



TARTU STATE UNIVERSITY

TEXTS FOR BIOLOGISTS

II

TARTU 1968

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Compiled by H. Laan

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Introduction

The present collection of texts is meant to provide reading material for the second- and third-year students of biology studying English as a foreign language.

The reader contains texts from different branches of biology (microbiology, botany, zoology, plant-physiology, biochemistry, genetics and the theory of evolution). In American texts the spelling of the original (color, millimeter, marvelous etc.) has been retained.

The reader is provided with an English-Estonian vocabulary. The pronunciation is not given in simpler cases. The vocabulary also includes words whose meanings are obvious but the pronunciation of which represents some difficulty, especially as regards the stress (such as hypothesis, nucleotide, enzymology, anthropogenous, etc.). As a result, only the contextual meaning is given. Proper Names are listed separately.

We should like to acknowledge our indebtedness to the professors and teachers of the Faculty of Biology of our University and to the research workers of the I.Z.B. of the Academy of Sciences for their kind assistance and advice in the compilation of this reader.

Tartu State University, December 1965.

H. Laan

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MICROBIOLOGY

Introduction

Microbiology in its broadest meaning is the science that deals with the study of all microorganisms, such as bacteria, yeasts, molds, algae. Bacteriology is the science that deals only with the study of bacteria.

From the point of view of classification, living organisms have been placed into either the plant or the animal kingdom. Most living organisms possess the characteristics of both plants and animals but for the sake of convenience they have been grouped under the plant kingdom.

Distribution of Bacteria

Bacteria are widely distributed in nature, being found nearly everywhere. They are found in the soil, air, water, foods, in decaying organic matter of all kinds, on the body surface, within the intestinal tract of man and animals, etc. The numbers vary from one place to another, depending upon the environmental conditions.

Some bacteria are more commonly distributed in certain places than others. The common occurrence of a species in a certain environment is spoken of as the natural flora of that particular environment. Changes in the environmental conditions produce changes in the bacterial flora.

SOIL. The numbers and kinds of organisms present in soils depend upon the kind of soil, quantity of plant or animal debris (humus), acidity, alkalinity, moisture content, etc. The numbers decrease with depth, owing to lack of oxygen and food materials. A rich garden soil contains many more organisms than a poor uncultivated soil. The great majority of soil organisms are found in the sur-

face layers.

AIR. Bacteria are found in the atmosphere, being carried there by air currents. Organisms do not grow and multiply in air because conditions are not favourable. There is no such thing as a normal atmospheric flora. The numbers and kinds depend upon location, amount of moisture, dust particles, wind currents, and the presence of toxic gases. The air over the ocean far removed from shore is practically free from microorganisms. The same holds true for air over high mountains. Dusty rooms usually show considerably more organisms than do rooms kept free from dust.

Bacteria are usually found adhering to particles of dust. This means that the more particles suspended in air the greater will be the extent of bacterial contamination. Spores of yeasts, molds, and bacteria are commonly found in air owing to the fact that these bodies are more resistant to the ultra-violet rays of the sun than are the vegetative cells producing them. These bodies are a frequent cause of air contaminations in bacteriological laboratories and, because of their great resistance to heat, require high temperatures to destroy them.

WATER. Most waters contain large numbers of bacterial organisms. The numbers vary considerably, depending upon the source of the water, e.g., from deep or shallow wells, springs, rivers, lakes, ponds, streams, etc. Water polluted with sewage may contain thousands or even millions of organisms per cubic centimeter.

Under some conditions disease organisms may also be present. Some bacterial species are constantly present and constitute the natural flora of that water. Usually fewer bacterial species occur in sea water than in the soil.

FOODS. Foodstuffs are rarely free from living organisms. Some of the organisms are of benefit in producing desirable fermentations, such as occur in the oxidation of alcohol to acetic acid or vinegar, the lactic fermentation of cabbage to sauerkraut, etc. Frequently undesirable or-

ganisms are found in foods and bring about abnormal changes. Sometimes foods are the cause of certain types of intoxications and disease processes due to the presence of pathogenic organisms.

BODY. The outer surface of skin of the body always contains microorganisms. The same applies to the alimentary tract and respiratory passages of man and animals. The skin, intestinal contents, and the respiratory passages contain a normal bacterial flora. These organisms are for the most part harmless. Occasionally some species penetrate the broken skin and intestinal wall, resulting in the establishment of a disease process. Usually the organisms are destroyed by the defense mechanisms of the host. It has been said that as much as one-fourth of the dry weight of the intestinal contents of man is composed of bacterial cells.

Functions of Bacteria

Those who are not familiar with the activities of bacteria usually believe that the vast majority of them are harmful; that their chief function is to gain entrance to the body and produce various kinds of diseases. This statement is entirely erroneous. The great majority of the bacteria are not only harmless but absolutely necessary for the existence of living things. Life could not exist in the complete absence of bacteria. They are necessary for the disposal of humus and animal carcasses. The remains of plant crops, plant stubble, leaves, etc., are converted into soluble compounds by the soil organisms and made available to the new plants. Some species are capable of taking nitrogen from the air and converting it into compounds that are utilized by the plants.

Bacteria are necessary for the disposal of sewage. They convert the insoluble proteins, fats, carbohydrates (cellulose) into soluble odourless compounds. The souring

of milk is the result of bacterial action. This is the first step in the preparation of butter and cheese. The ripening of cheese is brought about by the action of bacteria and molds, which are responsible for the odours and flavours imparted to cheeses.

These are only a few examples of the part played by the associated activities of organisms in nature.

Morphology of Bacteria

General Considerations

Bacteria belong to the great class of organisms known as the Schizomycetes (schizo = fission, and mycetes = fungi). The organisms grouped in this class are so named because they reproduce typically by cell division or fission.

Bacteria are characterized as typically unicellular plants, the cells being usually small and relatively primitive in organization. The cells may be spherical, cylindrical, spiral, or filamentous, and are often united into chains or into flat or cubical aggregates. Multiplication occurs normally by cell division. The cells may be motile by means of long, whip-like processes known as flagella. Some of the forms intergrading with the protozoa are flexuous. A few of the higher filamentous bacteria show an oscillatory movement.

The rod forms also show considerable variation. A rod is usually considered to be a cylinder with the ends more or less rounded. Some rod forms are definitely ellipsoidal in shape. The ends of rods also show considerable variation. Some species are markedly rounded and others exhibit flat ends perpendicular to the sides.

Rods may show marked variation in their length/width ratio. Some rods are very long in comparison to their width and others are so short they may be confused with the

coccus forms.

The shape of an organism may also vary depending upon certain environmental factors, such as temperature of incubation, age of the culture, concentration of the substrate, and composition of the medium. Bacteria exhibit their characteristic morphology usually in young culture and on media possessing favourable conditions for growth. Those forms which depart widely from the standard morphological picture, when one or more environmental factors are changed, have been called involution forms and forms of degeneration.

Bacterial variation resulting from changes in age and other environmental factors are only temporary. The original forms reappear when the organisms are inoculated into fresh medium.

SHAPE OF BACTERIA. Bacterial cells exhibit three fundamental shapes: the spherical, the rod, and the spiral forms. All bacteria exhibit pleomorphism in more or less degree, under normal or other condition, but a bacterial species is still generally associated with a definite cell form when grown on standard media under certain specified conditions.

Some of the round or coccus forms are apparently perfect spheres; others are slightly elongated or ellipsoidal in shape. Spherical forms that grow normally in pairs (diplococci), fours (tetrads), or chains (streptococci) are usually slightly flattened at their adjacent surfaces. A pair of such organisms is usually referred to as coffee-bean shaped.

SIZE OF BACTERIA. Bacteria are considerably smaller than yeasts, molds, algae and protozoa. They vary greatly in size according to the species. Some bacteria are so small that they cannot be easily seen with a powerful microscope. Regardless of their size none are visible with the naked eye.

A spherical or coccus form is measured by the size of its diameter; a rod or spiral form by its length and width.

The method employed for fixing and staining bacteria for microscopic study may make a difference in their size. The bacterial cell shrinks considerably during drying and fixing. This will vary somewhat depending upon the type of medium employed for the cultivation of the organisms. The magnitude of the shrinkage will average about one-third of the length of the cell when compared to an unstained, hanging-drop preparation.

All organisms that have been studied and classified have been measured. The measurements have been carried out for the most part on fixed and stained preparations. In some instances dried, negatively stained smears were used and in a few cases living material was employed. It follows from this that the method employed should be specified when measurements of bacteria are reported.

Bacteria show considerable variation in size. Some measure as large as 80 in length and others are as small as 0.1. The large forms are members of the sulphur and iron bacteria, which show characteristics intermediate between the true bacteria and higher plants. However, the majority of organisms, including the pathogenic bacteria, are about 0.5μ in diameter for the cocci and 5.0μ by 2 to 3μ for the rod forms. The most commonly employed method for measuring bacteria is by means of the ocular micrometer. Measurements may also be made by using a camera lucida attachment and drawing oculars, or by projecting the real image on a screen and making the measurements.

PRESENCE OF A NUCLEUS. Bacteria, as a group, are not all alike in their morphological picture. Differences in structure do exist between species. They display a marked degree of morphological differentiation which may be associated with a highly complex life cycle. It is generally agreed that a bacterial cell consists of a compound membrane enclosing cytoplasm and often cytoplasmic inclusion bodies, and a nucleus. The term protoplasm is commonly used to de-

note both cytoplasm and nucleus. In addition, some species contain resistant bodies known as spores, and some are surrounded by organs of locomotion called flagella.

There is still considerable doubt as to the presence of a well-defined nucleus in typical bacterial cells. Nuclear studies have been concerned mainly with the organisms classified with the higher bacteria having characteristics intermediate between the true bacteria and higher plants or animals. The organisms studied are for the most part very large. It is doubtful if any worker has conclusively demonstrated the presence of a well-defined nucleus in an organism belonging to the order Eubacteriales, or true bacteria.

CELL MEMBRANE. The bacterial cell is surrounded by three membranes: 1) the cytoplasmic membrane, 2) the cell wall, and 3) the slime layer.

The cytoplasmic membrane first appears in young cells as fluid film, becoming thicker and denser as surface active material accumulates. It is finally converted into a firm structure composed sometimes of several layers.

The cell wall is a more rigid structure and is responsible for the form of bacterial body. It behaves as a semipermeable membrane and apparently plays a fundamental role in the life activities of the cell.

The slime layer is considered to be a modified outer layer of the cell wall. The two structures give, in many instances, the same microchemical tests. When the slime layer is large and remains fixed around the cell, it is termed a capsule.

Capsules are mucilaginous or gummy envelopes of a carbohydrate nature. A few species are surrounded by relatively large capsules, which can be readily seen by appropriate staining methods and their presence may be used for diagnostic purposes. Capsules appear to be developed more strongly among the pathogenic organisms. It is not a degenerative process, as was formerly supposed

by some scientists, but an active bacterial reaction accompanied by an increase of virulence and resistance to immune sera and to phagocytosis. The capsule functions as a protective mechanism to the bacterial body when threatened by the defensive mechanisms of the host.

MOTILITY OF BACTERIA. Bacterial motion is due to the presence of organs of locomotion known as flagella. The presence of flagella does not mean that the organisms are always motile but indicates a potential power to move.

Flagella are very delicate organs and easily destroyed in the usual method of preparing smears. In the stained state they are long, slender, undulating organs with ends in some cases blunt and in others slightly thickened. The flagella are always directed backward to the direction of motion of the cell. Turning movements take place by swinging the flagella forward on one side only. They propel the organism by means of a spiral or a corkscrew motion. The length of flagella shows considerable variation, depending to a large extent upon age and changes in the environment.

The number and arrangement of flagella vary with different bacteria, but they are generally constant for each individual species. Some have only one flagellum; others have two or more. Also the arrangement about the organisms varies considerably. Therefore, presence, number and arrangement of flagella are used for identifying and classifying organisms.

