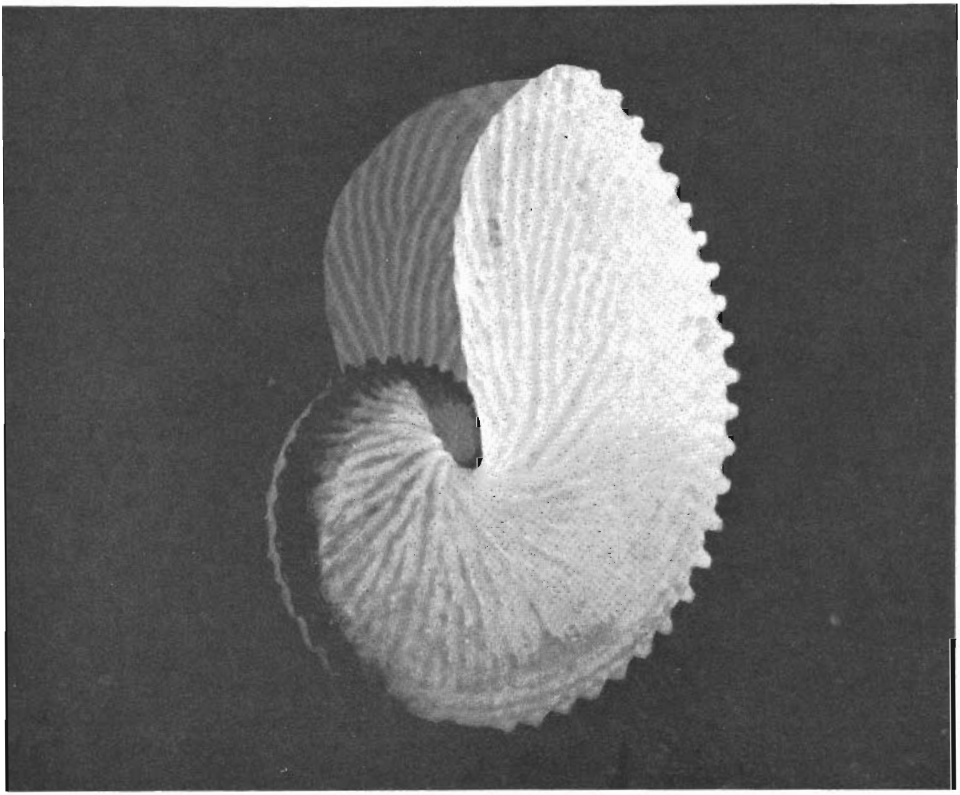

cuttlebones are scattered over a beach but the sagitta-shaped, transparent heteropod shells because of their extreme lightness are left at the high tide line.

Members of the other classes have not adapted themselves to the pelagic environment but nearly all the marine molluscs have a larval stage (veliger) which spends a shorter or longer free swimming period in the plankton. This pelagic period is the main factor in distribution of marine species for it enables predominantly sedentary bottom dwelling animals to be transported great distances from their birthplace before they settle into adult life. Settlement and immediate growth commences when conditions such as bottom, temperature, currents, and available food are right. Temperature which is the main controlling factor in distribution may be satisfactory for establishment and growth of the species but outside the range within which the animal can breed. Such a population can only be renewed or increased by outside recruitment.

GLOSSARY

Adductor muscles. Applied to bivalve shells; the anterior and posterior muscles draw the valves of the shell together leaving marks on the inner surface of each called the muscular impressions or muscle scars or adductor scars.

Alimentary canal. Channel in animal's body through which food passes.

Anatomy. Bodily structure.

Anatomical. Details of bodily structure.

Anterior. In bivalves, it is the side on which the head, or part analogous to the head of the animal, lies; it is known in the shell by the umbones, which, if turned at all, are turned towards that part. The anterior of a spiral univalve is that part of the outer lip which is at the greatest distance from the apex. Of a conical univalve such as a limpet, it is that part where the head of the animal lies.

Anus. Posterior opening of alimentary canal.

Apex. The tip, or small end of a shell.

Appendages. Something hung on (limbs, etc.).

Axis. In a univalve shell the centre or pillar upon which the spire turns.

Benthic. Bottom dwelling.

Byssus. The fibres by which some bivalve shells are anchored or moored to submarine substances.

Calcareous. Limy or shelly matter.

Cambrian. A geological period, the earliest of the Palaeozoic.

Canal. A groove which characterises some spiral univalve shells, where the inner and outer lips unite at the front part of the aperture.

Carnivorous. Flesh eating.

Chitin. Hard substance which forms the rigid structures in the body of many invertebrates.

Chitinous. Pertaining to chitin.

Class. A major division of a phylum.

Columella. The column formed by the inner sides of the volutions of a spiral univalve. It is sometimes described as the inner lip of the aperture, of which it forms a part.

Columella lip. The inner edge of the aperture, including that part of it which covers the body-whorl.

Decussated. Intersected by fine lines crossing each other.

Dehydration. Removal of water.

Desiccation. Extraction of water.

Detritus. Fragments of matter which include particles of food.

Digestive tract. Channel in animal's body through which food passes.

Diverticulum. Small pocket opening from the rectum.

Ecological. Pertaining to the ecology.
Ecology. That branch of science which treats of plants and animals in relation to the environment in which they live.
Ectoparasite. Parasites living on the external surface of their host.
Embryonic. Pertaining to an embryo.
Embryo. An organism in its early stages before birth.
Epidermis. External coating of shells. Also known as periostracum.
Exhalent current. The water expelled from the mantle cavity.
Family. The division of classification into which genera are grouped.
Fertilisation. The act of impregnation of the egg by the male cell.
Foot. Portion of the animal's body used for locomotion. In most bivalves a hatchet-shaped muscular organ capable of protruding beyond valve margins.
Fossil. Remains of plant or animal imbedded in stratified rocks.
Funnel. The organ through which water, etc., is expelled from the mantle cavity of Cephalopods.
Ganglia. Mass or group of nerve cells.
Genus. An assemblage of species, possessing certain characteristics in common.
Genera. Plural of genus.
Gills. The breathing organs of most aquatic animals.
Herbivorous. Feeding on herbage.
Hermaphrodite. Bisexual, containing both the male and female organs in the body.
Hinge. The edge of the bivalve shells near the umbones, including the teeth and ligament.
Inequivalve. Not equivalve.
Inhalent. The stream of water entering into the mantle cavity.
Insertion plate. The plates on the edges of Chiton shell valves to which the girdle is attached.
Internal shell. One which is enclosed by the mantle of the animal.
Larva. Juvenile stage, different from the adult.
Left valve. Sinistral valve of a bivalve shell may be known by placing the shell with its ligamentary or posterior part towards the observer ; the sides of the shell will then correspond with his right and left side.
Ligament. The true ligament is external, serving the purpose of binding the two valves of a shell together by the posterior dorsal margin.
Locomotion. Movement from one place to another.
Lung. A special cavity in the body through which air is breathed.
Mantle. External tissue which secretes the shell.
Mantle cavity. The cavity which is formed by the mantle.
Mesozoic. The second major geological era.
Metamorphosis. Change of form.
Mollusc. A member of the phylum Mollusca.
Mouth. Aperture or opening of a shell.
Muscle. The fleshy, contractile organ by which the animal is attached to the shell.
Muscle scar. Applied to bivalve shells ; the anterior and posterior muscles which draw the valves of the shell together leaving marks on the inner surface of each called the muscular impressions or muscle scars or adductor scars.
Muscular. Having well developed muscles.
Nacreous. Pearly ; like mother-of-pearl.
Operculum. The plate with which many molluscs close the aperture of their shell when retired within them. Cat's-eye of Turbo.
Order. A major division of a class of animals into which are grouped families.
Osphradium. The sense organ near the gills of molluscs used for testing the water, etc.
Pallial Line. In bivalve shells, the line of attachment of mantle to shell.
Pallial sinus. A notch in the pallial line occasioned by siphons.
Palaeozoic. Containing the earliest form of life. The first geological era.
Pelagic. Pertaining to, or inhabiting the open sea ; free swimming.
Periostracum. External coating of shells.
Phyla. Plural of phylum.
Phylum. One of the main divisions of the animal kingdom.
Plankton. Small plants and animals living on the surface of water.

Planktonic. Pertaining to the plankton.
Planorbid. Coiled in a flat spiral.
Posterior. The side known by the direction of the curve in the umbones, which is from the posterior towards the anterior. Posterior of univalve opposite end to the anterior (mouth).
Predators. Feeding on other animals.
Radula. Lingual ribbon. Usually bearing on its upper surface numerous transverse rows of teeth. Used for the mastication of food. It is absent in bivalves.
Rectum. Final section of digestive tract terminating in the anus.
Right valve. See left valve.
Sagitta. Shaped like an arrow.
Salinity. Degree of saltiness.
Sedentary. To lead a life of bodily inactivity, remaining in one spot.
Sessile. Attached, remaining in the one position.
Shell. A calcareous or horny covering secreted by the mantle of a mollusc.
Sinus. A deep indentation ; cavity.
Siphon. Tube leading to the respiratory organ of some univalves.
Species. A subdivision of a genus, a group into which is placed all individuals of the same kind.
Suctorial. Capable of attachment by suction.
Substrate. The sea floor.
Torsion. The process by which the visceral mass of Gastropods becomes twisted through 90 degrees.
Type. The specimen on which the original description of the species is based.
Umbo. Umbone ; the point of a bivalve shell above the hinge, constituting the apex of each valve. Embryonic shell.
Univalve. A shell consisting of a single piece, as distinguished from bivalves and multivalves.
Valve. One of the individual units of a molluscan shell which may be composed of one, two, or eight valves.
Veliger. Free swimming larval stage of molluscs.
Ventral. The margin of a bivalve shell opposite the hinge.
Vestigial. Degenerate, reduced.
Viscera. Internal organs of an animal.
Visceral. Pertaining to the viscera.
Whorls. A complete turn or revolution round the imaginary axis of a spiral shell.
Zoology. The study of animal life and structure.

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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 contains about 87,884 square miles, or 56,245,760 acres.

