FUNCTIONAL ANATOMY OF BIRDS

A. N. WORDEN

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by

ALASTAIR N. WORDEN

Director, Nutritional Research Unit, Huntingdon; formerly Milford Research Professor in the

FIRST EDITION

CAGE BIRDS

DORSET HOUSE, STAMFORD ST., LONDON, S.E.1

CONTENTS

ILLUSTRATIONS

INTRODUCTION

THE aim of this book, which is based on a series of articles that appeared in *Cage Birds*, is to provide in as straightforward language as possible, an illustrated account of the anatomy or structure of birds. It will, of course, be necessary to use some technical terms, but these will be explained as they occur.

A knowledge of the structure of the living body is of limited value unless we attempt to understand what the different parts actually do. Considerable attention will, therefore, be paid to what is called functional anatomy. In this way it is hoped to provide a sound basis for understanding the real workings of the bird's body in health and disease.

In the first chapter the skeleton (i.e. bones and joints) will be illustrated and briefly described. All our usual cage and aviary birds, and also our domestic poultry, belong to that great group known as the *Carinatæ* or flying birds—as opposed to the *Ratitæ* or running birds such as the Ostrich, Emu, Cassowary, Rhea, Kiwi and Moa.

The flying birds have, basically, well-developed wings and a keel (the Latin word for which is carina, hence *Carinatæ*) on the breast-bone. To this keel are attached the powerful muscles employed in flying.

The keel of the breast-bone in the *Carinatæ* varies a great deal in development. In Swifts, Humming-birds and in some of the Petrels it is exceedingly deep, whereas in birds that have become flightless, e.g. the extinct Dodo and many other present-day Rails, it has dwindled almost to nothing.

The word for running-birds (*Ratitæ*) is, by the way, derived from the Latin word *ratis*, a flat-bottomed boat, because in these birds the breast-bone as a whole has no keel and resembles somewhat a " ratis."

It will be obvious from the description of the skeleton as a whole how many other features of the group of birds with which we are concerned are really adaptations to flight.

Among captive species we pay much attention to colour, voice and behaviour, but these are all the properties of birds which have survived largely as the result of the capacity of themselves or of their ancestors to fly.

After the skeleton we shall deal first with the " outside features " —properly termed *surface anatomy*—and surface structures, and then with the leg, wing, digestive system, excretory system, reproductive system of both sexes, respiratory system, circulatory system, the

blood, the ductless glands, nervous system, eye, ear and organs of voice production.

Then will come an account of the egg and of the development of the chick before hatching, i.e. embryology.

General Principles Emphasized

The special features of different groups or species of interest will, of course, be dealt with, but it is to be hoped that the feature will be more useful in emphasizing *general principles* than in noting miscellaneous characteristics.

With a clear grasp of these general principles it should be possible to discuss in a more knowledgeable way the problems of health, behaviour, mating, egg-laying, moulting, voice-production, colouration, flight, beak-growth, food requirements and so on.

Further Reading

Even a simple outline such as this would not be possible without the help of works of reference, which are referred to frequently throughout the text. A full list of the textbooks referred to is given on p. 126.

The author is indebted to Dr. Robert A. Hinde, of the Department of Zoology and Ornithological Field Station, University of Cambridge, and to Dr. T. G. Taylor, of the Department of Agricultural Chemistry, University of Reading, for their kindness in reading the text and in making many valuable suggestions. Readers may find certain sections somewhat disjointed, but this fault is inherent in works adapted from a series of articles. Professional anatomists will appreciate that there are drawbacks when attempting to simplify a technical subject.

CHAPTER 1

Skeleton of a Flying Bird

THE accompanying diagram shows the skeleton (bones and joints) of a typical "flying" bird, as discussed in the Introduction. The skeleton of the bird has been described as a series of hollow girders and large plates. Even the tubular bones are very thin, and sometimes they are reinforced with internal struts that render them highly efficient by modern engineering standards. The bones of birds do not grow in length by the same means as those of mammals.

The skeleton is usually divided into two parts for classification purposes. The so-called "*axial skeleton*" comprises the skull, backbone, tail, ribs and breast-bone. The "*appendicular skeleton*" consists of the limbs, i.e. the wings and legs. (Some authorities give a different classification.)

The skull contains the brain-box or *cranium*, and it is able to rotate on the *atlas*, the first of the units or vertebræ that make up the spinal column. The front part of the skull is shaped to form the background of the face.