THE MARINE ALGAE

In sea's "weeds" may lie the future's insurance
against starvation

E.L. Palmer

Quintus Horatius Flaccus, more familiarly known to us as Horace, once wrote that : "Noble descent and worth, unless united with wealth, are esteemed no more than seaweed. While the time span back to the day of Horace - who was sixty-five years old at the beginning of the Christian Era - is of course relatively short, geologically or biologically speaking, and the facts and principles on which science is based have not changed, our knowledge of the marine algae has been enormously expanded. Today, we see in the marine algae - Horace's "seaweed" - a potential for great wealth and a great opportunity for new discovery.

Few references to the seaweeds appear in either Testament of the Bible. The usually all-observant Shakespeare seems to have given them but little attention. Even Hemingway, considered by some as the spokesman for our time, writes more about the great fishes than of the plants that form the basis of their food supply.

It is probable that life found early expression on earth in the seaweeds, and it is possible that these same "weeds" may offer us a major hope for survival in some future time. They may perhaps guarantee the human race a future that will not be characterized by nearstarvation conditions. The sea and its weeds, having generously nurtured us in the past, may well be utilized to save us in the future.

The plants we consider here are those that live in salt or brackish water, and that are, or have been, attached to bottoms where the water is not deep enough to cut off light

needed for plant growth.

For the most part, the world of marine algae is limited to coast lines. However, coast line plants are often torn free from their original attachments to the bottom, and continue to grow and develop while they drift in the ocean. Under these circumstances, it is possible to find marine algae anywhere near the surface of the sea, from the Arctic to tropical regions; and on rocks, sand, or in the ocean depths.

Among the factors that determine the kinds of seaweeds to be found in a particular place are sunlight, temperature, the chemical and physical nature of the sea bottom, violence of wave action, pollution, abundance of animals that feed on the plants, and a number of other factors. Only about two per cent of that part of the surface of the earth covered by the seas possesses water shallow enough to permit the entrance of light sufficient to support plants; and much of this area has a bottom of loose, shifting sand or mud, or is otherwise unsuitable for plant growth.

There is justification for the division of these seaweed-supporting areas of the oceans into a number of subareas. For example, there is the area permanently below the low tide mark, an area that never becomes dry, and is never subjected to the extremes of heat, light, and violence that affect the strip between the lines of lowest and highest tides. This is an area that may be explored with varying degrees of safety, and for varying lengths of time. In the intertidal area, most of the plants and animals are first submerged in sea water for about six hours and then exposed to drying for a similar length of time, twice a day. The existence of life under such conditions presupposes an ability to make some remarkable adjustments, or adaptations. The reproductive, feeding, and protective activities of living organisms must be fitted into the situation, and no two kinds of

living things meet these conditions in an identical manner.

It does not take a trained ecologist to recognize the fact that there are several different zones of plants along our shore lines. There is an uppermost beach area, above the highest tide, that is sprayed by spume and reached occasionally by the highest waves. Marine algae that require submersion in salt water need not, of course, be expected here, at least not in abundance. This supralittoral zone is wet by the high spring tides and by storm waves; and from this zone, down through the tidal zone, we may recognize several other areas on such places as exposed rocks, piers, or pilings.

The highest tide area is ordinarily bare of most marine algae, but it sometimes displays *Enteromorpha* and *Gladophora*. Below this, down to the low-water mark, is the realm of the rockweeds. Below the area marked by the highest low tide and lowest high tide, is the region dominated by, or at least characterized by, plants of the order *Laminariales*. Also found in this zone are the coral-like algae.

The plants of this general area must be able to survive conditions that would be fatal to most plants. They must withstand the beating of waves that strike them from all directions. They must survive extremes of heat, light, and desiccation, and they must support the inroads of the animals and plants that may feed upon them. Some must survive burial by shifting sands, and grinding of loose material on the ocean bottom. Not a few must exist in the pollutants that float on the surface of the ocean, and that may become especially concentrated along the edge of the shore.

Botanists are not wholly in agreement as to the proper classification of marine algae, and since these students of plants do not agree, we cannot criticize inconsistencies of students who propose other arrangements.

Basically, the marine algae belong to four or five groups. The blue-green algae - the *Cyanophyceae* or *Myxophyceae* of some authors - may be either fixed or free-

floating, and may be found abundantly in fresh as well as in salt water.

The green algae belong to the Class Chlorophyceae. They are for the most part green in color, as their class name implies, and may be either free-floating or fixed to the sea bottom or rocks.

The brown algae belonging to the Class Phaeophyceae include the oyster thief, stick bag, devil's shoelace, seer-sucker kelp, sea cabbage, sea palm, pompon, feather boa, and the woody chain bladder algae. Few of these are found in fresh water. They are considered by some as the most advanced of the thallophytes; they reach their maximum development in the cooler seas, and possibly dominate the rocky intertidal areas. A giant kelp of the Pacific, growing off the Chilean coast in waters to about 250 feet deep, belongs here. At least one of the brown algae grows on other plants.

The red algae belong to the Class Rhodophyceae. Most of the members of this group are larger marine organisms. The common name may be a misnomer, because we find members of the class that are red, purple, brown, violet, and green, and some that may be iridescent.

On the whole, these plants are found at relatively shallow depths, and while some of them may attain a length of more than six feet, most of them are much smaller than the brown algae. The red algae are most abundant in temperate seas, and relatively few are abundant in the intertidal zones. Some have played a prominent part in the building of lime deposits, and may be closely associated with the corals.

Certain writers recognize a special group of algae known as the yellow-green algae, prominent among which may be the diatoms, considered by some as belonging to the Class Bacillariophyceae. Some of these are freeswimming

and motile. Some merely float; others may be attached by strings of mucus. They serve as food and shelter for many aquatic organisms, and may be the basic food for minute organisms that in turn feed larger creatures. They are found in fresh as well as in salty and brackish waters, and from their shells man makes polishing powders, explosives, toothpaste, filters, and cement strengtheners. Their reproductive capacity is tremendously large, which may, in the long run, affect man.

We have all, at one time or another, calculated the age of a tree by counting the rings of its wood. To a limited extent we may do something of this sort with certain of the marine algae. Some of these algae are short-lived, many of them being annual; while some may live for a number of years. The pompon sheds some of its streamers each year, leaving a series of scars that allow one to recognize the growth of the year.

Normally, a submerged habitat may be considered more favorable to the growth of marine algae than an area exposed to the air, to large temperature variations, or to other extremes. Interestingly, the prolific growth of deeply submerged seaweeds reduces the amount of sunlight that can penetrate the water, and therefore a heavy growth may affect a given area botanically.

Some marine algae may grow in length at the rate of ten inches a day, but such a rate is not common to all algae, nor does it remain constant for any given alga. A plant that may grow at the rate of ten inches a day from March to June may grow at the rate of only inch a day during June and July. Then, too, the growth of plants in deep water may be more rapid than that of plants in the shallows. Competition is often a major factor affecting rate of growth and an early seasonal start may be of importance. Sediments in the water may at times cut down the available light at various depths, and affect the growth of algae there. In addition, seasonal storms and

floods may sometimes considerably affect the prosperity of a loosely fixed or free-floating seaweed.

Most of the marine algae possess two or three methods of reproduction - some have more. The simplest mode of reproduction is by fragmentation, in which each of the fragments becomes an independent organism. Then there is reproduction through the development of asexual spores, some of which swim and some of which do not. Sometimes these spores are produced in specialized regions of the plant, and in special structures; but this is not necessarily always the case.

In some algae similar spores may unite, the combined spores forming a new plant. On other algae, spores that differ conspicuously may be formed. A pair of unlike spores may unite in true sexual reproduction, and from such a union there may develop a new, individual plant. When this is the case in the marine algae, it is common for the resulting plant to produce asexual spores, so that there is an alternation of generations between plants that produce sexual spores and those that produce asexual spores. This alternation of generations in the marine algae is infinitely varied - to the delight as well as the occasional consternation of the botanist. Seasonal influences may affect the nature of such generations rather profoundly, but over the course of time a species continues to exist in spite of its several variations.

The origin of the marine algae is lost in geological antiquity. We can reasonably assume that, where the normal products of algal activity are found, algae must have existed to produce them. (There are, however, coral and lime deposits and diatomaceous oozes, in geological deposits that do not yield samples of the organisms that must have been their creators.) The earth's oldest fossil remains may well be associated with marine algae; and it is safe to say that the marine algae will be among the last representatives of life on earth.

Botanists who pry deeply into the behavior of marine algae - and fresh-water algae as well - recognize that their growth may be affected by various physical factors. This is also true of their reproductive processes. There have been some most ingenious studies based on the exposure of marine algae to light, pressure, movement, electricity, various chemicals, and to combinations of these factors. As a result, some of our laboratory manuals can now specify the proper agent for desired experimental results in dealing with the algae. Also, biological supply houses are now often able to submit materials that make it possible for a student living inland to learn as much about the algae as those whose homes are on or near one of the seaboards.

A kelp-covered rock at the tide line is almost always worthy of study. When the tide is out and the sun is high, environmental factors are most hostile for the marine algae. Water supply is limited. Temperatures are excessive. Light may be intense. Kelp-eating animals roam the shores, feeding on the plants. Portions of the plant may wither and die, or become severely fractured. Fortunately, however, the volume of the kelp blanket is such that, while exposed parts of a plant may suffer, there is much plant material that is protected through being covered by a soaking blanket of the kelp itself.

Plants near the low-tide mark may be subject to severe treatment for only a few minutes, until the tide turns; and even those higher up may be washed now and then by the dashing of the waves. It is interesting to note that the intertidal strip is more heavily populated with sea plants that may survive emergence than it is with land plants that can survive submergence. An evaluation of the comparative hardiness of land and marine plants can be made, based on the evidence of an intertidal strip and might well prove most rewarding.

The destruction of marine plants by desiccation, predation, and by violence and crowding is obvious and

important; but what really counts is whether such destruction is greater than the constructive work done by the organisms over the same period of time. The fact that there is a great surplus of observable material shows that the constructive forces constantly win. If such an observation is extended over the course of a year, it will be evident that there are periods when "hard times" are the order of the day; but in the long run these are balanced by the periods of prosperity.

It may be well to think of this conflict not only in terms of what happens to a given plant, but of what happens to the biological material collectively. The crowding of healthy material may not only save portions of a plant, but it may also protect smaller or more immature individuals of the same kind of plant, or perhaps less hardy plants of other species.

There are pessimists who say that human starvation is inevitable in the distant future. Optimists, however, point with considerable confidence to the great potential of the marine algae. Such plants may be food for man, for domesticated beasts, and for animals of the wild. They have an important place in man's vision of the future. Even today the marine algae form the basic diets of many human beings, and seaweed often enters unobtrusively into our diets here in America.

Health, of course, is a topic important to all of us, and most studies of disease involve the study of microscopic disease organisms. We can all identify a flock of geese without studying the details of its individuals; and so it is that microbiologists have learned how to recognize a colony of microorganisms without troubling to observe its individuals. This sort of study frequently involves the culture of the organisms on some medium that possesses a variety of special qualities. Agar is such a medium in common use, and agar is basically a marine alga. Its production is essential to our present-day civilization.

Within the past few years, the Russians have announced that they are producing a superior agar from marine algae not previously used for the purpose. They have not yet claimed to have created algae, but they have unquestionably found new uses for the plants that for hundreds of years were "esteemed no more than seaweed."

Much of the gelatin used in cookery may originate in the marine algae, and many of the foods used by hikers and explorers make use of marine algal material, which is easy to dry and yet which, with the addition of water, is quickly restored to the desired volume.