Victoria is bounded on the north and north-east by New South Wales, from which it is separated by the River Murray, and by a straight line running in a south-easterly direction from a place near the head-waters of that stream, called The Springs, on Forest Hill, to Cape Howe. The total length of this boundary following the windings of the River Murray from the South Australian border along the Victorian bank to the Indi River, thence by the Indi or River Murray to Forest Hill and thence by the straight line from Forest Hill to Cape Howe, is 1,175 miles. The length of the River Murray forming part of the boundary is approximately 1,200 miles, and of the straight line from Forest Hill to Cape Howe, 110 miles. On the west it is bounded by South Australia, on the south and south-east its shores are washed by the Southern Ocean, Bass Strait, and the Pacific Ocean. It lies approximately between the 34th and 39th parallels of south latitude and the 141st and 150th meridians of east longitude. 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, Westernport 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 Wilson's 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.

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

AREA OF AUSTRALIAN STATES

State or Territory	Area	Per Cent 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

Physical Divisions

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

The chief physical divisions of Victoria are shown on the map (Figure 2). 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, as is recognised in popular terms such as Mallee, Wimmera, Western District, and so on. The following is a table of these divisions :

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*) Wilson's Promontory

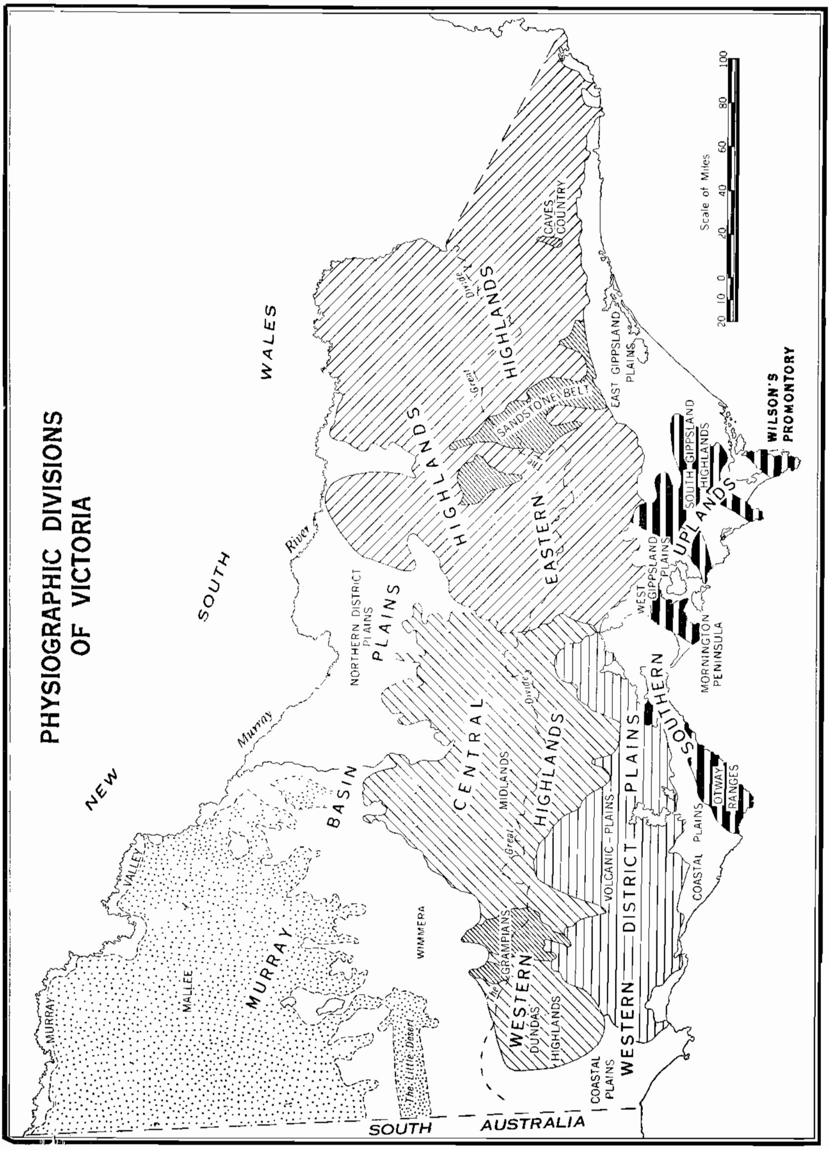

FIGURE 2.

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 periodical 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 Westernport Bay 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 off-shore 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.

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Physical Environment and Land Use

The Central Highland Zone (see Figure 2) 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 divide 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 airmasses, giving rise to heavy orographic rainfall of over 50 in p.a. 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 responsible for 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 in to 30 in p.a., cool winters, warm summers, rolling topography, open dry sclerophyll forest and grasslands, and moderately fertile if 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 2). 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 in p.a. in the southern Wimmera, but it decreases to under 10 in p.a. 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 enable 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 in p.a. in the western part to over 30 in p.a. 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, more reliable rainfall eastern section of the Northern District Plains 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. Here are the main ports of Victoria : Melbourne, Williamstown, and Geelong. 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 Keilor and Western District volcanic plain stretching west from the Bay. 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 in p.a. 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 is 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 as Victoria's third major port.

South of the Western District Plains lie the Otway Ranges, a sparsely populated region of rugged scenery and very high rainfall. The coastline between Lorne 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 2.) The fault trough with its rolling hills, 30 in rainfall, and year round pasture, is among the best dairying country in the Australian mainland, supplying the metropolitan whole milk 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 in p.a. between Traralgon and the East 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.

Variety, then, is the keynote of Victoria's farming system and physiography. Generally, shortage of water is the main environmental problem for agriculture, especially north of the Highlands. Coastal Victoria has a more reliable rainfall. The Highlands are the only region where temperature extremes limit agricultural utilisation, and these are less intensively farmed than other parts.

Generally, Victoria's farmers practise progressive and productive agriculture. The State's 70,000 rural holdings produced $713·9m in 1965–66 which was 25·2 per cent of Victoria's net value of production. The importance of Victoria's farmers is seen when it is realised that they produce a substantial amount of Australia's farm output, e.g., 22 per cent wheat ; 32 per cent oats ; 11 per cent barley ; 67 per cent dried vine fruit ; 39 per cent mutton and lamb ; 18 per cent wool ; 24 per cent beef ; 21 per cent pigs, and 52 per cent butter.

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 Mount Bogong, 6,516 ft ; Mount Feathertop, 6,307 ft ; Mount Nelse, 6,181 ft ; Mount Fainter, 6,157 ft ; Mount Loch, 6,152 ft ; Mount Hotham, 6,101 ft ; Mount Niggerhead, 6,048 ft ; Mount McKay, 6,045 ft ; Mount Cobboras, 6,030 ft ; Mount Cope, 6,026 ft ; Mount Spion Kopje, 6,025 ft ; and Mount Buller, 5,919 ft.

Further Reference, 1962 ; Coastal Physiography, 1967

Plant Ecology of the Coast

Introduction

The coast of Victoria presents a great variety of habitats for vegetation, ranging from sea cliffs and rocky shores through beaches, sand-dunes, and heathlands to lagoons and swamps, which may be fresh, brackish, or highly saline. Capes, promontories, and bays provide variations in aspect and a range of exposure to the prevailing west and south-west winds and salt spray, while the mean annual rainfall varies from 20 in along the western shores of Port Phillip to 44 in at Wilson's Promontory and Cape Otway.

*Sand-dunes and Heaths**

Coastal sand-dunes are built from sand blown inland from the beaches and stabilised by vegetation ; they may reach heights of over 100 ft. In Victoria they are found chiefly along the Ninety Mile Beach, in Port Phillip and Discovery Bays, from Point Lonsdale to Lorne, and in pockets on the rugged coasts of Wilson's Promontory, the Otways, and Phillip Island. The dunes east of Foster are predominantly of quartzose sands ; many to the west are of quartzose sands more or less rich in calcareous carbonate derived from broken shells.

Where successive dune ridges have been built parallel to the shoreline, there is often a zonation of vegetation across them. This can be shown to result from a succession (in time) of vegetation types, from pioneer grass communities on the young fore dunes through dense dune scrub to woodland or even to heathland. The sequence also reflects the progressive leaching of the dunes by rainwater, which rapidly removes any sea salt and more slowly dissolves out calcium carbonate, where this is present. Over some thousands of years a characteristic podsol soil profile is developed on the older dunes. Below a thin, dark grey layer containing humus the sand is bleached white where humus and, sometimes, iron compounds have been leached. They are deposited further down in a well defined cemented layer of " coffee-rock ". These soils become acid and very infertile, and the final stage of the succession on them may be a heathy woodland or an open treeless heath.

The earliest colonisers above high tide are strand plants, *Cakile maritima* and *Atriplex cinereum.* The grasses *Festuca, Spinifex,* and *Ammophila* bind the blown sand and assist in the formation of embryonic dunes. On older and higher dunes these grasses are invaded and replaced by shrubs. In Central and Eastern Victoria, *Leptospermum laevigatum* (Coastal Ti-tree), *Leucopogon parviflorus, Acacia sophorae,* and *Banksia integrifolia* are important species. In the west, the *Leptospermum and Banksia* components may be replaced by *Melaleuca pubescens.* A late stage of dune vegetation is usually a woodland with bracken and heath species in the ground flora. In the east of the State the trees are *Banksia serrata* and *Eucalyptus* species (*E. viminalis, E. baxteri* and *E. obliqua*). In the west *E. baxteri* predominates.

The sand dunes of Pleistocene age in many places west of Wilson's Promontory are very rich in calcium carbonate, which has been long ago dissolved and re-precipitated throughout the profile to form dune

* Examples shown in Figures 3 and 5.

limestone or aeolianite. This may form steep; rugged cliffs where it has been subject to marine erosion. Cementation of the sand in such dunes has often been most marked along decaying plant organs, thus producing branching structures (casts of twigs and shoots) exposed in eroding aeolianite. The upper layers of these highly calcareous dunes may, in time, be leached and become acidic locally ; they may then be eroded and blown inland to form new white dunes.

Many dune systems along Victoria's coasts are not parallel to the shore and have probably been extensively re-arranged after " blow-outs ". Such disturbance of the original pattern leads to secondary vegetative succession. On Sperm Whale Head, in the Gippsland Lakes region, parallel ridges have been partly re-arranged into parabolic dunes which bear younger soils and dune scrub vegetation, whereas the undisturbed parallel ridges bear woodland and heath. In contrast, at Tidal River it is a new series of parallel dunes which carry the earlier stages of the dune succession, and the older parabolic dunes behind them, with acid leached soils, are covered with dense heath vegetation.