The skull is made up mostly of fused bones. Those surrounding the brain-box are extremely thin. There is little point in reciting the names of most of these bones, but the accompanying diagram shows the general arrangement, and also the attachment of the lower jaw or *mandible*.

The mandible is divided into several portions, the front part of which (*dentary*) is the basis of the lower beak or bill. The upper beak is based on a bone termed the *maxilla*. A detailed account of the beak and its functions will be given in a later chapter. The *quadrate bone* permits the bird to open its mouth in characteristic fashion. There is no false palate in birds, so that the internal nostril opens into the mouth.

There are various holes (*foramina*) leading into the inside of the skull. The biggest (*foramen magnum*) is for the passage of the spinal cord. Others are for nerves, including the optic nerves from the eye and blood-vessels.

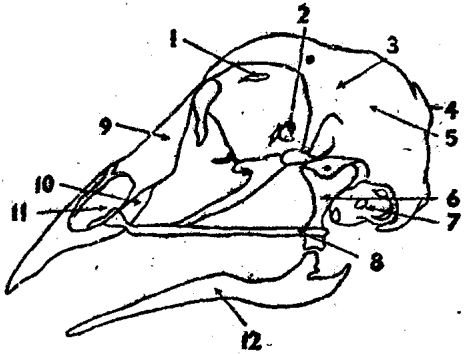
The skull of the bird has to combine size (for the relatively large cranium) with lightness. The bones are of almost paper thinness, and fractures may occur quite readily when the bird flies into some hard object.

The units or *vertebræ* that make up the spinal column vary in

number but are grouped as *cervical* (neck), *thoracic* (chest), *sacral* or *pelvic* (loins) and *caudal* (tail). Running through the centre of all the vertebræ, except those of the tail, is the spinal cord.

The number of neck vertebræ varies from 13 to 23 in different species. (It is almost invariably 7 in mammals.) As already indicated, the first is termed the atlas, which forms joints or *articulates* with the skull. The second is named as well—the *axis* or *epistropheus*—and the atlas turns on it.

The remaining neck vertebræ have processes or projections which serve for the attachment of the neck muscles and also for the protection of certain blood vessels. The neck of birds is extremely flexible.



THE SKULL

1: Olfactory foramen (for olfactory nerve). 2: Optic foramen (for optic nerve). 3: Cranium (rounded part of skull). 4: Occipital bone. 5: Parietal bone. 6: Quadrate bone. 7: Tympanic cavity. 8: Jugal bone. 9: Nasal bone. 10: Upper jaw (maxilla). 11: Nostril. 12: Lower jaw (mandible)

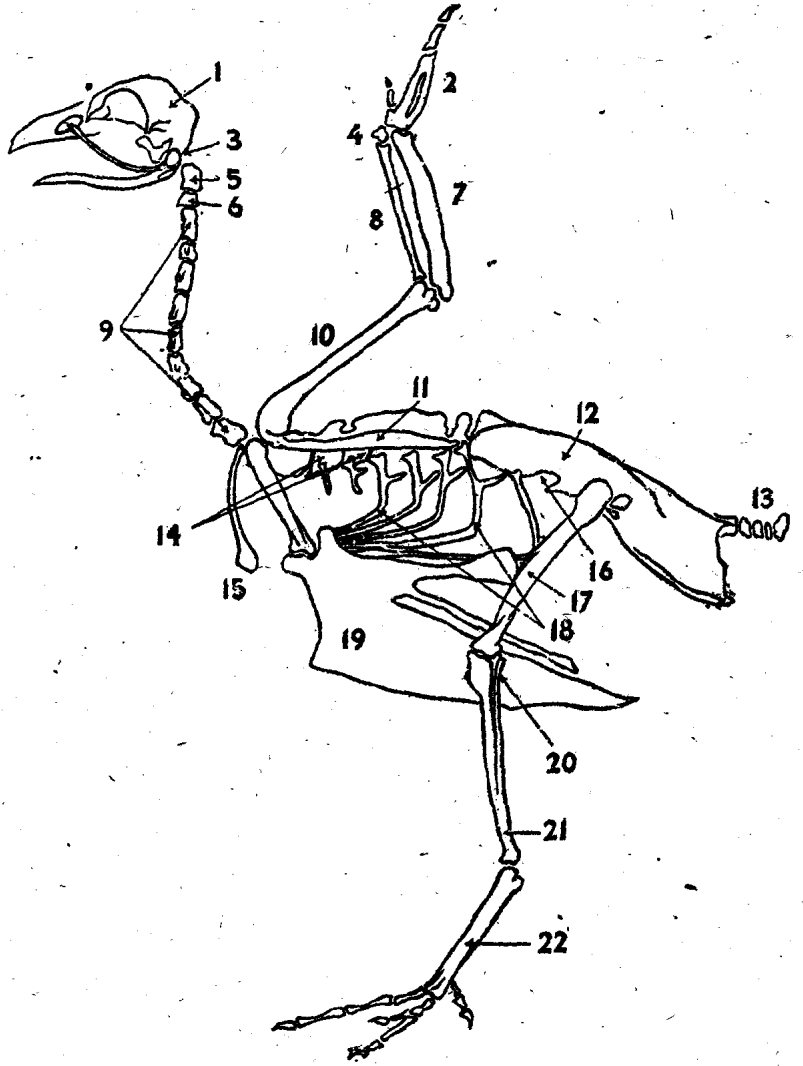
There are usually seven chest vertebræ, and these form the attachments for the ribs. They are alternatively known as the *dorsal* (back) vertebræ. In many species the middle chest vertebræ are fused together.