It is pleasant to assume that the supply of marine algae is inexhaustible. Americans have made that same assumption in the case of their forests, their topsoils, their buffalo herds, and their passenger pigeons. Methods we are now developing for harvesting marine fishes presupposes an inexhaustible supply of marine algae on which such fishes are dependent, so we shall probably have to learn our conservation lessons once again.

Today there is much concern over the needless destruction of marine life, and it is most encouraging that our colleges and universities are recognizing the importance of marine problems. Even those institutions located far from the ocean shores are providing specialized training that may make our future dealings with the sea much more intelligent than they have been in the past.

/Natural History, March 3, 1961, p. 33-39./

LESSONIA BORY, 1825

(After Lesson)

Stipe erect, with numerous divisions, becoming dichotomously branched in very regular fashion; laminae borne on the ultimate ramifications of stipe, splitting at the base into two equal parts, each of which develops into a new lamina with its own portion of stipe.

The plant occurs, always far beyond low-water mark, in the south Pacific Ocean in the vicinity of Chile and Cape Horn, the Auckland Islands, and New Zealand.

There is no better account of gigantic seaweeds than J.D. Hooker's description of *Lessonia fuscescens* Bory (found in the Falkland Islands), which appears in his "Botany of the Antarctic Voyage of H.M. Discovery Ships 'Erebus' and 'Terror', in the Years 1839-1843."

This and the following (*Lessonia fuscescens* and *L. nigrescens*) are truly wonderful Algae, whether seen in the water or on the beach; for they are arborescent, dichotomously branched trees, with the branches pendulous and again divided into sprays, from which hang linear leaves 1-3 feet long. The trunks usually are about 5-10 feet long, as thick as the human thigh. ... The individual plants are attached in groups or solitary, but gregarious, like the pine or oak, extending over a considerable surface, so as to form a miniature forest, which is entirely submerged during high tide or even half tide, but whose topmost branches project above the surface at the ebb. To sail in a boat over these groves on a calm day affords the naturalist a delightful recreation; for he may there witness, in the Antarctic regions, and below the surface of the ocean, as busy a scene as is presented by the coral reefs of the tropics. The leaves of the *Lessonia* are crowded with *Sertulariae* and *Mollusca*, or encrusted with

Flustra; on the trunks parasitic Algae abound, together with Chitons, Patellae, and other shells; at the bases, and amongst the tangled roots swarm thousands of Crustacea and Radiata, whilst fish of several species dart amongst the leaves and branches. But it is on the sunken rocks of the outer coasts that this genus chiefly prevails, and from thence thousands of these trees are flung ashore by the waves, and with the *Macrocystis*, and *D'Urvillea*, from along the beach continued masses of vegetable rejectamenta, miles in extent, some yards broad, and three feet in depth; the upper edge of this belt of putrefying matter is well inshore, whilst the outer or seaward edge dips into the water, and receives the accumulating wreck from the submarine forests throughout its whole length. Amongst these masses the best Algae of the Falklands are found, though if the weather be mild, the stench, which resembles putrid cabbage, is so strong as to be almost insufferable. The ignorant observer at once takes the trunks of *Lessonia* thus washed up for pieces of drift-wood, and on one occasion, no persuasion could prevent the captain of a brig from employing his boat and boat's crew, during two bitterly cold days, in collecting this incombustible weed for fuel!

The trunks are smooth and cartilaginous when fresh; upon being cut transversely they give the appearance of concentric rings of growth similar in a way to those of an exogenous trunk.

The substance of the trunk of the *Lessoniae* is very usefully employed by the Gauchos, for knife handles; the haft of the instrument is plunged into a rudely shaped piece of this weed, which contracts into a substance harder than horn.

=====

THE SMALLER SOCIAL UNITS

Fundamental Unit of Plant Sociology

J. Braun-Blanquet

"An association is a plant community of definite floristic composition" (Flahault and Schröter, 1910). In this statement the Third International Botanical Congress at Brussels recognized as fundamental the floristically uniform character of this unit of vegetation. The definition is at once too narrow and too broad: too broad, because not only the association but all the lower and higher units, variants, facies, societies, alliances, etc., are characterized to a greater or lesser extent by definite floristic composition; too narrow, because, with few exceptions, no two bits of vegetation have precisely identical floristic composition.

The possible combinations of plant species are indeed endless. To attribute to every actual combination in nature the value of a type would result in a chaotic splitting up of the units of vegetation. On such a basis every quarter of a square meter of a meadow community would form a separate unit. We are obliged, therefore, to institute comparisons between the various bits of vegetation. Pieces of vegetation with similar combinations of species are united into abstract types. These types are the "associations", the separate pieces being called the individuals or examples of the association or more simply the "stands".

/J. Braun-Blanquet, Plant Sociology, New York and
London, 1932, p. 22-23/

BIOTIC FACTORS

MAN

J. Braun-Blanquet

There is no sharp line of distinction between the influence of man and animals upon vegetation except in man's use of fire. Man's influence is often exerted through his domestic animals.

The effect of man's destructive hand upon vegetation is visible everywhere, from the tropics to the poles, and from the valley floors to the mountain tops. If we speak today of "untouched vegetation", we exaggerate greatly; Chevalier (1925) reminds us that even the concept of "virgin tropical forest" is a mere myth.

In all records of vegetation one should first attempt to account for the degree of human influence. Even our paleolithic ancestors of the early and middle Quaternary, with their primitive implements, knew fire, and they may have encouraged certain types of vegetation (meadow, steppe) at the expense of others (virgin forest). With the rise of commerce and transportation, agriculture, and stock farming in the neolithic period, the era of vegetational change begins. Great plant migrations which began under the influence of the "lords of creation" have not yet reached their conclusion (see particularly Thellung, 1915; Hauman, 1928).

No other factor of vegetation has been investigated and written upon so much as the influence of man. In fact, hundreds of volumes in agriculture and forestry have reference to it. We are obliged to limit ourselves to a few points and to refer, in general, to the texts on agriculture and forestry.

Fire

The most remorseless associate of man in the destruction of native vegetation is fire. While prairie and forest fires may occasionally be caused by lightning, that is the exception rather than the rule. In 90 out of 100 cases they are caused by man, either wilfully or accidentally. Contrary to the opinion of some American investigators, therefore, fire is to be classed among the anthropogenous factors.

Fire is particularly destructive upon very thin, sterile soils and especially in the transitional region between forest and prairie, where both types of vegetation are struggling for control. Wherever natural reforestation to-day is accomplished with difficulty, it is exceedingly difficult to reconstruct the original, natural appearance of the forest or to delimit exactly the forest and grassland climaxes.

In humid regions, which present no special hindrances to regeneration, fire is a periodically repeated phenomenon, even a form of cultivation. True cultivation with the aid of fire is still employed on a large scale in Finland and in the Atlantic regions of Europe. Elsewhere fires are employed in the destruction of noxious shrubbery, for the improvement of pastures, for increased blossoming (bee pasture), for cattle or game feed, and probably also for the mere pleasure of burning and, finally, out of sheer carelessness.

/J. Braun-Blanquet, Plant Sociology, New York and London, 1932, p. 278-279/

THE CLASSIFICATION OF COMMUNITIES

J. Braun-Blanquet

A system which is scientifically sound presupposes a knowledge of the material to be classified. The study of plant communities is not at present far enough advanced to supply the minute details for a strictly natural and therefore permanent classification, but the fundamental outlines of a system that will express natural affinities may be pointed out. These outlines can even now be used to advantage in treating the communities of a well-studied area.

Attempts at a classification of plant communities reach well back into the last century. The changes this classification has suffered remind us of the history of systematic botany. The first grouping was based upon obvious but purely superficial characteristics: physiognomy. Later Warming based his division upon one of the most cogent causes of physiognomy: the water relation. He distinguished three great classes:

Hydrophytes, communities with a high water balance.

Mesophytes, communities with a medium water balance.

Xerophytes, communities with a low water balance (Diels, 1948).

The individual plant communities are arranged under these principal classes.

Schimper's classification (1898) is based more upon the development of vegetation. The climatic terminal communities are distinguished from the beginning and transition stages and are grouped under the headings: forest, grassland, and desert.

Following out the dynamic-genetic principle of classification, Clements (1916) worked out a system of plant communities, but it was overloaded with hypothetical assumptions.

Of the newer classifications, mention should be made

of Graebner's division of communities according to the nutrients of the soil and also the physiognomic-ecologic divisions of Brockmann-Jerosch and Rübel (1912), Vierhapper (1921), Du Rietz (1921), and Rüber (1930).

/J. Braun-Blanquet, Plant Sociology, New York and London, 1932, p. 361)/

ECOLOGICAL PARADOX OF COASTAL PERU

E.Y. Dawson

"Salt the coast southward! When there no longer are any trees, you are in Peru!"

Such were the sailing directions given to early sixteenth-century navigators seeking from Panama the landfall to the Inca kingdom of gold.

The directions were surprisingly precise, for at Tum-pis, which was the northernmost coastal city of the Incas, a remarkably sharp line separates the forest vegetation of the humid tropics from the treeless desert. To the north the jungle extends, except for the semiarid Salinas Peninsula, through Ecuador to Colombia and Panama. To the south the vegetation fades quickly to the most meager scrub and then to absolute desert, which is almost without visible plant life for a stretch of over two thousand miles.

To those intrepid voyagers of the wind-lashed Peruvian seas, the utter desolation of this vast, rocky coastline pounded by breakers and backed by gigantic, bare mountains was as incomprehensible as their discovery of the towns, fortresses, and roads within it. Indeed, the Inca Empire had embraced all of this desert and accomplished some of the most stupendous feats of early American man.

Here and there, through V-shaped gorges in the coastal hills, turbulent streams that are born in the towering Andes flow to the sea. It was beside these waters that the peoples of Peru began five thousand years ago to build their towns and to spread water over the desert valley floors to grow their corn and manioc. By the year A.D. 1000, the Mochica civilization had completely dominated this arid environment and had built so extensive an empire that a single religious edifice commanded the use of 130,000,000 adobe bricks.

The use of these sun-dried bricks and the method of making them point to some of the remarkable features of this unique environment. Although often veiled by high clouds or by fog, the sun is always there. Rain does not fall. Sun-dried adobe is an ideal and durable building material in such a climate. To increase its strength, the early builders used the adhesive qualities of egg white. Where else in the world but Peru could a people find the millions of birds' eggs sufficient to bind the bricks of their cities. On numerous offshore islets dwelt the vast populations of sea birds that supplied both this building material and fertilizer for the fields. By the time the Tenth Inca had conquered the long coastal desert - before the voyage of Columbus - extensive cities had grown and major irrigation works watered the fields of corn and cotton and beans. So great and significant to the Inca Empire was the desert that a highway twenty-four feet broad was constructed along its length of over 2,500 miles.

A remarkable combination of natural features and forces created this environment, which shaped an ancient civilization, and now continues to support the descendants of the last conquerors. The study of these features, and the growing understanding of ways in which plants and animals respond to them, now enables man better to utilize his resources and to extend his occupation of the desert further.

The two principal causes of the coastal aridity are the mountains and the cool sea. The colossal escarpment of the Andes runs the full length of the continent. It is so excessively high that on its eastern side is effectively trapped nearly all the moisture that is pressed against it by humid air from the Atlantic lowlands.

Most of the little moisture that does manage to reach the western slopes falls as snow on the peaks and, as meltwater, rushes down steep gorges to the sea. Above 10,000 feet only a treeless belt of grassy herbage occurs. Below that level a marvelous assemblage of drought-resistant, succulent plants covers the precipitous slopes, but even the most tolerant of these give way to bare rock and sand at about 3,000 feet.