On the seaward faces dune scrub is closely pruned by high winds bearing salt spray, and the stability of the dune depends on the maintenance of vegetative cover. In many Victorian dunes shoreline erosion has, in recent times, removed the early stages in succession and cut cliffs into the higher parts bearing shrub or woodland vegetation. Any disruption of vegetative cover, after wave-erosion, fires, over-grazing or excessive trampling by holiday-makers, leads to the initiation of blow-outs, which may grow into large parabolic dunes migrating inland, or great sterile sand sheets or mobile dunes of the kind found behind Discovery Bay, on the Yanakie isthmus connecting Wilson's Promontory, and in the extreme east, close to Cape Howe, where Victorian sand is spilling over the border into New South Wales. For many years vegetation, particularly the introduced marram grass, has been used in efforts to halt and stabilise migrating sand dunes on the Victorian coast.

*Heathlands**

The highly characteristic low scrub plant community called heath-land is rich in woody species with small leaves resembling in form, but not in species, the heaths of Europe. They occur characteristically on deep, leached, sterile sands with a podsolic profile, and the coastal heaths may, in some cases, be the climax communities of the dune succession. But similar heaths are found on shallow sterile soils over massive rock (such as granite), and in Victoria heath is by no means restricted to the immediate coastal region. Similar vegetation occurs in the Grampians and in the moderately arid Big and Little Deserts of western inland Victoria : They are a rapidly diminishing reservoir of native plants that have the ability to grow on soils which will only support agricultural species after the addition of phosphates and trace elements. The chief native species of the coast sand heaths are *Leptospermum myrsinoides, Casuarina pusilla,* and *Hypolaena fastigiata* In the wet heaths with a seasonally high water-table, on hill-wash and swamp margins *Leptospermum juniperinum*, *Xanthorrhoea* (Grass

* Example shown in Figure 3.

Tree), and *Calorophus lateriflora* are prominent instead. But both types of heath carry over fifty species and their species composition varies with habitat and the incidence of burning.

*Coastal Lagoons and Swamps**

Estuarine lagoons have been formed where the mouths of river valleys, drowned by Recent marine submergence, have been partly or wholly sealed off from the sea by the development of sandy spits and barriers. The Gippsland Lakes are an extensive lagoon system, and there are many others on a smaller scale, from Nelson Lagoon and the Bridgewater Lakes in the west through to Lake Tyers and Mallacoota Inlet in the east. As a rule they show a gradation from fresh water through brackish lagoon to sea water at the marine entrance, but some are well insulated from the sea and almost fresh (Bridgewater Lakes), while others are cut off from the sea during summer droughts and tend to become more saline than open sea.

The variety of ecological conditions is responsible for a whole range of plant communities, from freshwater and brackish swamps to the true salt marshes. The shores of the lagoons show a zonation of vegetation which again can be explained in terms of succession. The submerged pond weeds (*Potamogeton* and *Vallisneria* in fresh water, *Zostera* in brackish areas) add debris and collect silt, so that in time there is an invasion of the taller Bullrush (*Typha*), Reed (*Phragmites*), and Sedges (*Scirpus*). This zone in turn is invaded by shrubs (*Melaleuca*, *Leptospermum*) which form dense thickets on land still subject to flooding. The oldest and higher zones carry swamp woodland ; the commonest tree in this is *E. ovata*, but in the far east Lilly-Pilly (*Eugenia*) rainforest can still be found.

Relics of reedswamp are found in and under the roots of the shrub communities, but the normal successional pattern is often modified or obscured by burning. As on the dunes, the vegetation influences the building and shaping of landforms, and is an example of the vegetation factor in geomorphology.

In the Gippsland Lakes salinity has increased following the cutting of an artificial entrance through the enclosing barrier in 1889. This has been a major cause in the disappearance of a former reedswamp fringe which has exposed the swamp scrub to erosion by wave action. In addition, the swamp paper-bark has been killed over large areas by the increase of soil salinity following repeated invasion by increasingly brackish flood waters, and salt marsh communities (*Salicornia*, etc.) have developed amid the dead sticks of *M. ericifolia*.

Salt Marshes†

The major coastal salt marshes in Victoria are found in Corner Inlet, Westernport Bay, on the western shores of Port Phillip Bay, and in the Barwon Estuary. Smaller marshes occur in river mouths and inlets from Mallacoota to the Glenelg. The number of flowering plant species concerned is small ; many of them are fleshy succulent plants, tolerant of sea salt and closely related to the species of the salt marshes in other parts of the world. Common genera include *Enchylaena* and

* Examples shown in Figures 3 and 5.
† Example shown in Figure 4.

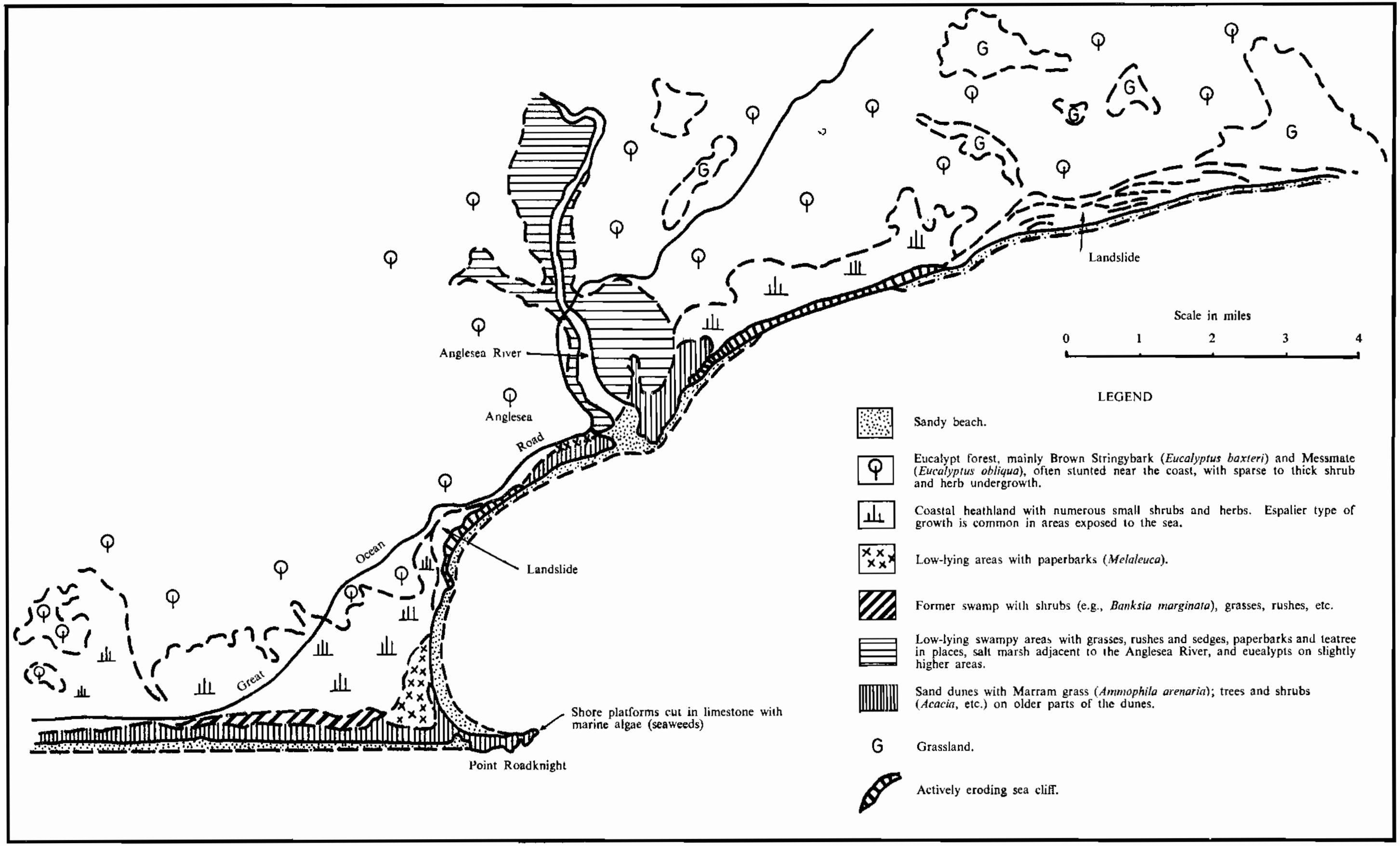


FIGURE 3.—Vegetation map of the Anglesea area.

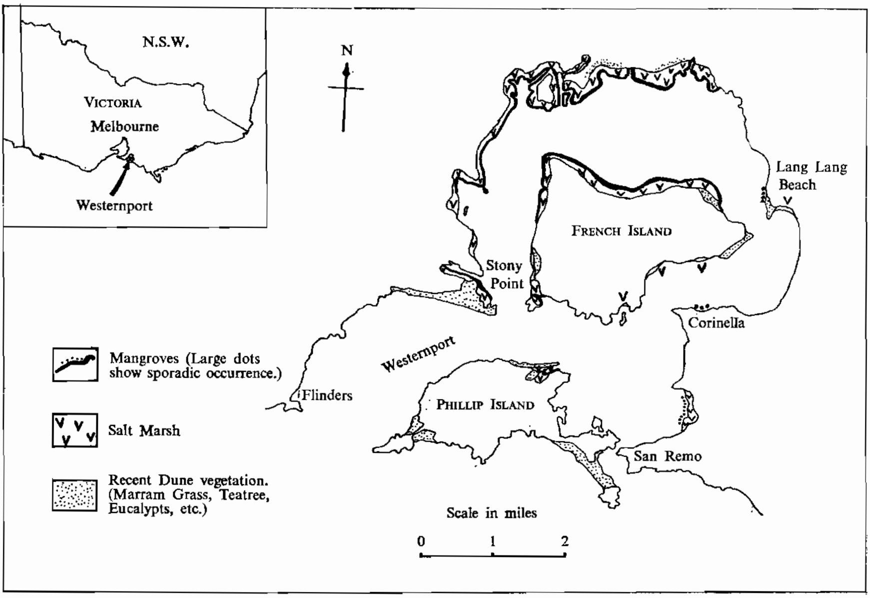


FIGURE 4.—Distribution of coastal vegetation around Westernport.