In birds, the loin or *sacral* vertebræ are fused together to form a bony mass. The last of the chest and the first of the tail vertebræ are usually incorporated in this bony mass, which is to do with the bipedalism or two-legged nature of the bird. The remaining tail vertebræ show considerable variation. The last few are fused to form the *pygostyle*, the part that bears the tail feathers.

The *ribs* form the main boundaries of the chest wall. Their function in relation to breathing will be dealt with in the appropriate chapter. The middle ribs are joined at their lower ends to the breast-bone or sternum and will be dealt with later when flight is described, as will the bones of the wing, while the leg bones are likewise due to be discussed separately.

The *pectoral girdle*, or shoulder-girdle, consists of three pairs of bones known as the *coracoids*, the *scapulæ* (shoulder-blades) and *clavicles* (collar-bones), the last pair usually fusing or coalescing along the mid-line to form the well-known "wish-bones" or "merry-thought," more properly referred to as the *furcula*. In certain Parrots, however, they are only vestigial, while in some Owls they do not

unite. The union of the thin blade-like scapula with the stout coracoid forms the *glenoid* cavity. The scapula helps to brace the wing away



FLYING BIRD'S SKELETON

1: Skull. 2: Metacarpal bones. 3: Foramen magnum. 4: Carpus or wrist. 5: Atlas. 6: Axis or epistropheus. 7: Ulna. 8: Radius. 9: Cervical (neck) vertebræ. 10: Humerus ("funny bone"). 11: Scapula. 12: Pelvic Girdle. 13: Pygostyle. 14: Thoracic (chest) or dorsal (back) vertebræ. 15: Clavicle ("wish-bone"). 16: (hidden) Pelvic vertebræ. 17: Femur or thigh-bone. 18: Ribs. 19: Breast-bone. 20: Fibula. 21: Tibia. 22: Metatarsal bone

from the ribs, while the coracoid holds the wing away from the sternum, being assisted in this by the furcula. The coracoid forms a joint with the sternum while the furcula has a looser attachment to it.

Now the skeleton, although hard and seemingly lifeless when we see it as a separate set of bones, is not only the solid structure on which the body hangs together. There is a wonderfully delicate series of joints and muscles that couple the skeleton together and render it a flexible and adaptable structure.

Watch a bird preen or feed, or move in response to some alarm, and realize how smoothly and delicately its bones must move. Nevertheless, by mammalian standards the mobile joints are few in number and the muscular system is simplified. These adaptations conform with the light but rigid skeleton necessary for successful flight.

Moreover, the bones themselves contain highly active tissues. The *bone-marrow*, although reduced in volume in birds to make way for the air cavities, has many functions, including the " manufacture " of the red and white cells of the blood. But even the bone-tissue itself is not just a hard, unchanging mass. In life, there is constant activity in the bone-cells, while the body's reserves of the important mineral salts (compounds of calcium, phosphorus and magnesium) are mainly in the bones.

These minerals are constantly entering and leaving the bony tissue: at the start of the laying period, when the level of calcium in the blood of birds rises, there must be frantic activity in some of the bone-cells. In later chapters we shall deal with some of these activities of seemingly inert bone, and also with the special adaptations of birds' bones to flight.