The sea's influence is nearly as great as that of the mountains. Up from the cold, far southern Pacific and hugging the western coast of the continent, the Humboldt Current sweeps to the Equator. As the Gulf Stream of the North Atlantic carries warm water far north to bring temperate climates to the high latitudes of Europe, so the cold Humboldt Current tempers the coastal climate of Pacific South America all the way to Ecuador. While the tropical northeast Pacific swelters in heat born of the warm sea, whose bordering lands are the tierra caliente, the southeast Pacific has none of this. Cool waters bathe that coast and have carried with them to the equatorial Calapagos Islands such unlikely animals for the tropics as sea lions and penguins. Not only does the Humboldt flow north with its cool water; this water is kept cool, despite incessant insolation along the desert shore, by the upwelling of colder subsurface water under the influence of prevailing southerly winds. The result is a unique phenomenon of the tropical world: a continental coast from the Tropic of Capricorn to the Equator along which the sea water is colder than is the air over the adjoining shore. A situation like this invariably

resulted in coastal aridity even without the influence of other factors, but, coupled with the rain shadow of the Andes, the shores of Peru and Chile are doubly guarded from precipitation, to the extent that they receive essentially no rainfall as such. Such moisture as does touch this barren land comes in the form of fine mist or fog, the garua, which shrouds the coast during much of the winter season - from May to September - and moistens the surface of sand and rock only enough to support the peculiar fog-desert vegetation of lichens and of species of Tillandsia.

The garua, however, is not ordinarily sufficient to wet the soil enough to permit seed germination and the growth of rooted plants. Accordingly, except at a few favored localities, such plants are not to be seen in the coastal desert. Nevertheless, another interesting oceanographic factor does provide for occasional true rain in the north, and with it an unbelievable change, when the desolate shoreline turns to flowering greenery. Such times are "years of plenty" for the desert agriculturists, during which the long-dry coastal mesas and flats can be planted to cotton. These favored years come from the influence of another current, known as El Nino.

Along the far north coast of Peru, at the boundary of Ecuador, the Humboldt Current suddenly turns due westward and moves toward the Galapagos Islands, in convergence with the southward moving warm waters from the region of the Gulf of Panama, which are also forced westward at this point where they meet the western bulge of the southern continent.

On the north, the warm current carries with it the characteristic tropical rainstorms of the jungle coasts of Colombia and Ecuador, while on the south the cold Humboldt stream effectively guards the coast from rain. This accounts for the sharp line of demarcation between the forest and the desert at Tumbes - the modern name for Tumpiz - in north Peru. However, the point of convergence of the warm and the cold streams is not stationary, but characteristic-

ally makes a slight southward shift at about Christmas time during most years. Because of this southward extension of warm water and the accompanying rain that falls on areas ordinarily in drought ten months or more each year, the current came to be known as El Nino, and was equated with the joy attendant on the coming of the Christ Child.

Thus, the coastal regions of south Ecuador and north Peru receive a quite regular, pronounced, but shortlived rainfall that has favored the development of a succulent and thornbrush vegetation capable of sustaining itself through long months of drought. The El Nino with its rains does not regularly extend south of Tumbes, however, and there begins the true desert. Nevertheless, there are such irregularities in the position of the Humboldt - El Nino convergence that occasionally, roughly at intervals of five to eight years, the warm current extends farther south for a brief period and brings rain as far as Piura or even Trujillo. Some of the finest cotton in the world is grown in north coastal Peru from plantings made during these occasional heavy rains.

One remarkably drought-resistant, surface-rooted plant, the cactus *Neoraimondia macrostibas*, is able to conserve water during all these intervening rainless years and to persist on the rocky hills as the only conspicuous, treelike plant of that region.

Still another irregularity of longer cycle occurs in the oceanic convergence and, rather than "years of plenty", it usually provides widespread disaster. It consists of a rare, far-southward extension of El Nino that does not quickly return to the normal convergence point off south Ecuador. This extraordinary displacement occurs two or three times a century and brings great changes to the established pattern of life on the land and in the sea--so much that the lives of men on the desert shore are drastically affected. The last great displacement occurred in 1925, and it was chronicled by the ornithologist

Robert Cushman Murphy, who was there to observe the disaster in connection with the sea birds.

The rains began to fall in February and continued with brief interruptions for five months. The warm current spread southward all the way to Callao and, as it came, killed the marine life of the normally cold-water coast with its heat. Fish that did not succeed in moving southward fast enough died and were cast on the beaches in endless stinking windrows. With the destruction of the fish, the vast sea bird populations began to starve. Millions of birds fled south, but millions more died of starvation around their nests, where multitudes of eggs and nestlings were lost. Beaches and harbors were littered with carrion. The phenomenon of "The Callao Painter" appeared. The early Spaniards had given it the name because such high concentrations of hydrogen sulphide developed from decaying bodies that the paint of vessels at anchor turned black. Thousands of tons of precious guano were washed from the bird islands into the sea. With this nitrification of the water, together with the pollution from its dead inhabitants, came a "red tide" - dinoflagellate blooms that seemed to streak the sea water with blood.

On the land, terrible erosion of the already barren soil occurred, together with destruction of the weakly roofed adobe dwellings of the people. Their supply of fish gone and the normal transport of supplies cut off by communications wrecked by flooding, the people began to starve. Standing pools of water bred mosquitoes; malaria broke out among those who had not known it in a lifetime; and typhoid resulted from suddenly contaminated wells. Even the rats became starved from disruption of accustomed food supplies, and in their weakened condition began to die of plague, which spread to men who lived in squalor with them. So badly were railways and roads destroyed by the incessant rains that in Lima files of llamas were, as in ages past, driven down from the sierra bearing loads of foodstuffs for

the city. But then in June the cold water reappeared; the rains stopped; flowers bloomed and died in the sand; fish and birds returned; the sun came out to bake the land; and it was desert again.

In all of this we see a remarkable contrast in life on the land and in the sea of Peru, depending upon seawater temperatures. The cold water of the Humboldt stream supports rich marine life that cannot tolerate the high-temperature, low-oxygen waters of El-Nino. On the other hand, the all but lifeless desert shores burst into greenery and flower with the warm tropical rains. In one the limiting factor is water; in the other it is oxygen.

In the sea neither water nor carbon dioxide are normally limiting for the growth of algae that are the pastures of the oceans. During daylight hours the seaweeds and phytoplankton produce food and oxygen used in respiration, but at night oxygen is often of limited availability while respiration goes on. Accordingly, it is in areas of high oxygen concentration, whether in colder water where the solubility is higher, or in surfy places where more atmospheric mixing occurs, that the richest developments of marine plants are found. Along the desert coast of Peru both of these conditions are met, and we find an abundant vegetation in the sea. This, in turn, supports enormous populations of marine invertebrates, fishes, and fish-eating birds and mammals.

On the land, where water is the limiting factor, we find that the climax vegetation usually consists of the most elementary phases of plant succession. One often thinks of succession in terms of gradual development of a plant-supporting soil, beginning with bare rock upon which crustose lichens begin to grow, followed, as the soil buildup proceeds, with mosses, annuals, shrubby perennials, and finally forest-provided, of course, that water is available. Here, however, the intense aridity provides little further advance in the composition of the flora

than rootless plants capable of surviving on the ephemeral surface wetting provided by the garuas. Several kinds of plants have successfully met these difficult conditions and persist on the desert with the most meager moisture.

One of these is the blue-green alga, *Nostoc*, which lives most of the time as dry, black granules and crumbs loose on the surface of the ground, dehydrated to the extreme, but holding a residue of life in its drought-resistant aplanospores. With the coming of garuas, these crumbly fragments expand as the colloids of dead cell walls absorb the moisture. The aplanospores germinate and spread a skein of filaments that covers the ground with a dark, glistening slime so long as mist or puddle remains. Then they shrink, dry, and crumble to await a future rebirth.

Similarly, the lichens on bare rocks survive by this technique, but instead of alga alone, the food-making alga is surrounded and protected by interlaced filaments of fungus that may assume the most bizarre forms. This association of plants grows only during the time of moisture, adding cellular material that acts as a sponge to hold and conserve water even after the plant is dead. Thus, the lichen may consist largely of dead cells or filaments that serve the living ones by their absorbent qualities.

Throughout most of the Peruvian coastal desert the lichen is the most advanced component of the flora, and often there is a great diversity of species, from thin, crustose ones to intricately branched, bushy, or foliose ones, that catch and condense any droplets of water from a sea-borne fog.

Apart from these algae and lichens that persist by alternately growing and then retreating into minute, resistant spores, two other kinds of plants survive perennially by means of highly efficient adaptations for water absorption and conservation. The most widespread of these on the central Peruvian coast are species of *Tillandsia*, related to our well-known Spanish moss (*tillandsia usneoides*).

des), and more distantly to the pineapple.

Tillandsia occurs in great, dark patches on soilless sand hills throughout the coastal desert. It needs no soil, for its roots are only briefly functional for anchorage of young plants and, indeed, are essentially absent in older ones. *Tillandsia* is truly an "air plant", and here in the Peruvian desert is strictly a mist-catcher. Its leaves are so arranged that during garua season the moisture, condensed on minute epidermal scales, runs down into small catch basins at the leaf bases, where specialized absorptive cells take it in much as do root hairs in other plants. Once the water has been absorbed by its succulent leaves, it is vigorously conserved over the ensuing dry months by an impervious epidermis. So effective is this conservation that even as the hot, parched summer is well advanced, *tillandsias* may be found using a little of their reserve water to send up a flowering shoot for the fulfilment of their reproductive functions.

In a few favored spots another perennial plant succeeds in a life dependent upon roots. This is the cactus, and it is scarce indeed on the very dry coast, for there are few places suitable for a shallow-rooted plant. However, on some rocky hills the presence of smooth, shale-like rocks permits the least precipitation to run from the rocks to cracks between, wherein the roots of *Haageocereus* quickly pick up all that reaches them and immediately store it in the hydrophilic tissues of its water-impervious stems. Such plants scarcely grow at all, except during the rare years of appreciable rainfall, during which the seeds also may germinate, and a young plant now and then survives under a protective rock long enough to receive the marginal sustenance of the next garua.

Then, of course, there are the numerous desert annuals that meet the problem of survival somewhat like the alga - by going into a drought-resistant stage. But these are not true "annuals" here, for their seeds may lie on the

parched ground for ten years or more without receiving sufficient moisture for germination. The last time where there was a flowering of annuals in the coastal hills around Lima was in 1957. The extraordinary longevity of many of these minute seeds under the most severe conditions of heat and drought is one of the most fascinating of all the desert phenomena.

Whereas the life of the land is so frugal, so scant, and so ephemeral, that of the sea is rich and varied and free. The shallower waters of the rocky shores teem with invertebrates and fish among dense beds of kelp and sea palm, while the offshore waters support so rich a plankton that great schools of anchoveta abound, followed and fed upon by guanay and tuna.

The vegetation of the inshore waters is of special interest, for, despite a latitudinal displacement of some twenty degrees, one sees in it much resemblance to the temperate northeast Pacific marine flora. Thus, at Lat. 12° S. the intertidal flora of the Lima area corresponds closely with that of southern California at Lat. 32° N. The genera are for the most part identical, and even some of the same species are present in each of the areas.

Yet, we cannot go far with the comparison, for even now, in the second half of the twentieth century, we are only just exploring this Peruvian coast for its marine plants. Only a fraction of the species have been recorded in the botanical literature to date, and these essentially only from intertidal and driftweed collections from a few localities. The flora of the infratidal belt along this rugged coast has yet to be obtained and studied. But we are now in the age of the Scubadiving botanist who one day will help to complete man's exploration of this desert shore - an exploration that was begun on land five thousand years ago by the earliest Indian agriculturists.

/Natural History, October 8, 1962, p. 32-36/

NORWAY SPRUCE

Picea abies (Linnaeus) Karsten

Common or European spruce, spruce fir, white fir,
Christmas-tree *P. excelsa* Link. *Abies excelsa* de
Candolle

A tall tree with a narrow crown, short branches, and short, blunt-pointed needles. The distinctive cones are usually present on or below the tree.