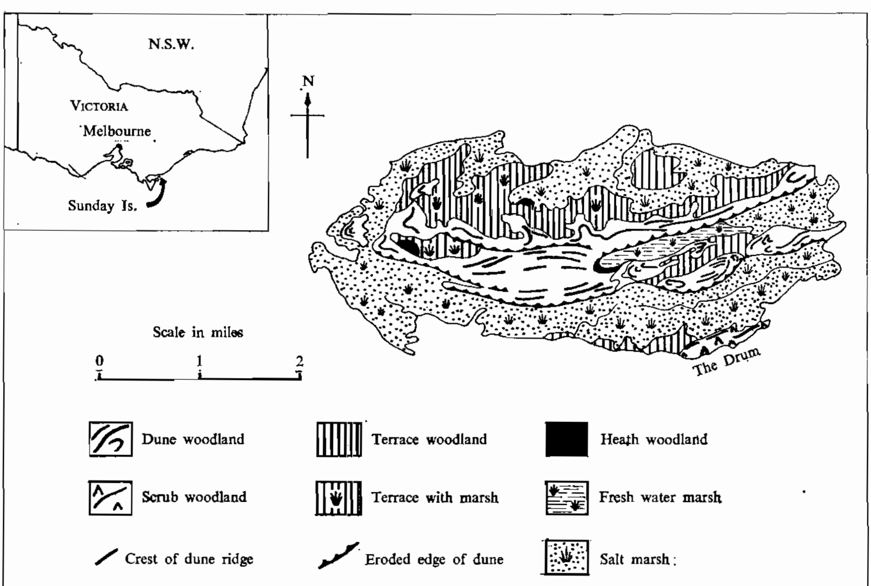


FIGURE 5.—Land and vegetation features on Sunday Island.

Atriplex (salt bushes), *Suaeda* (seablites), and the very abundant *Salicornia* (Glassworts also called Samphires) ; all these belong to one family, the Chenopodiaceae. Species of *Diphysma* (Pigface), *Samolus* and *Frankenia* also occur, with some Rushes and Grasses.

Salt marshes are characteristic of sheltered habitats where silt and sand are accumulated by current. Some marshes are sandy, whilst others are silty or clayey; often a gradation occurs.

The tidal range is an important feature of their environment—in Westernport and Corner Inlet extensive marshes extend over a vertical tide range of 6 to 9 ft, whereas in Port Phillip this is reduced to 2 to 3 ft. The marshes undergo variations of growth and erosion resulting in complex patterns of species distribution which depend on frequency of inundation, rainfall and desiccation, salinity and, above all, aeration.

In marshes, which are actively building, the lowest tides expose beds of grass-wrack, *Zostera.* In the zone regularly washed by the daily tides the shrubs of the white mangrove (*Avicennia marina* var. *resinifera*) form thickets from 10 to 12 ft high in the most favoured sites in Westernport to 3 to 4 ft in the southernmost limit in Australia at Corner Inlet. This extension of tropical vegetation is not continuous. There are gaps of several hundred miles between the mangroves in New South Wales and St. Vincent's Gulf ; in Victoria the species is found only in Corner Inlet, Westernport, Barwon Heads, and Port Phillip Bay, where it is dying out owing to industrial pollution. Its vertical " breathing roots " project into the air at low tide and are clothed with red algae. These roots hinder currents and assist in the trapping of mud and sand.

Landward of the mangroves there is a sparse growth of low succulents, succeeded by a region of woody samphire. These plants may be 6 to 8 ft tall in the well aerated sites, but usually average 2 to 3 ft, with dense low herbaceous succulents between them. This community can, in time, develop a peaty top soil. Further inland a bare zone is sometimes encountered, salt-encrusted in summer, carrying only *Diphysma.* In most situations a grass-sedge zone, with an accumulation of flotsam and jetsam, marks the limit of the highest spring tides. This zone carries *Stipa teretifolia* (grass), *Gahnia filum* (sedge), and *Juncus maritimus* (rush). In wetter areas, as in Westernport, the grass zone abuts on to ti-tree and paperbark thickets (chiefly *Melaleuca ericifolia* and *Leptospermum juniperinum*). These thickets probably represent a near climax stage of the succession and sometimes scattered trees of *Eucalyptus ovata* are present forming a layered woodland. In drier areas, as in the west coast of Port Phillip Bay, the succession may proceed to a grassland with Lignum (*Muehlenbeckia*) and *Casuarina* ; much of this area is used in the production of salt.

In landward extensions of salt marshes the top soils are high enough to be leached of salt but may remain waterlogged, with mottled iron-stained sand and clay in the sub-soil. Because the wet habitat slows down decomposition, many of these soils are high in organic matter. The draining and clearing of the large Koo-Wee-Rup swamp has provided rich farmlands.

Vegetation of Cliffs

On cliffs which weather to produce heavy clay soils (e.g., the Basalt of Phillip Island), the vegetation is tussock grassland dominated by *Poa poiformis*. On granite and on sandstone and marly cliffs of the Jurassic sediments and Tertiary rocks, shrubby vegetation is the rule. On exposed faces this may be pruned to espalier form by salt spray. Where the cliffs are vertical, shrubs cling precariously to crevices and ledges. Near the high tide limit the continual accession of salt spray permits growth of salt marsh species ; further up will be tussocks of *Poa* and loose cushions of the white-leaved *Calocephalus brownii*. The sea buckthorn (*Alyxia*) is one of the larger shrubs common on cliffs.

On the granite cliffs of Wilson's Promontory a low heathy scrub gives way above the salt spray to thickets of *Casuarina stricta*. In more sheltered areas Ti-tree (*Leptospermum laevigatum*), *Casuarina*, and *Kunzea ambigua* form thickets almost to the high tide level.

The heavily eroded aeolianite cliffs at Cape Schank, Cape Nelson, and Cape Bridgewater provide a great variety of habitats. On the rough Portland coasts salt marsh species occur on cliff-tops 50 to 100 ft above the sea, where salt spray accumulates.

These brief notes indicate that no simple generalisations can be made about the vegetation of cliffed coasts. There is great variety in the geology and topography, in exposure to wind and salt spray, in marine erosion and soil slumping. Hence there is no such thing as a " typical " cliff vegetation and it is perhaps understandable that there has been no thorough ecological investigation of these areas in Australia.

Further References, 1966–67

Rivers

The characteristics of rivers which relate to land are fixed, whereas those relating to water are variable.

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 has 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 1,000 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	Murchinson	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	1906 (*a*)	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	1901 (*b*)	777	51	2,634	362
	28	Bunyip	Bunyip	268	1908 (*c*)	124	47	246	56
	29	Yarra	Warrandyte	899	1892	685	48	1,215	265
	30	Maribyrnong	Keilor	500	1908 (*d*)	91	35	266	3
	31	Werribee	Melton	446	1917 (*e*)	68	49	259	5·3
	32	Moorabool	Batesford	430	1908 (*f*)	58	16	149	2·5
	33	Barwon	Winchelsea	370	1922 (*g*)	115	33	412	25
	35	Carlisle	Carlisle	30	1930 (*h*)	32	31	71	14·5
	36	Hopkins	Wickliffe	540	1921 (*i*)	28	34	103	1·4
	38	Glenelg	Balmoral	606	1889 (*j*)	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		1933–34 to 1943–44
e)	1952–53		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 1963 Victorian Year Book.

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 part 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 in to 20 in. Above this amount, roughly half the rainfall appears as stream flow.

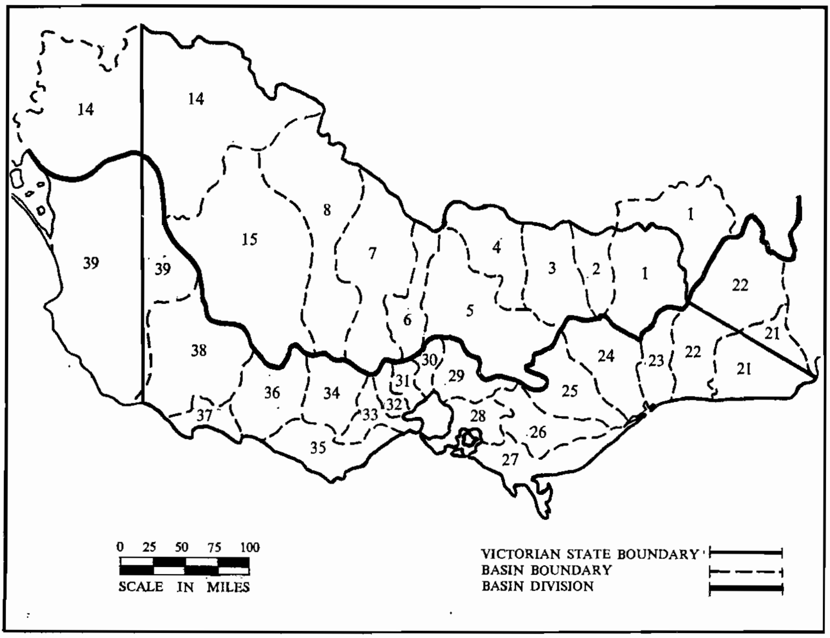


FIGURE 6.—Relevant Basins of the two Divisions (South East Coast Division and Murray–Darling Division) which include Victoria and some adjacent areas. The Basins are numbered as shown on Map 3 (Sheet 2) in *Review of Australia's Water Resources* (Published by Department of National Development, 1965).

SOUTH EAST COAST DIVISION		MURRAY–DARLING DIVISION
21. East Gippsland	30. Maribyrnong River	1. Upper Murray River
22. Snowy River	31. Werribee River	2. Kiewa River
23. Tambo River	32. Moorabool River	3. Ovens River
24. Mitchell River	33. Barwon River	4. Broken River
25. Thomson River	34. Lake Corangamite	5. Goulburn River
26. Latrobe River	35. Otway	6. Campaspe River
27. South Gippsland	36. Hopkins River	7. Loddon River
28. Bunyip River	37. Portland	8. Avoca River
29. Yarra River	38. Glenelg River	14. Mallee
	39. Millicent Coast	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 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 in 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 R.L. 388, around Lake Corangamite, plus any higher land rendered inaccessible to the landowner by the initial surrender. The legislation makes similar provision also 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 in over the State is crude, but is 3 in more than the next highest figure of 35 in in 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

The Department of Crown Lands and Survey is responsible for surveying and mapping of Crown lands (for the purpose of boundary definition) and for the preparation of maps.

Surveys are made to define boundaries and determine the dimensions of allotments for which Crown Grants are subsequently issued. Survey parties are mainly centred in country districts and are equipped with modern survey instruments. The information so obtained has always formed the basis of the Parish plan which the Department is endeavouring to keep up to date and to redraw in many cases where the original is unsuitable for reproduction.