CHAPTER 2

Surface Characteristics Explained

IN the accompanying diagram the main "points" of a typical flying bird are shown. It has been thought best to adopt, with due acknowledgement, the nomenclature used in that classic work, *The Handbook of British Birds*, by H. F. Witherby, F. G. R. Jourdain, Norman F. Ticehurst and Bernard W. Tucker.

In birds the main *body cavity* is not so clearly divided into two parts (thorax and abdomen) as it is in mammals. The *diaphragm* of birds is a rudimentary structure. This arrangement is reflected in the outside appearance of the bird's body, which is of a more even contour than that of the average mammal, and does not possess a "waist."

In many species, including the majority of cage and aviary birds, the neck is less obvious from the exterior than in mammals. The neck is, however, extremely flexible and most birds can rotate their head through a wide arc. The head as a whole can in fact be rotated so as to rest on the body, as during sleep. This saves a great deal of muscular effort.

The general compactness of the bird's body is further shown by the position of the wings when at rest. They lie neatly folded to the sides of the body unless injury, lack of condition, or disease causes them to droop.

Even the legs of most species can be "streamlined" during flight, or tucked closely into the body if so required at other times. Generally speaking, the faster a bird can fly the more perfect is its streamlining.

The head of most birds is of a fairly uniform shape, with a well-marked conical "*face*" and a pointed *beak* based on the bones described in the previous chapter. There is considerable modification in beak form in different types of bird—a subject that will be dealt with later—while in some species, e.g. Budgerigars and particularly Owls, the face is compressed.

The outside depression corresponding to the junction of the cranial portion of the skull with the face is called the *cranio-facial hinge*. Ornithologists have a standard measurement for the length of the beak or bill, from its tip to the cranio-facial hinge.

The two *nares* or *nostrils* are situated in a portion of naked (i.e., unfeathered) skin termed the *cere*. This runs down the beak for a varying length in the different species.

It is sometimes swollen and in many birds is pigmented. In some instances the cere is pigmented differently in males and females. Skin may project for a short distance under the lower beak also, and, of course, it covers the junction between upper and lower beaks.

The ridge that runs along the centre of the upper beak is termed the *culmen*. The lower beak has, in some species, a prominent ridge towards the tip and this is called the *gonys*.

The more or less sharp lower margins of the upper beak and upper margins of the lower beak are referred to as the *cutting edges*. When the mouth is opened the angle formed by the upper and lower jaws is referred to as the *gape*.

In some species (notably domestic fowls) are appendages termed *wattles*. These are rich in blood vessels or "highly vascular," thereby differing from the ordinary skin of birds.

In the fowl they lie under the jaw, while in pigeons and some other birds they are found between the nose and eyes, and in turkeys there is a single wattle under the jaw, the colouration of which at 7–8 weeks of age is called "shooting the red." Other skin appendages will be dealt with later in relation to their special functions, e.g. *brood-* or *incubation-spots*.

On the crown of the head a *comb* is found in some species, again notably in the domestic fowl. When present it is a *secondary sexual character*, i.e., one of several features that depend for their normal development or structure upon the circulation of the appropriate sex hormone. Comb growth and appearance can be altered almost at will by appropriate injections of male and female sex hormones.

Birds do not possess a defined *external ear* (pinna) as do mammals. The external end of the *auditory canal* is surrounded by a fringe of feathers (the *ear coverts*), while at the internal end of the canal is a delicate *tympanic membrane* beyond which lies the *middle ear*.

Large, Prominent Eyes

The eyes of birds are normally large and prominent, and are lodged in the two *orbital cavities*. The coloured portion of the surface of the eye is called the *iris*, and the aperture in its centre is the *pupil*.