The trunk is erect. The bark is dark brown, at first smooth but later breaking into small, thin scales. In all but very old trees it remains thin. The young shoots are reddish-brown to orange-red, usually smooth but occasionally scattered with minute hairs. The buds are yellow-brown, smooth, and pointed, and not coated with resin. The leaves are light to dark green, stiff, up to 1 inch long, and end in a horny point. Each of the four sides bears lines of stomata. Persisting for 6 or 7 years, the leaves are arranged so that those on the upper side of the shoot point forwards and largely cover it, while those on the underside spread in two ranks, exposing the shoot.

The stalked male catkins are about 1 inch long, pendulous or spreading, red at first but becoming yellow as the pollen is scattered in late April or early May. The female cones are stalkless, erect, and crimson-coloured. After fertilization they turn green or violet-purple, and gradually turn over until in the autumn they are hanging, becoming light reddish-brown in the process. They open and release their seeds in the spring sunshine. (it is said that in Scotland the sun is not powerful enough to effect this, and that many seeds fall still enclosed within the cone and so never germinate.) The cones are variable in size, up to 6 inches long, with scales having a texture like tough paper. They are borne on trees 30 to

40 years old (sometimes younger) in the open, 70 years old in forests. Seed is quite freely produced, and remains fertile for several years if properly stored. It is dark brown, and pear-shaped, with a pale yellow-brown wing. Germinating in the first spring, the seedling has 5 to 10 (usually 6 to 8) toothed cotyledons, and is bright green in all its parts. Though frail-looking it is in fact sturdy, and needs protection only against frost lift. At first the young trees grow slowly, but later show more vigour.

There are several geographical strains of the common spruce, and numerous forms have arisen under cultivation. Several are only shrubby and suitable for rockeries. Of the others, 'argentea' ('variegata') has white variegation of the leaves, 'aurea' has yellow leaves, 'pendula' has weeping branches hanging close to the stem, 'columnaris' very short crowded branches forming a narrow column - and there are more. The snake-branch spruce is a variety, *virgata* (Jacques) Th. Fries, occurring naturally in several places; it is sparingly branched, with pendent branchlets, the leaves surrounding the shoots.

The Norway spruce has a wide range, covering most of Scandinavia and a deep band across northern and central Europe through Poland into Russia. It abounds in the Alps and Pyrenees, thence spreading south-east into the Balkans. A lowland tree in the north, it becomes a mountain tree (up to 6,000 feet) in the central and southern parts of its range. In central Europe trees reach a height of 200 feet and girth up to 20 feet, but they are much smaller in northern Europe.

It is not a native of Britain, but fossilized remains exist. It was grown here when William Turner wrote his "Names of Herbs" in 1548, and was much in use as an evergreen in seventeenth- and eighteenth-century gardens. From the early nineteenth century it has been planted extensively as a forest tree, particularly in Scotland. Now it equals European larch as one of the principal trees in high forest.

This fir was early introduced to North America, and grows well over much of the United States and Canada.

It is an important timber tree in northern Europe, providing the white wood or white deal of the Baltic countries which has been imported into Britain for centuries. The light-coloured wood is fairly tough and elastic. It decays when out of doors and is subject to infestations by wood-boring insects. It is difficult to impregnate effectively with preservative. Boxes, especially for food-stuffs (which being odourless it does not contaminate), interior joinery, and structural work are among its principal uses. Specially selected timber is used for the fronts of violins and cellos. It is third rate as a fuel wood. Young plants are the Christmas-trees of Europe; raising them is now a specialized branch of British forestry. The foliage and young shoots are used in making spruce beer. In Scandinavia and central Europe the trees are tapped for resin which provides Burgundy pitch, used medicinally and in varnishes.

This fir is propagated from seed. In Britain it will grow well on many kinds of soil, even light and calcareous ones. On shallow soils the surface root system may cause losses from wind throw and droughts. It will stand moderate shade when young. The persistent side branches are troublesome, and if not removed cause knotty timber. Formerly planted unmixed, it is now grown more with other kinds, such as beech. In some districts it reproduces itself, and it will stand severe cold but may be damaged by unseasonable frosts.

In Britain it has on rare occasions exceeded 130 feet in height and 20 feet in girth, but normally trees much over 80 feet high are exceptional.

From the foresters' point of view, the higher and quicker timber production of the Sitka spruce makes this species far superior to the European kind; against this,

P. abies will grow and thrive under conditions found in much of Britain where the Sitka will not.

/British Trees By Miles Hadfield, London
J.M. Dent & Sons Ltd. 1957, p. 40-43/

ENGLISH OAK

Quercus robur Linnaeus

Common or pedunculate oak. *Q. pedunculata* Ehrhart

The more rugged of the native oaks, commoner throughout Britain except in mountainous and hilly places, and even there usually found growing in the valleys. The leaves are on very short stalks, the acorn cups on long stalks.

When the tree is growing in the open the massive, rough-barked trunk and wide-spreading and elbow-like branches form a crown often broader than the tree is high. The distinctive features of the common, pedunculate oak are: the young shoots bear very little down, and any hairs are simple, not branched; the bud from which the shoot extends is usually not coaxial with the previous year's shoot, and the bud-scales are not downy; the base of the leaf forms two earlike lobes (auricles) on either side of the short stalk; the few hairs found on the blade are simple, and the acorns are on long stalks.

The common oak will bear fertile acorns at 10 years old, and will subsequently produce a crop annually for perhaps another 700 years. The number of acorns varies

from year to year, but the crop is heavy at frequent intervals. The acorns are sweeter (it is said) than those of the durmast, and therefore more popular as food. In addition, creatures that can get among the branches are able to remove them as they ripen and before they fall from the cups, the long stalks serving as an easily grasped handle. Rooks in particular take quantities in this manner, and by dropping them as they fly distribute the acorns far and wide. Furthermore, many acorns are carefully hidden for future use by being buried - and are then forgotten.

In nature (as can be seen in any walk through an oak wood) this species varies a good deal. Cultivated varieties that are sometimes seen are the cypress oak, 'fastigiata', a distinct form with narrow, erect growth, of which a purple-leaved variant is also grown; 'pendula', a form that 'weeps' in varying degrees - indeed, occasional self-sown trees could claim this name; 'filicifolia', a small tree with remarkable fern-like foliage with inrolled edges, and having long-stalked acorns but leaves with stellate down - this may be a hybrid; and the golden oak, 'concordia', with bright yellow leaves. Purple, reddish-leaved, and variegated-leaved forms are sometimes encountered.

The range of this species is rather wider than that of the durmast oak. It thrives on deep fertile clays and loams and, from this disposition, spreads into drier regions than the durmast oak which is happier on the lighter soils which, however, require a higher rainfall to maintain their fertility.

There can be little doubt that in Britain it has largely replaced the durmast oak in many districts. This is due to the activities of man from medieval (perhaps earlier) times to the early nineteenth century. Because of its useful 'crucks' and heavy crops of mast it was of far more value to our early economy than the durmast oak. That species would, therefore, be discriminated against on

every possible occasion. Thus aided by man, and assisted by its own greater reproductive and colonizing ability (fruiting at an earlier age and bearing heavier crops of acorns which, thanks to their stalks, were carried further afield), it was soon able to dominate the durmast oak except on the hills and lighter soils where that species had an inherent advantage. One authority goes so far as to suggest that the English oak is not a native, but was introduced by the early farming monastic orders - a point that will probably never be decided unless it becomes possible to distinguish between the pollens of the two species found in post-glacial peat deposits.

In later times this species was almost always used in the extensive replanting of the royal forests that followed the Napoleonic wars. To-day it is not so valuable a tree as the durmast, and only thrives on soils which can be used to better purpose. There is no discernible difference in microscopic structure or qualities between the timbers of the two species; they vary only in the form that the branches take.

Any detailed mention of historic or famous oaks, practically all of which are of this species, is impossible. When comparing size, however, it is well to separate pollarded from maiden trees - the girths of the former exceeding those of the latter. It has been suggested that any maiden tree girthing more than 14 feet and a pollard above 18 feet can be classed as a notable specimen. On rare occasions a height of 100 feet is reached.

/Miles Hadfield, British Trees, London J.M. Dent & Sons Ltd 1957, p. 222-225/

COMMON HAWTHORN

Crataegus monogyna Jacquin

Whitethorn, quickset, may. *C. oxyacanta* var.
monogyna (Jacquin) Loudon

A small tree found in open spaces, generally leaning away from the prevailing wind, with a spreading or rounded head of spiny intertwining branches and twigs. Often seen in rows, evidently the relics of now derelict hedgerows. Much the commoner of our two native thorns, and recognized by having normally only one style in the flower and one nutlet in the haw.

The trunks of old trees become gnarled and furrowed, the branches long and tortuous, often pendulous at their ends. The shoots are hairless and, except for some vigorous first-year shoots, armed with numerous short spines; longer spines tipping short shoots are also formed, from the bases of which further growth may proceed.

The buds are small, usually hairless, and brown or crimson. They begin to open early in the year, and towards the end of March the trees are usually hazed over with green. The leaves are variable in size and shape, with from three to seven lobes usually cut more than half way to the midrib. The margins of the lobes are either undivided or bear a very few teeth towards their apex. A few small, entire leaves are usually present. The leaves are generally hairless except in the axils of some of the veins of the lower surface. Occasionally, however, they bear a few scattered hairs. The stipules, large on vigorous shoots, soon fall.

The flowers usually open about the middle of May; they are numerous, up to 16 or more in each inflorescence. The flower-stalks and receptacles are usually downy, but

may be hairless. The petals are usually white, but occasionally pink forms are found; when these occur they may locally be not uncommon. There are usually 20 stamens with red anthers and normally 1 style, though an occasional flower may have 2. The flower is heavily scented and attracts numerous insects, particularly honey-bees. In some seasons it yields them much nectar, but in others pollen seems to be the main objective. The small fruit turns red in early September; it is rather variable in shape, and retains the style. There is very rarely more than 1 nutlet in each. The haws are taken off the tree by birds when ripe, or fall in late winter. Much of the seed lies dormant until the second spring. Seedlings are hardy, and the spines that they soon develop enable them to survive grazing, and to colonize open uncultivated land of all sorts except where it is very wet or extremely acid. This thorn will not, however, tolerate shade and the seedlings do not thrive in woodland except at the open edges.

This species does not vary greatly in nature. There is a yellowfruited form, 'aurea'. A fastigiata form, 'stricta' (fastigiata), is sometimes seen, as is a weeping one, 'pendula'. A shrubby kind, 'semperflorens', has a very extended flowering season. The most interesting cultivated form is the Glastonbury thorn, 'biflora' ('praecox'). This has two flowering seasons, the first, which does not result in the production of fruit, during mild spells in mid winter (allegedly on old Christmas Eve, 5th January), and the second in the normal season. Most of the trees now cultivated can be traced as offspring of the famous tree at Glastonbury, first mentioned in the early sixteenth century. By the time of Charles I a legend was current that it had sprung from the staff which Joseph of Arimathea struck into the ground after landing in Avalon, when fatigued and in despair after climbing Wearyall Hill. The staff broke into flower, and the miracle refreshed his body and missionary zeal. The subsequent his-

tory and mystic properties of the thorn cannot here be related, but it may be said that John Parkinson in 1640 and Sir Thomas Browne in 1646 were among those who regarded the precocious flowering as a natural and not miraculous occurrence. A number of specimens now exist, particularly in Herefordshire, where this variety may possibly have also arisen naturally.

The common hawthorn is found throughout Europe (except in Iceland) and in the Mediterranean regions, from whence it spreads into Asia as far as Afghanistan. It is very common in most parts of the British Isles but becomes rare in northern Scotland. In places where conditions are favourable it forms a scrub 20 feet or so high, sufficiently dense to prevent growth of other plants beneath it.