Geodetic surveys are also being carried out throughout Victoria to link the State's mapping with that of the rest of Australia, and to provide control for aerial photographs from which the series of maps are prepared by the use of stereoplotting equipment. The Department spends at least $70,000 annually to obtain aerial photography over selected parts of the State and this may be used for general small-scale mapping or even, under special circumstances, for maps at a scale of 40 ft to an inch. The very large scale maps are required for developmental purposes (such as design, street construction, and sewerage) and indicate all occupation, streets and street names, and natural physical features with contours shown at 1 ft, 5 ft, and 10 ft intervals. The geodetic survey parties are equipped with theodolites capable of reading direct to one second of arc together with tellurometers (electronic distance measuring equipment) for determining the length of lines from 1 mile to 40 miles in length.

The map of Victoria has now been published in four sheets and is available to the public. The scale is 1 : 500,000 and it shows in colour main highways, roads and railways, names of towns, mountains, watercourses, and natural physical features.

There is complete co-ordination between the Lands and Survey Department of Victoria, the Department of the Army, and the Division of National Mapping (Commonwealth) in the preparation of small-scale maps to cover Victoria. A ten-year programme has been prepared and is expected to cover the State by topographic maps at a scale of 1 : 100,000 within this period. In the meantime a smaller scale series at 1 : 250,000 is nearing completion by the Army and Division of National Mapping. The existing topographic map at 40 chains to an inch is being discontinued but all the information will be used and converted to the universal scale of 1 : 100,000.

Maps are being prepared for the use of the Country Fire Authority and are being drawn from existing information. They will be the basic maps used for State fire control and other emergencies. Large-scale mapping at 400 ft to an inch of the Mornington Peninsula and Ballarat has also been completed ; Geelong is now being compiled ; and Bendigo was commenced in 1967. Complete information of survey and mapping activities is obtainable from the Central Plan Office in the New Treasury Buildings where maps, plans, and aerial photographs are available for purchase by the public.

Further Reference, 1966

Climate

Climate of Victoria

General

The State of 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 the Southern Ocean 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 48.

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 in for the driest parts of the Mallee to over 60 in for parts of the North-Eastern Highlands. An annual total exceeding 140 in 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 in, with over 40 in on the Central Highlands, Otway Ranges, and South Gippsland. The wheat belt receives chiefly between 12 and 20 in. 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 in have been recorded on rare occasions 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 in at Tanybryn in the Otway district in June, 1952.

An estimate of the areas of the State subject to different degrees of average annual rainfall, and the actual distribution of rainfall in Victoria as shown by area for 1965 and 1966 are shown in the following table :

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (In)	Area ('000 Square Miles)		
	Average	1965	1966
Under 10	Nil	5·7	1·7
10–15	19·7	23·7	19·2
15–20	13·4	17·0	10·1
20–25	15·7	19·9	11·3
25–30	15·8	10·5	13·6
30–40	14·2	6·2	9·4
Over 40	9·1	4·9	22·6

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

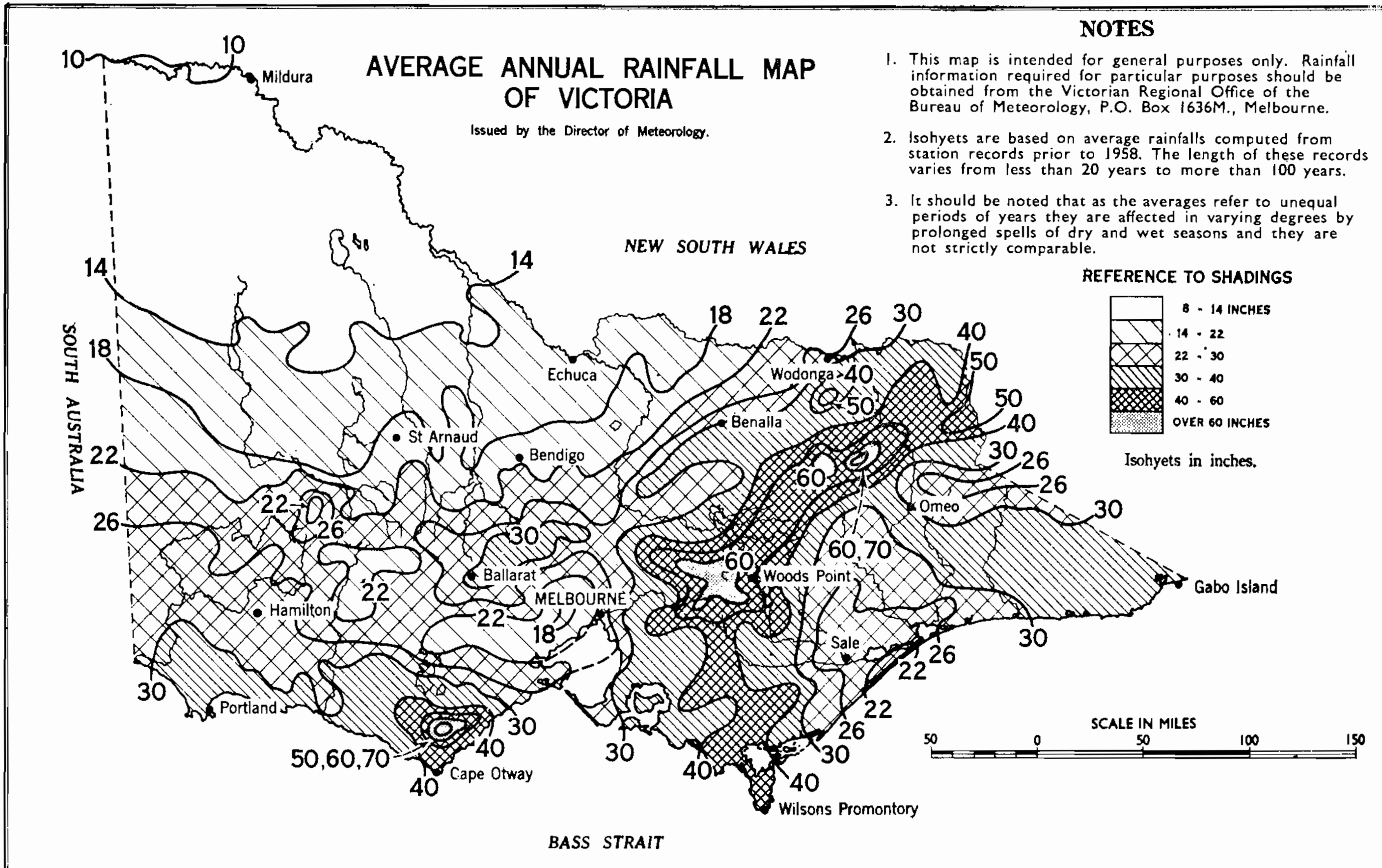
Depressions off the east coast bring most rain to this district, and such rainfall can be very heavy. The average rainfall shows a summer maximum. Fronts moving in a westerly stream bring very little rain, and with north-westerly winds in winter, the coastal section has the mildest weather in the State.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

VICTORIA—RAINFALL IN DISTRICTS

(In)

Year	Districts							
	Mallee	Wimmera	Northern	North-Central	North-Eastern	Western	Central	Gippsland
1957	9·67	14·87	13·55	23·01	27·32	26·82	24·85	31·98
1958	15·45	17·65	21·40	31·57	37·78	29·05	28·99	35·42
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
Averages* ..	12·93	18·09	18·50	27·83	34·57	28·48	29·33	33·70

* Averages for 53 years 1913–1965.



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
Gabo Island
Sale
Portland
Cape Otway
Wilsons Promontory
10
14
18
22
26
30
40
50
60
60,70
50,60,70

FIGURE 7.

VICTORIA—DISTRICT MONTHLY RAINFALL : AVERAGE AND 1966

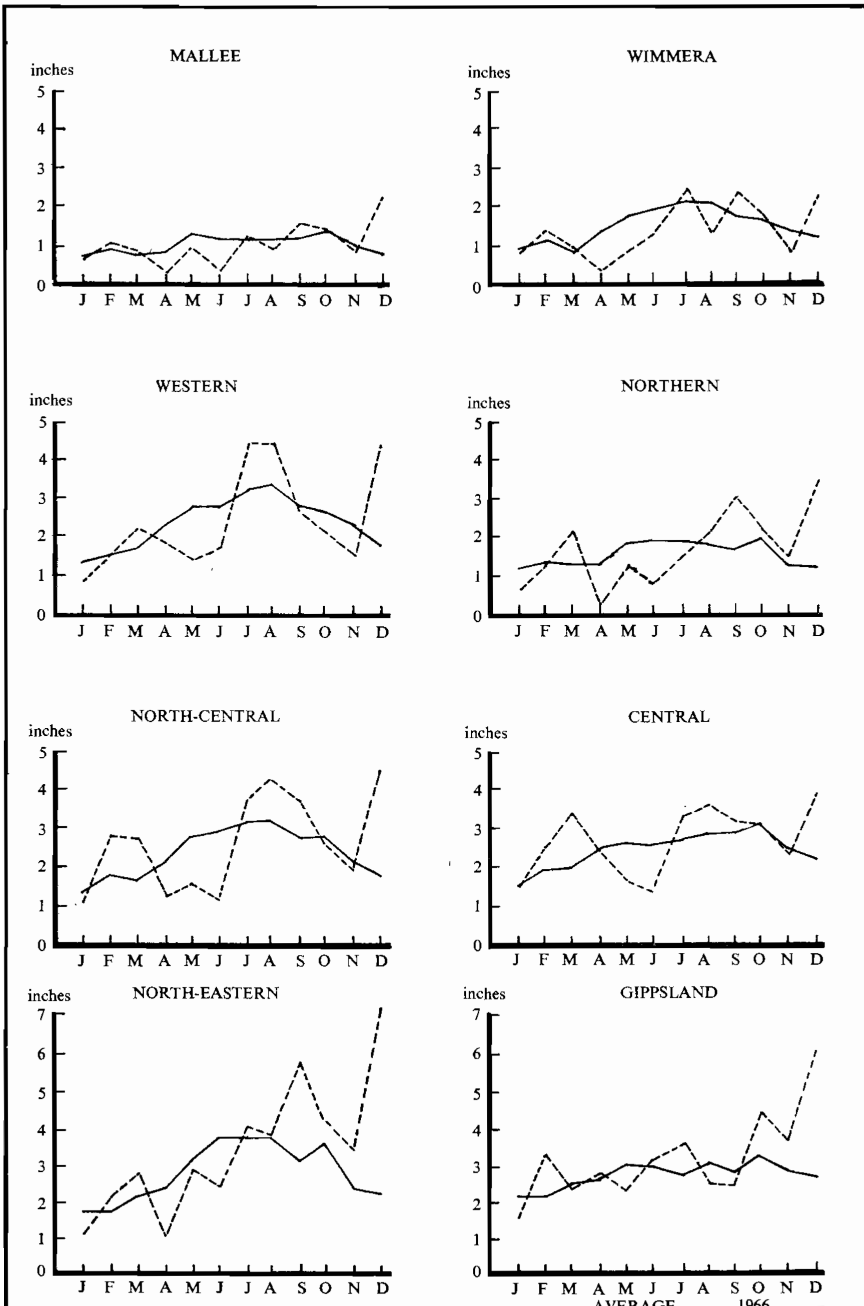


FIGURE 8.