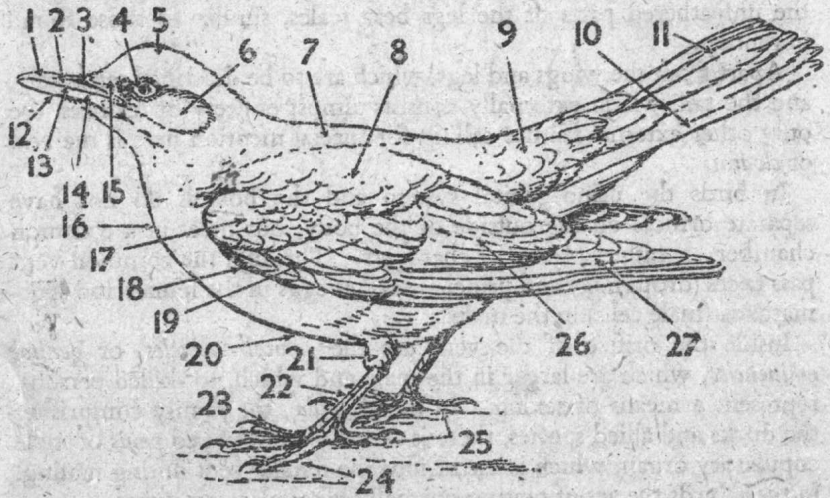
Of the two *eyelids*, the lower is the better developed and more movable than the upper. There is also a so-called third eyelid or *membrane nictitans* (nictitating membrane), which is normally hidden in the medial or inner corner of each eye, but which can extend to cover the whole of the visible portion of the eyeball. Its movements are very rapid and are controlled by two special muscles. It contains a gland which has lubricating properties.

The skin of birds is much thinner than that of most mammals and is remarkably free from glands. The only skin gland is, however,

a large one, lying over the last vertebra. It is called the *uropygial gland, oil gland* or *preen gland.*

It is absent or vestigial, i.e., present only as a vestige or remnant, in some birds of prey. The opening of the gland has in it a nipple-shaped projection of the skin.

The gland itself contains two lobes which secrete an oily substance formed by the breakdown of cells in the numerous little tubules that make up the lobes. The oily secretion varies in composition from species to species, but on the average it contains about 50 per cent of fat. The secretion is, of course, spread by the bird over its feathers,



THE "POINTS" OF A FLYING BIRD

1: Culmen
2: Upper Mandible
3: Nostril
4: Iris
5: Crown
6: Ear Coverts
7: Mantle
8: Scapular Feathers
9: Upper Tail Coverts
10: Outer Tail Feathers
11: Retrices
12: Gonys
13: Cutting edge of Mandible
14: Lower Mandible
15: Lores
16: Breast
17: Lesser Wing Coverts
18: Ala Spuria (bastard wing)
19: Greater Wing Coverts
20: Belly
21: Tibia
22: Tarsus
23: Inner Toe
24: Outer Toe
25: Hind Toes
26: Secondary Remiges ("Secondaries")
27: Primary Remiges ("Primaries")

and a Chinese scientist some years ago brought forward evidence that it contained a precursor or forerunner of Vitamin D.

He found that when the preen gland was removed, and the bird isolated so that it could not steal the secretion from normal birds, it became ill. The symptoms of illness could be relieved by feeding the bird with Vitamin D. His findings, however, have not been altogether confirmed by later American work.

Poultry breeders have found that in chicks reared artificially the preen gland often fails to function. This has been ascribed partly to the dry atmosphere in which they are maintained and partly to the fact that they have not learned to preen from observing their parents.

A bird's skin is extremely sensitive, there being numerous nerve endings, especially at the roots of the feathers. The bundles of muscles that lie under the skin are so arranged that when they contract they cause the feathers to erect.

The outer skin as a whole contains fewer blood vessels than does that of mammals. The parts of the skin on which feathers grow are covered by a thin, dry and scurfy layer termed the *epidermis*, while the unfeathered parts of the legs bear scales, similar to those found in reptiles.

Apart from the wings and legs, which are to be described separately, and the tail, which externally consists almost entirely of feathers, the only other external feature calling for special mention here is the *vent* or *cloaca*.

In birds the urino-genital system and the bowels do not have separate orifices on the outside of the body, but meet in a common chamber, or rather a series of chambers. Through the common vent pass fæces (droppings) and urine, as well as eggs in the female and spermatozoa (male cells) in the male.

Inside the orifice of the vent are the *genital tubercles*, or *genital eminencies*, which are larger in the male and which, to skilled persons, represent a means of sexing. In the *Anatidæ*, the family comprising the ducks and allied species, there is actually a developed *penis* or male copulatory organ, which is thrust into the female vent during mating. In these birds the act of mating normally takes place on water.

In all other birds the two vents are brought into apposition during mating, and the lining of the male vent becomes partly everted in order to facilitate transmission of the spermatozoa.

In the female there are corresponding changes within the cloaca, as will be discussed more fully in the appropriate chapter.