In parts of England, Ireland, and south-west Scotland the thorn has long been the subject of superstition and a cult, of which the Glastonbury story is a part. The legends still linger in Ireland that the tree is the meeting-place of fairies and must not be cut; in England that the branches, particularly when in flower, must not be cut and brought into the house. They all seem to indicate some necessity to protect the tree. Similar legends exist on the Continent, notably in Brittany. Dr. Vaughan Cornish traced the districts in Britain where the cult existed, which even now are fairly well defined. He showed that they were those colonized by the same Gothic and Belgic tribes that inhabited those continental places where similar legends still cling. He concluded that certain thorn-trees were used as landmarks, meeting-places, and sites for religious rites. The fact that ancient thorns assume markedly individual characteristics in wild open spaces where other trees and landmarks are scarce gives a good deal of weight to this theory.

It is interesting to observe that the name 'may' for this tree is of modern usage, being very uncommon before the nineteenth century. The 'may' of the garlands, 'bushes', and the like so often referred to by the poets in

old literature, which were the relics of pagan rites on May Day, is now widely assumed to have been hawthorn, but on further inquiry is found to have been any green stuff; in fact, birch and rowan seem to have been the usual sources of supply. The fact that the saying 'Ne'er cast a clout till May be out' is recorded in the early eighteenth century seems to confirm that the month, not the tree, is intended.

Because of its spininess and the ease with which it can be plashed or laid - the thicker stems partly cut through, then bent over and intertwined so as to form a dense barrier - it has been used for fencing from time immemorial. The remains of protective thorn hedges can often still be distinguished when Roman forts are excavated. Tens of thousands of miles were planted following the enclosure Acts, particularly during the eighteenth and early nineteenth centuries.

Thorn-trees may sometimes reach 30 feet high but are usually less. Generally they do not reach a great age.

The timber, being small in size, is not of much account. It is tough and fine-grained, and was once favoured for wood-engravers' blocks. It is one of the best of firewoods, burning hotly, steadily, and slowly, and it was at one time much in demand for bakery ovens.

Thorn comes from the Old English *þorn*, which was the name for this tree; it is still an easily identifiable element in many English place names. Until the last century it was generally called whitethorn to distinguish it from other thorny trees and shrubs. Quickset refers to its use as a live hedge as opposed to a dead fence.

The Gaelic name is *sceach* or *scitheogs*, the Welsh *ysbyddaden* or *draenen wen*.

/Miles Hadfield, British Trees, London J.M. Dent & Sons Ltd 1957, p. 272-276/

A QUESTION IN WHALE BEHAVIOR

Most solitary strandings seem to be in response
to sickness

C. Ray

Whales - some of them gigantic almost beyond comprehension - bring to mind the awesome, powerful, and mysterious. Today, we even suspect that they are as intelligent as any mammal but the primates. These "reconstructed" land animals, reversions to a life in the sea, occasionally return again to land. The reasons whales do this - stranding themselves usually to die - are the subject of investigation of this article. At the New York Aquarium, we have had firsthand experience with strandings of two species of the smaller whales, and two species of their relatives, the porpoises and dolphins.

The feelings of most people who encounter a large whale stranded on a beach have been summed up by the Dutch artist who in 1598 made the delightful copper engraving. This is a male sperm whale, the source of spermaceti, sperm oil, and ambergris. A champion diver, it goes down a halfmile or more in search of the formidable giant squid - its favorite food.

Who can help but be excited when he finds one of these giants on a beach! Sometimes the animals are stranded alive. As the whale struggles in the ebb tide, it only manages to dig itself deeper into the sand. Its expressionless mouth may occasionally gape, or a rush of air may issue through the blowhole on top of the head. As the ebbing water deserts the body, the creature's weight becomes its own worst enemy, bearing down upon the chest, eventually causing suffocation.

The words "whale", "dolphin", and "porpoise" need not

confuse one as applied to those mammals which, together, make up the order Cetacea. Scientifically, the cetaceans are divided into two suborders: one is composed of toothed animals and the other of those that have baleen or whalebone - an epidermal derivative that is homologous to hair or nails - instead of teeth.

Species of the latter suborder, the Mysticeti, feed on plankton strained from the sea through the whalebone that hangs from their upper jaws. All the mysticetes are large, so all qualify as whales. They range in size from the pygmy right whale, *Neobalaena marginata* (length to 20 feet), to the largest animal that ever lived, the blue whale, *Balaenoptera musculus*, that reaches lengths of over 100 feet and weights of more than 120 tons. There are few kinds of mysticetes - a few species of rorquals (including the blue, finback, piked and sei whales), gray whales, humpbacks, right whales and bowheads.

The toothed cetaceans - suborder Odontoceti - include some whales, but its membership is primarily composed of porpoises and dolphins. The odontocetes are a large group, comprising several families of several dozen species. Which of them is called whale, and which dolphin or porpoise, is generally clear if one but mildly considers its zoological relationships. The only really huge, toothed cetacean is the afore-mentioned sperm whale, *Physeter catodon*, males of which occasionally grow to more than 60 feet in length. The female is about half the size of the male. The odd and rare beaked whales of the genera *Mesoplodon*, *Ziphius*, *Hyperoodon*, and *Berardius* grow to moderate size, mostly from 15 to 30 feet. *Berardius* is the largest, reaching over 40 feet.

Fortunately, the smallest cetaceans that we commonly call whales all fall into small, special families: the white whale or beluga, *Delphinapterus leucas*, and the strangely armed narwhal, *Monodon monoceras*, together constitute the family Monodontidae. The pygmy sperm whale,

Kogia breviceps, is a diminutive member, and the only other living member, of the family the *Physeteridae*. All three of these little whales mature at close to ten feet in length, but their zoological peculiarity helps even the layman to distinguish them as "whales" from the dolphins and porpoises.

The family *Delphinidae*, largest of the cetacean families, includes some species large enough usually to be called whales. The male killer whale, *Orcinus*, grows to thirty feet, while the largest male pilot whale, *Globicephala*, is nearly that large. We call small members of this family dolphins, but all members have in common their cone-shaped teeth. The best-known are the common dolphin, *Delphinus delphis*, and the bottle-nosed dolphin, *Tursiops truncatus*.

The porpoise family, *Phocaenidae*, in turn, all have spade-shaped teeth and are all small. Best-known is the harbor porpoise, *Phocaena phocaena* (a large male is scarcely six feet long). A handsomer and smaller porpoise is the Dall's porpoise, *Phocaena dalli*. This is one of the smallest of cetaceans, reaching a mere five feet. Here we are concerned with four species by these definitions: two species of whale, a porpoise, and a dolphin that were stranded or trapped in shallow waters. All but the porpoise, which died en route, were brought alive to the New York Aquarium for observation.

How do whales and their relatives live their highly specialized lives? Marine mammalogists are just beginning to learn some answers to this question. Quite a bit is known of cetacean anatomy, less of behavior, and of the way in which they use sound in their delicate underwater navigation. We have scattered information on birth, migration, and death. But as yet we are in possession of only fragments of the total life picture.

One way of learning more is to take every advantage of the fact that some whales are stranded alive. Such de-

licate measurements as electrocardiograms have been taken under these circumstances. Dead, stranded animals may be measured, and some of their organs preserved. Every so often it is possible to bring a stranded animal back to captivity, where it can be observed over a period of time. What we discover in such cases may be only a slight beginning of knowledge, and as we shall see, most of it is knowledge about sick animals. Nevertheless, sickness is a part of life, too, and this information may prove to be more important than we now can determine. Finally, small whales and their smaller relatives are presently being kept successfully in captivity. A third generation bottle-nosed dolphin is now thriving in Marine Studios, Florida, never having seen the sea at all!

No one can guess how many cetaceans are stranded annually throughout the world, although scientists, particularly in England, have for years kept records of reported strandings. In the last three years, we have observed five pilot whale strandings on Long Island and New Jersey shores alone, and surely this is far from a total count for this species for even one short length of the Atlantic coast. Why are cetaceans thus stranded? This is a question to which we are beginning to get an inkling of an answer. First, strandings of a single animal are one thing: they occur quite frequently. Mass strandings, involving whole groups or schools of cetaceans, are quite another matter.

Several expressions are used to describe one theory as to why schools of some whales, particularly the pilot whales, come ashore. "Mass mania" is one; "group hysteria" or "death wish", others. But these bits of psychological - and anthropomorphic - phraseology really say little or nothing. The fact is that groups of apparently healthy animals will drive themselves onto the beach, where they suffocate or die in the sun. A further fact is that, if forcibly hauled out to deeper water, the animals will swim back up on the strand. One dubious theory some-

times offered to explain these mass strandings is that the school follows a "pilot". If something happens to this animal, the whole school goes awry. But not nearly enough is known of pilot whale behavior to verify this theory. All that we can say is that these are highly social and group-dependent animals, and the reason underlying mass strandings may be related to that fact. As is well known by the Newfoundland whale drivers who herd their quarry to the beaches for the slaughter, schools of pilot whales can be driven to strand themselves in seeming panic. As we have noted, many strandings involve apparently healthy animals. If stress is a factor, perhaps examination of the endocrine glands - particularly the adrenals - will yield a clue as to cause.

As to isolated strandings, the question is: why should an intelligent animal, equipped with an effective navigational system, be trapped in shallow water? Probably the correct answer in the majority of cases is that the animal is not in good health. Whale and porpoise may be as subject to sickness as other mammals. Autopsies of our stranded individuals indicate that some cetaceans are subject to such diseases of the respiratory tract as pneumonia. They also reveal that several roundworms parasitize both heart and lungs of some individuals, in addition to the many roundworms and flatworms common in the liver and digestive tract.

Thus it may be that a respiratory disease or parasitic infestation "gets ahead" of an individual animal which, as it becomes moribund, tends to fall behind the rest of the school. If far from land, it might die and sink to the depths of the sea or be attacked and eaten by predators - sharks or killer whales. Possibly, sick individuals that reach the protection of shallow water may actually seek the support of land for their tired bodies.

Let us take as examples three East Coast Atlantic strandings of 1960. On May 13, a pilot whale, 12 feet

9 inches long, was stranded on Brighton Beach, scarcely half a mile from the New York Aquarium. With the aid of the New York City Park Department, a wooden sled, a tractor, we retrieved the animal and it lived in our tanks for 29 days. On July 4, 1960, a 10-foot beluga was captured from very shallow waters at Prince Edward Island, Canada. It had strayed into the Kildare River, far from its normal summer range in the St. Lawrence River, and had lived alone there for over a month until it was captured by local fisheries officers. It lived in captivity for 64 days. Finally, a 7-foot-2-inch common dolphin, *Delphinus delphis*, was stranded on the eastern shore of Staten Island on December 6. It was looked after by police until we arrived, and lived with us for only four days. These three are not the only cases we have met locally, but are the only cetaceans brought back alive.

We suspected at the outset that all these animals were sick when they were stranded or captured in waters strange to them. We knew they would probably die in a short time, but we made every effort to effect a cure, even though we were in the dark as to the nature of the diseases. The longest that any stranded cetacean has ever lived in captivity is seven months.

Even though we had little hope of curing the animals, there was much we could learn by keeping them alive for even a short time. In the three cases cited, we were able to take live weights when the animals reached our doors or whole weights at death - information that is rare indeed. We were also able to make photographs of the whole animals, and of various surface features - squid tentacle marks on the pilot whale, and circular marks on the beluga that looked surprisingly like the work of lampreys.

There was a major problem in transporting these three animals to the Aquarium alive. Cetaceans are not adapted for life out of water, but they can be transported that way. Usually, they are carried on slings of thick rubber

mattresses or on air mattresses. They are placed on their sides to relieve weight from the chest, and the body is covered with a light sheeting that is kept constantly wet to keep the animal moist and cool. The beluga was trucked in a large wooden tub and partly covered with water. Under the animal, as cushioning and support, and to give stability, were many burlap bags. The water too, helped relieve the weight on the animal for, as stated earlier, when out of the water weight is the whale's worst enemy. It is not too serious a problem with small cetaceans, but can be critical for larger ones.