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.

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 " 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 9) for the 30 years 1931 to 1960 and the results are tabulated below in order of rainfall reliability :

VICTORIA—ANNUAL RAINFALL VARIATION

District	Average Annual Rainfall*	Standard Deviation	Coefficient of Variation
	in	in	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

*Average for 53 years 1913–1965.

[Australian National Travel Association

The Otway Coast, showing cliffs and shore platforms cut in hard rocks. A pocket beach can be seen in the middle distance.

Coastline of Victoria

[Professor J. S. Turner

Embryonic sand dunes rising above the beach in the background at Sunday Island, Corner Inlet, with the grass *Festuca littoralis* stabilising the blown sand. Older dunes in the foreground carry another species of grass, *Spinifex hirsutus*, and plants of the shrub phase are invading from the right.

Dune vegetation on Sunday Island, Corner Inlet. Young dunes stabilised by dune grasses ; older dunes in the background have been colonised by shrubby vegetation.

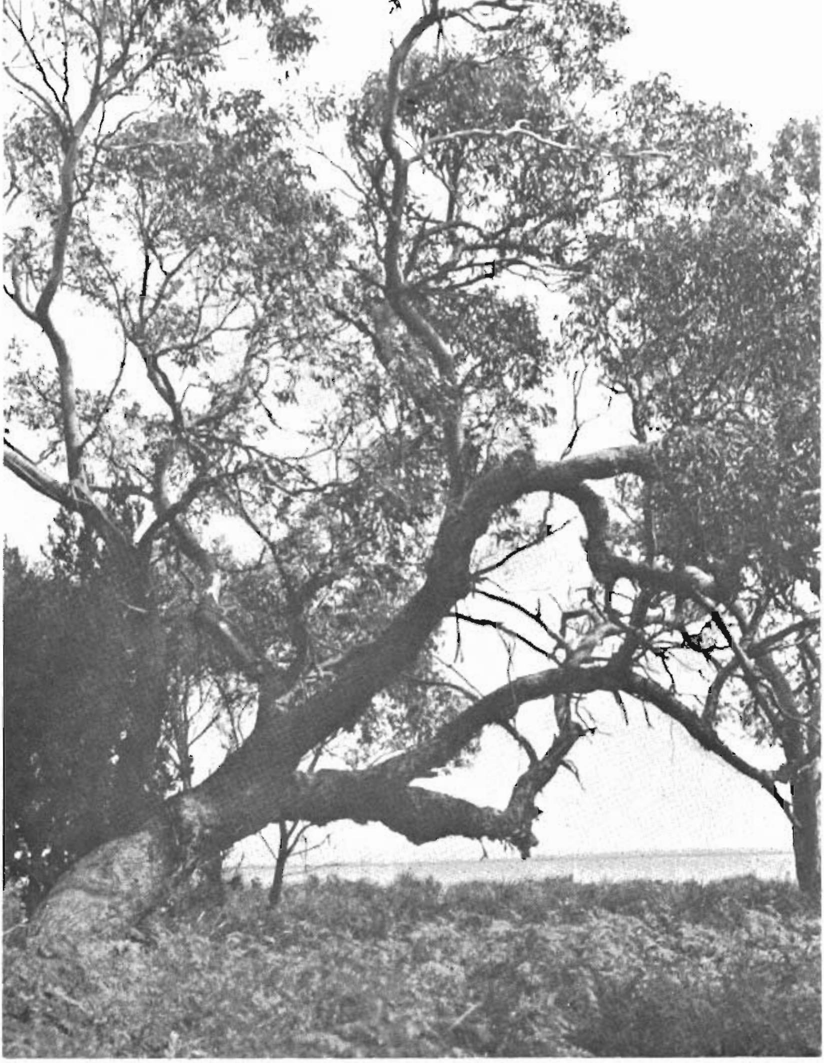
[Professor J S Turner

[Dr. E. C. F. Bird

An area of complex coastal topography and vegetation at Tidal River, Wilsons Promontory. The rocky headlands carry cliff vegetation and *Casuarina* woodland. Parallel with the beach are several comparatively young dune ridges, with alkaline soil derived from the beach sand. Separated from these by the white pathway are the much older and acid parabolic sand dunes carrying heath vegetation. Tidal marshes can be seen near the mouth of Tidal River.

Mangroves east of Tooradin at high tide. The aerial roots of the mangroves, which are exposed at low water, are not showing here.

[Dr. J. J. Jenkin

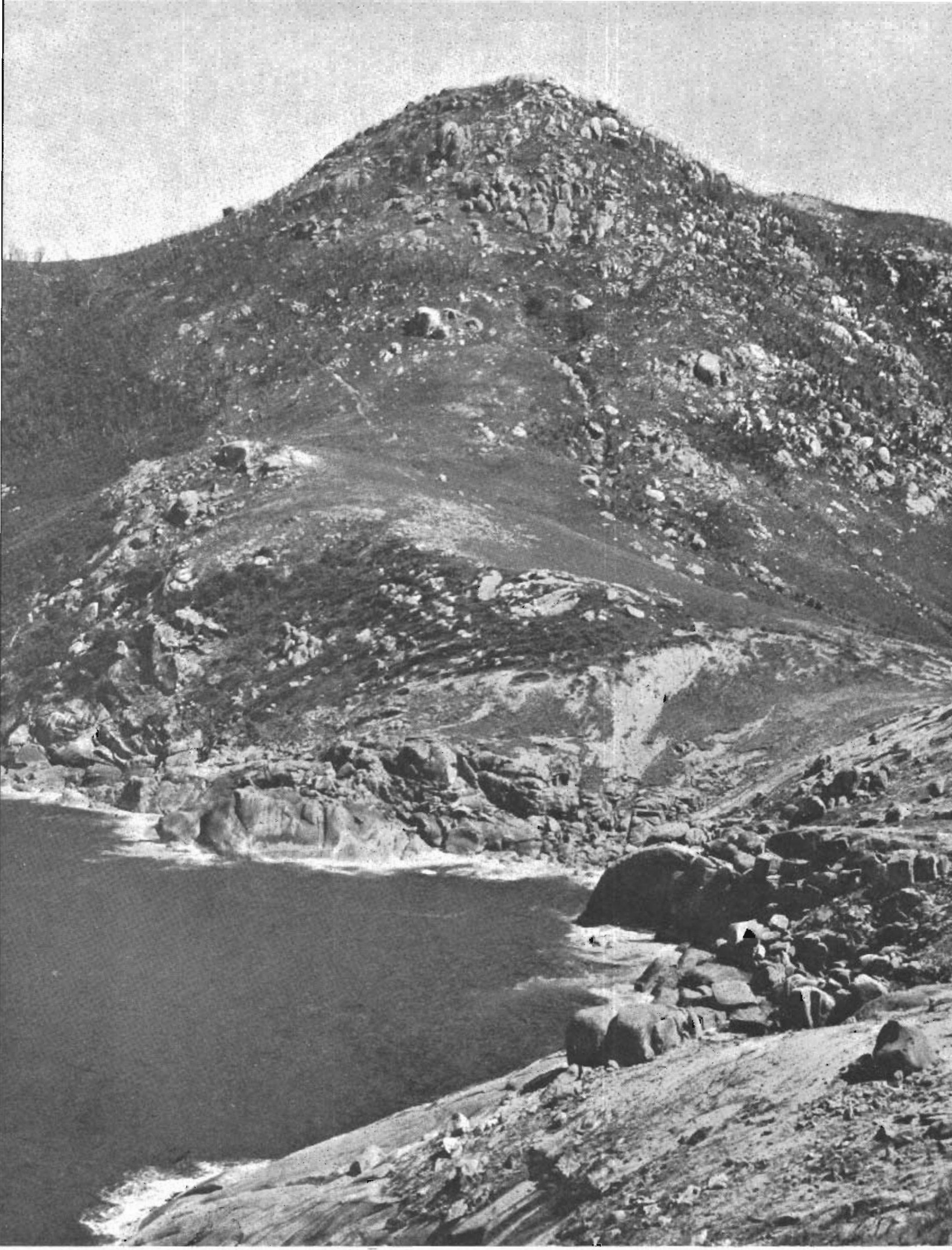


[*Professor J. S. Turner*

An older stage of dune succession the dense shrubs of younger dunes have been replaced by an open dune woodland with *Eucalyptus viminalis*. Bracken and some scattered heathland species form the ground layer. In these older dunes the leached soil is acidic.

The sandy barrier between the Ninety Mile Beach (right) and Cunninghame Arm, an estuarine lagoon (left) east of Lakes Entrance. The dune ridge on the barrier shows scrub (mainly *Banksia integrifolia*, *Acacia sophorae*, and *Leptospermum laevigatum*) invading Marram grass (*Ammophila arenaria*) and coast fescue (*Festuca littoralis*) on the seaward side.

[*Dr. E. C. F. Bird*



[Dr. L. H. Smith

South Peak, Wilsons Promontory, shows a rocky granitic coast with unequal weathering of the granite leaving scattered rocks and tors embedded in a skeletal acid soil. The vegetation includes *Eucalyptus* woodland, cliff scrub showing wind pruning, and heath.

[Australian National Travel Association

The surf beach at Anglesea, Victoria, showing active cliff erosion in soft materials (left foreground and distance) with a crescentic beach ridge and dune blocking the creek outlet in the middle distance.

Coastal scrub on a steep slope with skeletal soils and some blown sand at Wilsons Promontory. This shows the characteristic pruning and espalier form of the shrubs due to salt laden winds. In the background taller shrubs are sheltered by the large granite blocks.

[Professor J. S. Turner

A young dune showing how the long-rooting runners of the dune grass *Spinifex*, and the dense-rooted tussocks of Marram grass help to bind the blown sand. *Acacia sophorae*, a dune shrub, is invading from the right.