CHAPTER 3

The Feathers

As already indicated, only birds possess feathers. The development of this unique type of covering in primitive birds must have paralleled that of the capacity to fly efficiently. Feathers are not, of course, indispensable to flight among higher animals, for bats are mammals and unfeathered. Conversely, flightless birds have feathers. But in flying birds the capacity to fly can be removed by clipping the primary flight feathers.

In replacing the scales of the reptilian or reptile-like forms from which birds are believed to be descended, feathers conferred a number of other advantages. They form an efficient system of conserving body heat, since they prevent an excessive loss of heat by radiation.

Modern birds, like mammals (which are usually covered by fur, wool or hair) and unlike reptiles, can maintain an even body temperature despite the vagaries of the weather. The adjective used to describe this ability is *homoiothermic*.

Feathers do not develop at random over the skin but in definite *feather tracts* or *pterylæ*. The unfeathered tracts, e.g. that over the "keel" of the breast-bone, are termed the *apteria*. In some cases these tracts may retain a light covering of *down*.

In some species, particularly those in which it is essential for the young to be active immediately or very soon after hatching (e.g. game-birds), a covering of down develops while the birds are still in shell. These birds are also hatched with their eyes open. They are referred to as *nidifugous*, owing to their ability to leave the nest.

In most species, including passerine birds, the young are blind and naked when hatched, and appear helpless. They are termed *nidiculous* and a varying but considerable time elapses before they are capable of leaving the nest. At whatever stage the down first develops, that which precedes true feathers is likewise arranged in definite tracts. The down-tracts of a typical passerine nestling are depicted in the accompanying sketches.

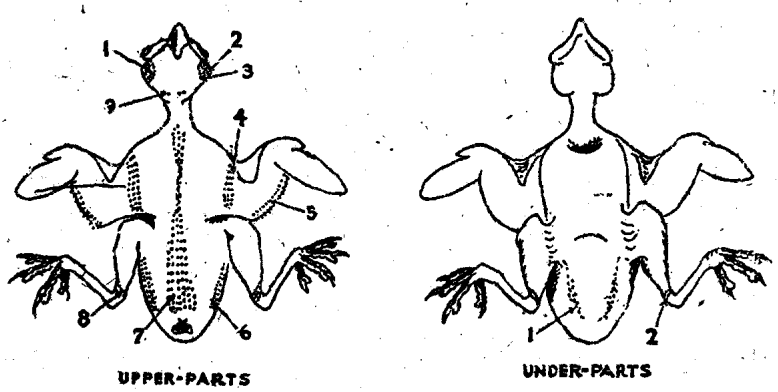
There is considerable variation in the succession of downy coats. Many species have two coats of *neossoptiles* or *nestling-down*, known respectively as *protoptiles* and *mesoptiles*. Where one coat only of nestling-down occurs, there is some doubt as to which of the normal two coats it represents.

The nestling-down feathers usually differ from the typical adult

feathers to be described below by having a very short calamus, long and slender barbs and no barbules. This accounts for their fluffy appearance. In a few species, the nestling-down is almost or entirely suppressed.

The feathers or down that succeeds the neossoptiles are referred to as the *teleoptiles*, and there may be, of course, various manifestations of juvenile plumage before the normal adult appearance is attained.

As already indicated, some down often persists on the otherwise featherless tracts termed *apteria*. This down is to be found also among



A nestling bird showing the down-tracts referred to in this chapter. Upper-parts —1: Outer supraorbital tract. 2: Eye. 3: Inner supraorbital tract. 4: Humeral tract. 5: Ulnar tract. 6: Femoral tract. 7: Spinal tract. 8: Crural tract. Under-parts—1: Ventral tract. 2: Crural tract

the contour feathers of many species, and the feathers constituting it are known as *plumules*.

When such down behaves in a certain way (as, e.g., in Parrots), it is referred to as *powder-down*. The quill as it grows does not form a central shaft but splits into numerous barbs and barbules, which are brush-like in appearance. These barbs and barbules continuously disintegrate into a bluish-white or a greyish-white powder, which permeates the plumage.

A diagram of a typical adult feather is shown on p. 13. The developing feather has been described as a bulbous cylinder of the outer layer of body tissue or ectoderm.

This cylinder forms the quill or calamus and also grows to produce the *rhachis* (principal shaft) and *barbs* (*rami* or *lamellæ*), which collectively form the *vane* (*vexillum*) of the feathers.

There is a small opening at the body end of the quill (the *inferior umbilicus*) and another at the junction of the quill and vane (the