We dosed our captive animals with penicillin and streptomycin, and even with vitamin shots and tranquilizers. Although the results were hard to assess directly, we have accumulated some knowledge of the dosages required for handling and treating these three species. On the whole, we suspect that except for certain tranquilizers to which these animals may be sensitive, the dosages are not atypical of other mammals. Under the direction of Dr. Ross Nigrelli, pathologist of the New York Aquarium, and with the co-operation of several physicians, eyes scraped or partially punctured by beach sand were cured, sunburn alleviated, cuts and abrasions healed.

Feeding was the greatest problem. Before using any forceful methods, we continually tossed dead fish and squid to the animals and even placed specially collected living fish and squid into their tank. On its second day in captivity, the common dolphin surprised us by feeding heavily, and continued to do so until the day before its death. The pilot whale and the beluga steadfastly refused the food handed to them by a swimmer in their pool or tossed to them. In consequence, we developed a technique of gentle force feeding. Twice each day we drained the pool of all but a foot of water. Three men then went in with the whale. One took up his position at the animal's tail and two stood at its head. The mouth was gent-

ly pulled open by one of the two "head" men. The whale did not particularly resist this manipulation. The other head man thrust a morsel down the whale's throat to the back of the tongue. The whale was then allowed to close its mouth, and the fish was swallowed voluntarily. Only toward the last days of life did any regurgitation occur. We learned that a bit more than 25 pounds of squid could be given to our pilot whale at a "sitting", and almost 20 pounds to the beluga. It is doubtful if either of these sick animals would have lived so long without this feeding technique.

We could observe only a few things about the behavior of a sick, none-too-active cetacean in captivity. We did manage to evolve a rough sort of "index of stress", based on the animals' breathing rates. When first brought to our tanks, the intervals between breaths were short, as was the duration of the breath; respiration was not unlike gasping. We have the best records for pilot whale and the beluga. Both began with breathing intervals of approximately 1/4 to 1/2 minute. This interval lengthened over a period of a few days until a pattern was set up, characteristic for each individual. This consisted of one or more long intervals - from nearly one minute to two minutes - with several short, five- to thirty-second intervals between. These shorter intervals in succession resembled the human diver's technique of hyperventilation as a means of "storing up" oxygen. At the point when this more regular breathing pattern is adopted, the animal may be assumed to be accustomed, comparatively, to its confined surroundings.

We also noted that the pilot whale is less maneuverable than the extremely supple beluga, which is able to scull with its tail to swim backward.

Another remarkable thing we noted during the short lives of these sick animals was their extreme gentleness. Only the beluga attempted to bite, and it was not a hard bite at best. Occasionally, our patients snapped their jaws threateningly - but for the most part the animals

were docile and easily handled. The pilot whale seemed to recognize one keeper who often swam with it, or at least it recognized the keeper's good intentions. We discovered that this animal enjoyed having its sunburned skin scratched with a piece of rough netting, so daily it was accommodated with this treatment.

Eventually, all three animals died. Autopsy by Dr. Nigrelli revealed a remarkable coincidence - all three had suffered from advanced cases of pneumonia, the lungs being abscessed and full of pus. Roundworms were associated with the infection in the pilot whale and the beluga. This coincidence is fortified by another case. A locally stranded harbor porpoise, which did not reach our tanks alive, showed the same condition of advanced lung infection and parasites. Whether the parasites have anything to do with the animals' susceptibility to pneumonia is not known. What we can say, on the basis of our experience, and that of others, is that cetaceans stranded alone will probably have respiratory infections. If such diseases involve difficulty in breathing, which seems likely, it may well incline the animals to seek calm, shallow waters and even the fatal pillow that the beach affords.

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p. 46-52/

A SURVEY OF BULGARIAN BIRDS

Ornithologists make first postwar study of the
Balkan area

G. Mountfort

Three great European rivers' deltas - those of the Rhone in France, the Rio Guadalquivir in Spain and the Danube in Bulgaria and Rumania - have become centers of great interest to naturalists. All three provide refuge and breeding grounds for some of Europe's rarest birds, but the pressure of human needs, such as agricultural land reclamation by largescale drainage projects, is threatening each of them. The animal and plant ecology of the famous Camargue sanctary^u in the Rhone Delta has been extensively studied. So, to a lesser degree, has that of the Coto Donana sanctuary at the mouth of the Guadalquivir. The delta of the Danube, however, has been inaccessible to detailed study for decades and little has been known about its wildlife.

Last year, thanks to the co-operation of the Bulgarian Committee for Cultural Relations with Foreign Countries and of the Academy of Sciences at Sofia, a British expedition of nine leading ornithologists was permitted to make the first postwar exploration of the south bank of the Danube, the adjacent Dobruja steppe, and the Black Sea coastal regions.

The first task was to locate the Dalmatian pelican and the white pelican - two species that have long been famous among Bulgaria's birds. In 1868, the combined populations in the delta area were numbered at several million. Today, because of constant persecution by peasant fishermen and the extensive annual cutting or burning of the reed beds in which the great birds nest, the total is no more than 1,000

pairs, of which only 700 breed yearly.

The Dalmatian pelican, the larger bird of the two, represents only a third of these totals, and is obviously in considerable danger of extermination as a European species. Small mixed colonies have been located on the Rumanian side of the Danube, but in Bulgaria only about thirty pairs still nest on Lake Sreburna. When the expedition reached this lake, we were horrified to find that all the nests had just been burned, with young birds in them. Lake Sreburna is listed as a wildlife sanctuary, but enforcement of the law is difficult in such a remote area, and the local peasants have no love of birds that eat fish.

The expedition therefore moved south down the beautiful Black Sea coast in search of the white pelican, 700 of which were eventually located and photographed on Lake Burgas. They were nearly, all immature birds and no nests were found. The flock was too large to be the non-breeding part of the Rumanian bird population, and it seems probable that many must have come from the Russian breeding grounds in the Volga Delta.

The use of poison bait to kill wolves and jackals in Bulgaria has inevitably reduced to a critical level the numbers of carrion-eating birds, such as the bearded vulture and some of the carrion-eating eagles. Fortunately, other large birds of prey are still fairly numerous in remoter regions, and the British expedition was successful in finding and photographing a lesser spotted eagle at its nest. This fine bird occurs only in the Balkans and eastern Europe. The white spots on its dark plumage, from which it gets its name, are visible only in the immature birds. The nest that we located was in the center of a swamp forest. In the course of two weeks, working for one hour each day, we gradually constructed a pylon over forty-five feet high next to the nest-tree, and a hide for the photographer was secured on top.

When all was ready, violent storms turned the region

into a quagmire. Next day, though it was still raining, we reached the site, only to find that the newly hatched baby eagle had been blown out of the nest! After its forty-five foot fall, it lay on the wet ground, apparently dying and already flyblown. However, after being warmed inside Eric Hosking's shirt, it was revived and replaced in the nest. Soon both parents returned to feed frogs and small mammals to the fledgling, thus providing a fine series of pictures, the first ever obtained of the handsome species.

Bird life is extremely varied in the Black Sea coastal region. We found great reed warblers nesting colonially around all the lakes, in addition to colonies of various species of ducks, gulls, and terns. The strident chorus of the warblers' songs vied with the yelping cries of black-winged stilts, which patrolled the shallows on grotesquely long, pink legs, guarding their speckled eggs on the muddy shores. Along the country roads, handsome lesser gray shrikes and blue-and-chestnut rollers sat on the telegraph wires, ready to pounce on lizards or beetles that were then quickly carried to hungry nestlings. Red-backed shrikes were so numerous in some localities that nests could be found in almost every bush. Around the forest margins and the vineyards, the contralto "poo-poo-poo" of hoopoes and the ringing "weela-weeoo" of golden orioles could be heard on all sides. White storks were nesting confidently in or around all the villages, and there were flocks of brilliantly colored bee eaters, goldfinches, and rose-colored starlings.

The expedition specifically sought evidence on the migration of birds along the Black Sea coast. Previously, it had been assumed that spring migrations moved north along the coast and thence either across the Ukraine and up the valleys of the Dniester, Bug, and Dnieper rivers, or westward along the Danube. The expedition found, however, that while huge flocks of migrants occurred in the region of the Burgas coastal lakes, scarcely any were to be

seen north of there. It therefore appeared that, instead of continuing to follow the coast, the flocks turned west across Bulgaria along the southern flank of the great Balkan Range, followed the so-called "Balkan Corridor" valley, and thence moved northwards through Yugoslavia. This view had already been expressed by Mr. Anthony Lambert, the British Minister in Bulgaria, as the result of observations he had made in early spring, but an intensive study must be undertaken to verify the preliminary findings.

Although Bulgaria has as yet no ornithological society and little amateur interest in the subject - indeed, it does not even have any illustrated textbooks on birds - there are indications that vigorous efforts will be made to preserve the exceptionally rich bird life remaining in the region.

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THE LUNGFISH OF AFRICA

J. Bouillon

Three genera among the living fishes of the world belong to the group known as the Dipnoi - or lungfish - fossil representatives of which are found as long ago as the Devonian period of the Paleozoic era, nearly four hundred million years ago. The higher bony fishes - as distinct from the jawless fishes, the first (and now extinct) jawed fishes, and the sharks - may be divided into two groups: the ray-fins and the lobe-fins. The ray-fins include such common living fishes as herring and perch. The lobe-fins, however, are represented today only by the coelacanth (Latimeria) and the dipnoans.

The three surviving dipnoan representatives are the genus *Neoceratodus*, found in Australia (Queensland); the genus *Lepidosiren*, found in tropical South America (the Amazon Basin); and the genus *Protopterus*, which occupies various African basins. The Order Dipnoi, as the name (dipnein: "double breathing") indicates, have two modes of respiration: through their gills, in the usual manner of fish, and also through their pulmonary sacs, or lungs, (as do certain other fishes) - for they will come to the surface to gulp air, thus filling their lungs. This allows the lungfish to survive not only in oxygen-poor, stagnant water but even in mud, or away from water altogether. Some ray-finned fishes have similar adaptations, but only a few can leave the water even for short periods.

There is almost no essential difference between the latter type of respiration and that of the land vertebrates. It is not surprising, therefore, that these animals were long considered intermediates between the fishes and the amphibians. The credit belongs to the Belgian paleontologist L. Dollo for pointing out over half a century ago that such is not the case. In spite of remarkable convergences Dollo showed that the Dipnoi could not have been the ancestors of the amphibians, for both morphological and chronological reasons.

Among present-day dipnoans, *Neoceratodus* of Australia has retained the most archaic features. It is the only living representative of the family Ceratodontidae: as in its ancestors, the skeleton of the paired fins is covered with lobes of muscle and with scales. Although it can breathe air, it remains exclusively aquatic, not being able to live out of water. *Neoceratodus*, moreover, possesses only one lung. In contrast, the other two modern dipnoans - *Lepidosiren* of the Amazon Basin, and the African *Protopterus* (together, they constitute the family Lepidosireniidae - have the paired fins reduced to tapering filaments without scales or rays. The well-developed lungs occupy

almost the whole length of the body cavity.

My own experience with lungfish has been primarily with the African genus, *Protopterus*. Four species of this genus exist in Africa: *P. annectens*, (Owen), *P. amphibius* (Peters), *P. aethiopicus* (Heckel), and *P. dolloi* (Boulenger). All are powerful animals, often of considerable size and weight. *P. aethiopicus* may attain a length of more than six feet and weigh nearly seventy pounds. *P. dolloi* may measure over three feet in length and weigh seventeen pounds or more. *Protopterus* has a long body that ends in a pointed tail: it lives on the bottom, where it moves about like an eel, with long undulations of its body. The head is rather flat; the extremely small eyes are barely visible; the nasal cavities open into the mouth forward of the palate. The superficial bones of the skull are highly reduced, the body is covered with large, thin scales, the internal skeleton is cartilaginous, and the notochord persists in the adult stage. The pointed, paired fins have a central axis of short, cartilaginous segments. The anterior fins appear to have mainly a sensory role - the detection of prey. The upper jaws are absent; the palate is fused to the brain case and is armed with strong cutting teeth, lacking in the lower jaw.