[*Professor J. S. Turner*

Dune vegetation in two phases, as seen from the coast at Corner Inlet. In the foreground, the low sand dune is colonised by *Spinifex* grass with some Marram. Older and higher dunes in the background carry a mixed scrub, with *Acacia*, *Olearia*, and *Helichrysum* species.

[*Professor J S Turner*

[Public Works Department, Ports and Harbours Branch

View looking west from Cape Conran on the eastern Victorian coast, showing a stretch of sandy beach backed by vegetated dunes. The beach curves away from the point of granitic rocks in the foreground.

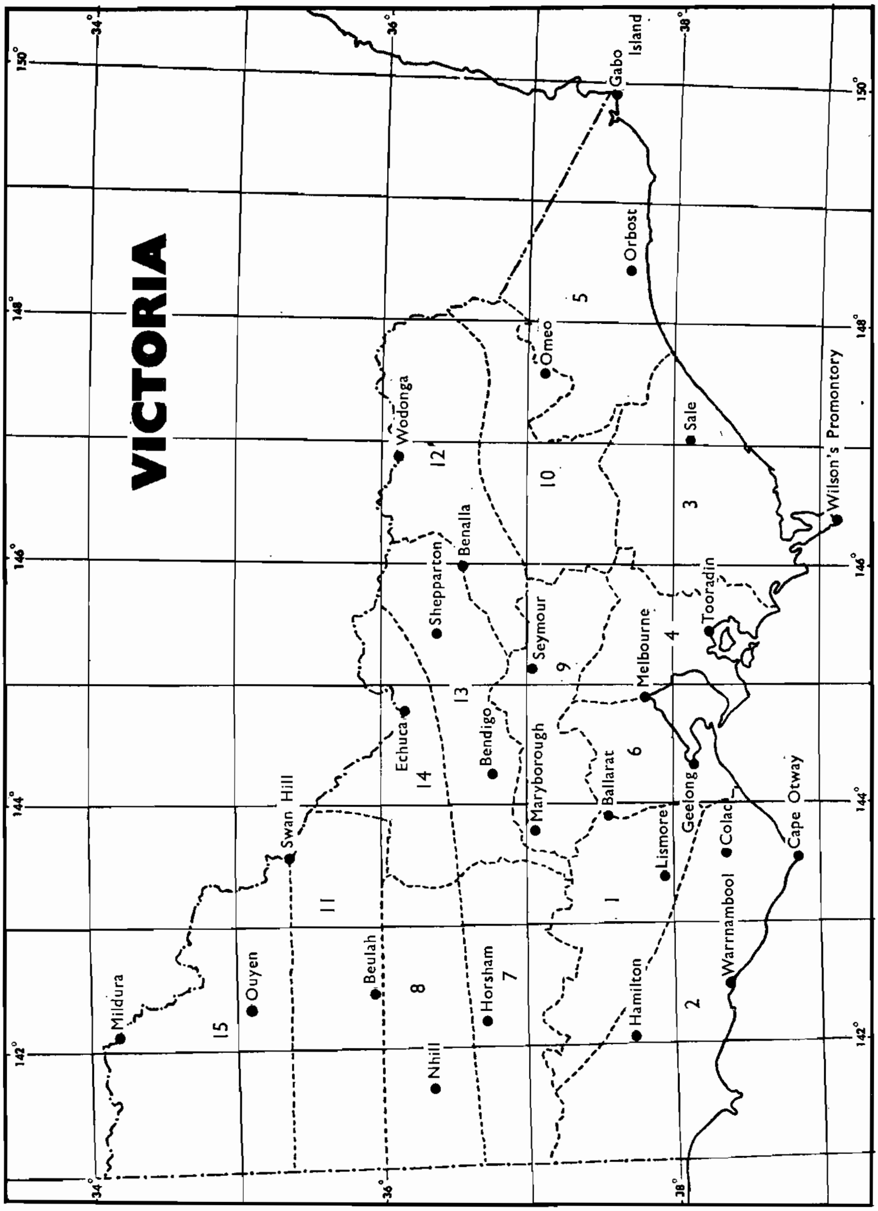


FIGURE 9.—Relative rainfall variability based on district annual rainfall. Names of districts are shown in table on page 50.

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.

Most of the elevated areas of eastern and southern Victoria normally receive over 40 in and over 60 in in some wetter sections. Interspersed between these wet mountainous areas are sheltered valleys which are deprived to some extent of their rainfall by neighbouring highlands. Along practically the whole south coastline of Victoria the average number of wet days (0·01 in or more in 24 hours) is over 150, with an average rainfall below 30 in. The average number of wet days a year is reduced to 100 at a distance of approximately 100 miles inland from the coast.

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.

Droughts

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 enough and long enough to be classified as droughts. The worst drought since white settlement in Australia occurred in the period 1897 to 1902. From 1945 to 1965 there were no serious droughts in Victoria, but in 1965 a dry spell of several months affected East Gippsland. The severity of major drought or dry spells is much lower in Gippsland and the Western District than in Northern Victoria. An approximate idea may be formed of the liability of these areas to drought or dry spells from the following table which shows the figures for total duration of unbroken dry periods. An unbroken dry period is one of three or more consecutive months where the rainfall over the area concerned is markedly below average.

Northern Victoria : 412 months in 98 years of records.

Western Victoria : 222 months in 94 years of records.

Gippsland : 291 months in 77 years of records.

Of the above totals, 88 per cent are due to droughts of a duration of twelve months or more in the North, 77 per cent in the West, and 69 per cent in Gippsland.

The figures are taken from the publication " Droughts in Australia ", Bulletin Number 43 of the Commonwealth Bureau of Meteorology, published in 1957. Readers are referred to this publication for a definitive treatment of the subject of droughts in Victoria.

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 owing to 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 page 40.)

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 with January only slightly cooler. Average maximum temperatures are under 75° F. along the coast and over elevated areas forming the Central Divide and North-East 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 Mount 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., whilst 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 the bulk 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

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

Measurements of evaporation in Victoria are made with the standard form of evaporation tank at about 27 stations, about half of which are owned by the Commonwealth 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 in. 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 in. 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.

As a consequence of the awakening of various authorities to the vital importance of evaporation in agricultural and hydrological studies, the Australian network of recording stations has almost doubled during the past twenty years.

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 are experienced. 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 90 m.p.h. There is no doubt, however, that stronger gusts have been experienced over the State, although not in the vicinity of a recording anemometer. A number of tornadic squalls have been experienced and from the severe local damage engineers have estimated wind strengths over 100 m.p.h. It is considered that any place in Victoria could feasibly experience at some time a local gust of 100 m.p.h. 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 20 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.

Meteorology in Fire Prevention

Each year a large area of Australia faces the danger of uncontrolled fire, which may cause heavy losses of vegetation, livestock and, sometimes, human life and property. The weather is one of the most important factors in the outbreak of such fires and the Bureau of Meteorology is responsible for notifying weather conditions conducive to the outbreak of fires and ensuring that meteorological information is available to authorities responsible for suppressing them.

The most important meteorological factors affecting fires are wind, temperature, and humidity. In addition, the wind and temperature up to a height of some 7,000 ft have a great bearing on the behaviour of bush and forest fires.

VICTORIA—MEANS OF CLIMATIC ELEMENTS—SELECTED VICTORIAN TOWNS

Locality		Legend No.*	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.
MALLEE	Mildura	1	97	96	71	62	106	101	112	98	81	129	98	53
		2	89·8	90·0	84·4	74·5	66·9	60·4	59·5	63·9	69·9	76·5	83·2	88·2
		3	61·0	61·7	57·2	50·5	45·6	41·3	40·5	42·5	46·1	50·9	55·4	59·6
	Ouyen	1	92	104	77	88	118	126	130	128	105	168	111	90
		2	89·4	86·0	82·1	73·1	65·7	59·4	58·7	62·8	68·9	74·1	79·9	86·7
		3	58·7	58·4	54·1	47·8	44·5	40·7	39·8	40·6	43·3	47·2	52·6	56·0
WIMMERA	Horsham	1	111	129	98	146	170	193	183	192	154	177	133	102
		2	85·1	86·3	80·2	70·7	63·0	56·6	56·0	59·0	64·1	70·2	77·2	82·7
		3	55·2	55·9	51·9	47·0	42·9	40·2	38·8	39·9	41·9	45·1	49·6	53·2
	Nhill	1	106	117	89	128	158	178	180	186	148	162	130	122
		2	84·3	85·0	79·6	70·5	63·3	57·0	56·5	59·4	64·4	70·4	76·9	82·2
		3	55·2	56·3	52·8	47·6	43·9	40·4	38·6	40·1	42·5	45·7	49·7	53·8
WESTERN	Ballarat	1	139	195	177	259	269	261	275	304	282	295	247	211
		2	75·7	76·9	71·6	63·0	56·3	50·4	49·8	52·5	57·1	62·4	67·4	72·5
		3	50·5	52·9	50·1	45·8	42·6	39·5	38·4	39·4	41·2	43·6	46·0	49·3
	Hamilton	1	149	163	188	260	254	261	291	318	276	259	216	177
		2	77·3	78·7	74·2	66·3	60·1	55·1	54·1	56·2	59·9	64·8	69·1	74·0
		3	50·7	52·4	49·9	46·3	43·2	40·2	39·3	40·4	42·3	44·0	46·3	49·2
	Warrnambool	1	137	139	212	252	270	282	321	345	257	255	211	173
		2	69·9	70·9	69·1	64·6	60·5	56·3	55·6	56·9	59·4	62·6	64·8	67·9
		3	54·7	56·0	54·2	51·0	47·8	44·8	43·6	44·4	46·2	48·1	50·2	53·0
NORTHERN	Bendigo	1	125	164	127	177	205	211	247	209	194	228	168	123
		2	83·0	83·9	78·1	68·8	61·3	54·8	54·2	57·0	62·5	68·9	75·2	80·5
		3	56·5	58·3	54·0	48·2	43·7	40·7	39·4	40·2	43·0	46·7	50·9	54·9
	Echuca	1	105	126	141	143	139	163	195	150	136	188	124	96
		2	86·2	86·8	80·7	71·1	63·6	56·7	56·0	59·0	64·7	71·7	78·5	84·1
		3	58·9	60·1	55·9	49·3	44·5	41·3	40·2	41·2	44·3	48·6	52·7	56·9

NORTH-CENTRAL	Alexandra	1	174	172	208	244	236	269	301	307	250	292	259	182
		2	84·6	85·3	78·8	69·1	61·3	53·9	53·6	57·3	62·6	69·2	75·7	81·9
		3	52·5	53·7	49·1	43·8	39·7	37·5	36·8	37·8	40·3	43·3	46·7	50·7
	Kyneton	1	143	201	146	237	251	309	354	330	265	288	223	186
		2	81·2	81·5	74·7	65·0	57·5	51·0	50·1	53·1	59·1	65·2	72·3	77·5
		3	49·8	50·5	47·2	42·3	38·5	36·2	34·8	35·3	37·9	40·4	44·1	47·6
CENTRAL	Geelong	1	117	180	137	213	185	210	207	217	199	245	243	176
		2	76·2	77·3	73·9	67·6	62·1	57·2	56·5	59·0	62·8	67·3	70·3	73·8
		3	55·4	56·9	54·7	50·7	46·6	43·1	42·0	42·9	45·0	47·5	50·4	53·7
	Mornington	1	148	215	172	261	264	264	274	262	269	289	261	203
		2	76·5	77·1	73·9	66·8	61·5	56·3	54·9	56·7	60·6	64·4	69·0	73·6
		3	55·2	55·9	54·4	50·5	47·8	44·5	42·9	43·8	45·9	48·4	51·1	53·4
NORTH-EASTERN	Omeo	1	199	251	224	229	207	246	209	228	222	317	290	243
		2	77·8	78·7	73·0	65·2	57·9	51·4	50·5	54·0	59·7	65·4	71·2	75·9
		3	48·3	48·9	45·8	40·2	35·8	33·0	31·9	33·2	37·3	39·7	43·2	47·1
	Wangaratta	1	160	167	190	215	196	272	263	242	221	268	204	167
		2	86·7	87·5	80·9	71·3	63·5	56·4	55·2	58·3	63·8	70·2	78·2	84·1
		3	58·5	59·3	54·0	46·9	41·9	39·3	38·1	39·7	42·8	46·7	51·4	56·3
WEST GIPPSLAND	Wilsons Promontory	1	168	230	314	364	398	437	433	505	353	390	327	237
		2	66·7	68·2	66·4	62·3	58·6	55·1	53·9	55·1	57·3	60·3	62·2	65·1
		3	56·9	58·7	57·4	54·7	52·1	49·0	47·7	47·7	48·8	50·3	52·2	55·1
	Yallourn	1	194	272	198	241	419	360	344	399	364	380	344	266
		2	77·7	77·4	74·3	65·8	60·7	55·3	54·9	57·3	62·0	66·3	70·2	75·3
		3	53·7	54·7	49·1	48·2	43·9	40·5	38·8	40·5	42·5	45·7	49·1	52·3
EAST GIPPSLAND	Bairnsdale	1	245	223	263	238	193	246	182	181	194	281	298	284
		2	75·3	76·1	73·0	67·5	62·5	57·5	57·0	59·5	63·2	67·5	70·6	74·0
		3	53·5	54·5	51·7	46·9	42·5	38·8	38·1	39·6	42·7	46·1	49·0	52·4
	Orbost	1	286	256	298	335	255	382	263	224	241	324	316	317
		2	76·5	75·6	73·1	67·5	62·5	57·9	58·0	60·0	64·0	66·4	70·2	74·3
		3	54·3	54·5	52·5	48·2	44·2	40·3	38·5	39·7	42·1	45·9	49·7	52·0

(Points : 100 = 1 inch).

* Legend : 1. Average Monthly Rainfall in Points. (For 30 years 1931–60). 2. Average Daily Maximum Temperature (°F.). (For 30 years 1911–40). 3. Average Daily Minimum Temperature (°F.). (For 30 years 1911–40).

In Victoria, during the fire season which normally lasts from November to April, a special forecasting service is provided to the fire control authorities (Country Fire Authority, Forests Commission, State Electricity Commission, Melbourne and Metropolitan Board of Works, and Metropolitan Fire Brigade). This consists of forecasts of the maximum temperature, and associated relative humidity, wind direction and speed to be expected at approximately seventeen places throughout the State. These forecasts are issued at 5.30 p.m. each afternoon for the following day, and confirmed or amended at 7.30 a.m. the following morning. An estimate of the time of any wind change is included, together with the expected winds at elevations of 3,000 and 5,000 ft. A general outlook for the weather up to four days ahead is also given.

The predicted weather elements are used to calculate a fire danger rating according to a scale developed by the Commonwealth Forestry and Timber Bureau. When the predicted fire danger is high in any district of the State, all public weather forecasts for that district note this fact. When the predicted fire danger is extreme, a fire weather warning is issued to the authorities and to the public. This warns of weather conditions conducive to the extremely rapid spread of fires.

When fires occur, operational forecasts are provided to the fire control authorities on request. These are forecasts of weather conditions at the place of outbreak for the following six hours and are renewed every three hours.

The Bureau also has a programme of research in hydrometeorology, agrometeorology, forecasting, and other facets of meteorology, including research into the effects of weather conditions on the behaviour of fires.

Agricultural Meteorology, 1964; Maritime Meteorology, 1966; Aeronautical Meteorology, 1967

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., whilst along the Bay, Black Rock, subject to any sea breeze, has 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 such as at Watsonia, which has a good open exposure and where average minima are a few degrees lower than those observed in 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 average 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, whilst 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 outer suburbs and probably to over 30 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 25·97 in over 143 days. From January to August, monthly averages are within a few points of 2 in ; then a rise occurs to a maximum of 2·71 in in October. Rainfall is relatively steady during the winter months when the extreme range is from half an inch to 7 in, but variability increases towards the warmer months. In the latter period totals range between practically zero and over 8 in. 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 19·01 in. Rainfall increases towards the east, and at Mitcham averages 35·95 in a year. The rainfall is greater still on the Dandenong Ranges and at Sassafras the annual average is 53·83 in.

The highest number of wet days ever recorded in any one month in the city is 27 in August. 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 sixteen days and the longest dry spell 40 days. Over 4 in of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to March. No fall above 2 in in 24 hours has ever been recorded in the cooler months. Fogs occur on four or five mornings each month in May, June, and July, and average 21 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 47. 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 nearly 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 m.p.h., whilst means exceeding 20 m.p.h. 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 m.p.h. At Melbourne, gusts exceeding 60 m.p.h. have been registered during every month with a few near or over 70 m.p.h., and an extreme of 74 m.p.h. on 18 February 1951. At both Essendon and Aspendale wind gusts over 90 m.p.h. have 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 25. 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 aborigines suggested they had never seen snow before.

Victorian Weather Summary for 1966

Summer

Rainfall was below normal in most of Victoria in January despite general rain with some thunderstorms about the middle and at the end of the month. General rain fell again in mid-February, and heavy rain fell in East Gippsland in the last week of the month, but monthly totals were well below average along the west coast and in the northern Wimmera.

After a heat wave in the last week of January, February was cool, particularly in the eastern half. In Melbourne the temperature did not reach 90° F. during the month.

Autumn

There were widespread thunderstorms in the middle of March, but rainfall in east Gippsland, the far south-west, and the western Wimmera was below normal for the month. Rain fell in most of the State in late April and middle of May, but totals for these two months were below normal in all districts except south Gippsland.

A hot spell occurred between 3 and 9 March when several towns recorded century temperatures, but for the remainder of the season temperatures followed closely to the seasonal trend.

Winter

Heavy rain fell in east Gippsland in the middle of June, but the month was dry in all other areas. At the end of June, many places in the south-west and the Wimmera had had less than half the normal six-monthly rain. Substantial falls were received in these areas during July, but dry conditions continued throughout the winter in most of the Mallee.

June was a particularly cold month ; at Bendigo and Echuca it was the coldest June for almost 60 years. During July and August mean temperatures were again below normal throughout.

Spring

September rainfall was above normal in the wheat areas of Victoria ; much of the northern country and lower north-east received more than twice the average rainfall for the month. Very heavy rain fell in east Gippsland in the first week of October, causing flooding of rivers and some roads were washed away. In other districts October rain was close to normal and further rain fell during the first half of November when there was minor flooding of Gippsland rivers. The last half of November was dry, and during a hot spell from 19 to 23 November the temperature in Melbourne exceeded 100° F. for the first time in November for almost 40 years.

Rainfall in December was well above average throughout the State and at several places broke the previous December rainfall records by some inches. Heavy rain in the north-east on 13 December caused severe flooding in the King River. Severe thunderstorms with hail and strong winds caused much damage at Mildura on 12 and 13 December, and on 19 December the same area was hit by a severe duststorm. Heavy thunderstorms with hail occurred in the Melbourne area and the Latrobe Valley at Christmas.

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)	7·36	6·05	6·63	5·89
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)*	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

* Scale 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1962 to 1966. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological Elements	1962	1963	1964	1965	1966
Mean Atmospheric Pressure (millibar)	1016·2	1017·2	1014·2	1017·3	1017·2
Temperature of Air in Shade (° F)—					
Mean	60·1	59·5	58·6	59·3	59·3
Mean Daily Maximum ..	68·6	68·0	66·5	67·8	67·5
Mean Daily Minimum ..	50·7	51·0	50·7	50·9	51·1
Absolute Maximum	104·0	99·0	103·3	106·9	102·8
Absolute Minimum	31·8	29·3	36·0	32·4	32·9
Number of Days Maximum 100° F and over	4	0	4	7	5
Number of Days Minimum 36° F and under	12	12	1	10	7
Mean Terrestrial Minimum Temperature (° F)	47·3	48·5	47·7	47·9	48·4
Rainfall (inches)	23·06	29·04	27·80	23·24	26·81
Number of Wet Days	140	149	166	122	157
Total Amount of Evaporation (inches)	43·21	37·79	35·54	44·87	47·08
Mean Relative Humidity (Saturation = 100)	61	67	66	62	63
Mean Daily Amount of Cloudiness (Scale 0 to 8)*	4·5	4·7	5·1	4·4	4·8
Mean Daily Hours of Sunshine ..	6·4	5·5	5·4	6·2	6·0
Mean Daily Wind Speed (m.p.h.) ..	8·4	7·5	8·4	7·2	6·9
Number of Days of Wind Gusts 39 m.p.h. and over	77	52	97	62	47
Number of Days of Fog ..	9	20	12	21	6
Number of Days of Thunder ..	15	12	12	9	6

* Scale 0 = clear, 8 = overcast.