Internally, the uniqueness of *Protopterus* lies in its double pulmonary sacs, the structure of which is nearly identical to that of the lungs of land vertebrates. These highly developed sacs extend back dorsally above the digestive tube and are connected to the throat by a canal, which passes to the right of the esophagus. The gills of *Protopterus* are but slightly developed; only the fourth and fifth arches have functional gill filaments. Gill respiration is thus markedly reduced: however oxygen-rich the water in which the animal lives, it must come to the surface regularly for air. Indeed, metabolic studies show that gill respiration accounts for only two per cent of the lungfish's oxygen consumption. *Protopterus* thus ab-

sorbs almost all of its oxygen from the atmosphere. As a concomitant, the circulatory apparatus of *Protopterus* is highly specialized, tending toward convergence with the amphibians.

Protopterus is generally considered omnivorous, feeding on mollusks, crustaceans, small fish, and frogs. In most cases, however, its digestive tube on examination is found to contain almost nothing but vegetable debris - such as herbaceous plants, leaves, fruits, and so forth - mixed with bottom mud. *Protopterus* is too slowmoving to be much of a hunter: it can, however, snap up any prey that passes within reach.

The lungfish is unbelievably unaffected by even the most serious wounds; its metabolism is probably very low, and its sensory faculties poorly developed. It snaps indiscriminately at everything that passes, and sometimes even devours its own tail. The animals devour each other as well, elder eating younger.

Original studies by Brien (1938) and subsequent exhaustive research by Jonnells and Svensson have shown that the life of the species *P. annectens* has two distinctive phases. First, there is a burrowing stage, which begins with the dry season. At this time, the animal falls into a state of torpor inside a "cocoon". Second, at the beginning of the rainy season, the animal enters a nest-building, or reproductive stage. At the beginning of the dry season, *P. annectens* burrows down in the bottom mud, hollowing out a shaft, the depth of which varies from a few inches to well over a foot, depending on the size of the animal. For as long as water still lies above the mud, the lungfish makes periodic ascents up this shaft for air.

As the water disappears and the mud becomes progressively drier and harder, *P. annectens* digs in at the bottom of its shaft and curls up. The skin secretes an abundance of mucus, which dries as the mud hardens and

soon forms the close-fitting cocoon. On its upper surface this cocoon has an aperture, connected by a tube of mucus to the animal's mouth. The lungfish now enters the torpid state in which it will remain for the duration of the dry season. In order to breathe, the animal slowly and regularly draws in, through the mucus tube, air that travels down the shaft that the lungfish has previously hollowed out in the surrounding mud.

It is important to emphasize that such a torpid phase is a response to the conditions of desiccation in the animal's environment. Torpor does not take place in the case of fish able to remain in water. In fact, at the very same time that some torpid lungfish in their cocoons are being dug out of the mud by the natives - who deem them a delicacy - others, in their normal, active state, are being caught in nearby rivers and ponds.

During the course of two field trips to the swamps of the Stanley Pool, near Leopoldville, during 1957 and 1958, Brien, Poll, and the author made studies of another African species, *P. dolloi*. The information that follows is extracted from our joint work, published in the Annals of the Royal Museum of the Belgian Congo. *P. dolloi* is found only in the Congo Basin and along the coastal rivers of the French Congo; swamps are its usual habitat.

In the Stanley Pool, different types of swamps can be found; those of the islands of the Bamu Archipelago and the Djili; the swamps bordering the shores of the Pool; and those at the mouths of the rivers that empty into it. All of these swamps are grassy or wooded, and access to them is very difficult. Although differing in appearance, they have one characteristic in common. Beneath the surface mat of desiccated mud and vegetation, in the dry season, lies a layer of acid, muddy water, very poor in oxygen and rich in organic materials and in carbon dioxide. This underlying water zone still communicates with the river, however, and at floodtime water again inundates the swamp.

Most of our observations on *P. dolloi* took place in the wooded marshes on the shores of the Pool. In such places, it is difficult to walk on foot, because of the tangled mass of lianas, branches, and fallen tree trunks that have been uprooted and shattered by the floods of preceding years. These form a landscape that is tortured and ravaged, but is also impressive and not without grandeur. In the rainy season, when the swamps are flooded, one can catch both male and female *Protopterus*. In July, when the waters recede and the swampy ground slowly emerges, muddy and wet, the lungfish disappear, burying themselves in the still-soft layer of mud.

P. dolloi thus behaves as does *P. annectens* when overtaken by the receding of the waters. The latter species, as we have seen, hollows out soil as it is drying up, and then wraps itself in a cocoon. In the Stanley Pool swamps, by contrast, when *P. dolloi* digs down into the bottom mud, it encounters a more and more liquid ooze, and finally reaches the subterranean water table already mentioned. Normally, *P. dolloi* enters neither a cocoon stage nor a state of torpor. It is only in the event of prolonged drought that such behavior patterns are manifested.

Jonnels and Svensson have carefully analyzed the movements with which *P. annectens* digs down into the mud. They state that the animal hollows out its shaft by forcefully gulping down mud, then ejecting it immediately afterward, through the second gill openings. Adult lungfish, kept in aquaria, have been observed swallowing bottom sand mixed with water, and ejecting it immediately afterward, under force, through their second gill openings - which, as a matter of fact, are their largest. They work the bottom over in this manner, and effect enormous displacements of sand or mud. This, however, is not the method that *P. dolloi* employs to dig its way down into the mud.

Our field experiments showed that *P. dolloi* buries itself in quite another manner. When placed on top of very

damp, soft mud (of the sort that forms the swamp when the floodwaters begin to recede), the animal immediately plunged in, headfirst, burying itself by body-undulations comparable in speed and character with those of a large earthworm.

Now, normally, as has just been pointed out, *P. dolloi* undergoes no dormant period. Though it has withdrawn to the subterranean water of the swamp, it nonetheless needs to breathe air at the surface. It can do this only by going back up through the top layer of swamp mud. Perhaps, to do this, it utilizes the same hole it hollowed out in its descent. But more probably it opens up a new path of access to fresh air. In any case, the passage used by the lungfish, as it emerges from the subterranean layer of water, generally has only a slight degree of inclination. When it is a foot or so from the surface, the passage turns upward to form a small shaft, open to the fresh air. The shaft exit may be at ground level or, more often, at the top of a little mound of mud, which resembles a molehill. The presence of this mound is clear evidence that *P. dolloi* digs its channel from bottom to top, forcing the mud outward, mole-fashion. A study of incompletd shafts further confirms this. If the mud cap crowning the top of the mound is removed, the imprint of the lungfish's snout is seen in a mucus-lined cavity.

In the dry season, the swamps of the Stanley Pool thus show mounds that look much the same as those in the dried-up swamps where *P. annectens* dwells, but their significance is quite different. Those at the Stanley Pool do not denote the site of a cocoon buried in the hardened earth, but rather the terminus of an air shaft used by the active *P. dolloi* in order to breathe air at the surface of the water. The air shaft and its entry channel are hollowed out in the most compact areas of the swamp. The terminal mound is most frequently located among the large roots at the foot of some tree stump.

These air shafts in the wooded swamps of the Stanley Pool - and doubtless in the grassy swamps as well - are permanent. They are flood-resistant, lasting until the next dry season, when the same mounds can again be seen. The lungfish reoccupy them from year to year, coming back to them at the beginning of the dry season. Since the onset of the dry season varies from year to year, the date of spawning also varies. The fall of water serves as the stimulus that sets off spawning in animals that have reached sexual maturity.

The number of eggs in a *P. dolloi* nest is much smaller than the number for either *P. annectens* or *P. aethiopicus*. Greenwood reports that the number of eggs per nest for *P. aethiopicus* varies from 2,000 to 5,000. He further finds that the ovocytes, ready to be spawned in the ovaries of a sexually mature female, number 2,000. This suggests that several females may lay eggs in a single nest. The nests of *P. dolloi*, however, contain only a few hundred eggs. The ovary of a sexually mature female contains three hundred to four hundred eggs at most. Moreover, while the state of development may vary from one nest to the other, it is homogeneous for each single nest. Thus, it is evident that only one female spawns at each nest.

The spawning of *P. dolloi* takes place in the entrance passage of the air shaft. The eggs are broadcast along the length of the entry channel, to rest on the bottom mud. This distribution of the eggs can be interpreted in two ways: the female may release her eggs gradually as she moves about in the passage leading to the air shaft; or the eggs may all be expelled at once, and the male may then spread them about as he moves back and forth in the channel.

During the whole spawning period, females with empty ovaries are caught in the river or taken by draining the wettest portions of the swamps. It seems likely, therefore, that when the water begins to recede and the mud is till very soft certain mature females are attracted to the swamp

by the males, and then into the entry channel of an air shaft. When the spawning is completed, they are then apparently driven away. Occasionally, if the dry season lasts longer than usual, late-spawning females remain imprisoned in the swamp. They survive only by entering a state of torpor until the next inundation.

It is along the entry channel that the eggs develop and the larvae are born. When these larvae become mobile, however, they congregate in large numbers near the bottom of the air shaft. Only the male remains near the nest, in the entry channel. He lies there passively, inactive during the day at least. He moves about from time to time, however, by means of long undulations of the body, coming to the surface of the water at the air shaft to breathe. The movements of the male through the channel agitate the water enough to dissolve traces of oxygen. As the lungfish takes air, part of it is expelled, or allowed to escape, through the gill openings. These air bubbles also contain a little oxygen or permit the formation of air pockets in the channel, where the larvae come to breathe. It is thus probable that the male contributes appreciably to the respiration of the larvae.

The male may also defend its young against predatory fish, which inhabit the swamp. It is noteworthy that males collected around the nest are large in size, while small males are caught in the rivers and tributaries. It would seem, therefore, that excavation of the nest and pairing in couples is the privilege of males that have reached a considerable size.

According to native reports, the male lungfish is capable of leaving its aquatic redoubt and moving about on the dry surface of the swamp. Most authors have repeated this assertion, but we were not able to verify it. We did, however, see captured and wounded males move about relatively rapidly on the ground, propelled by powerful undulations of their bodies. In a moment of inadvertence on the

part of a fisherman, we saw one of these males travel in this fashion to the hole from which it had been extracted, reach the channel it had inhabited, and make good its escape. It is thus not impossible, and perhaps it is even probable, that the lungfish moves about on the mud of the swamp, in the manner of eels, at least during the time when the waters are beginning to recede and the swamp is still completely muddy.

The abundance of palm fruits in the gut of nesting males favors this possibility. The natives report that when the male (whom they take to be the mother and call "mama") is disturbed in his channel, he carries off in his mouth the nestful of young that he is guarding, in order to save them from harm. This was the explanation offered us for nests found suddenly emptied following our first collection of young. No rigorous observation was made that would permit us to confirm the native claim. However, we captured one male at the nest with eggs and hatched young in its mouth and gill cavity; another was caught with its gut stuffed full of larvae. It must therefore be conceded that the male is capable of taking eggs and young in its mouth. But perhaps it does this involuntarily, as is the case with everything it ingests, by breathing in water under force, ready to eject the swallowed objects through the gill openings, as is its habit.

As soon as the larvae can move about, they gather in schools in the channel near the air shaft, for even in this early stage it is urgently necessary for them to come to the surface of the water to breathe. Three modes of respiration thus succeed one another during the period of lungfish larval growth. As the embryo develops, respiration through the outer cell layer is reduced and external gills develop and take over the function of respiration. The lungs, however, are also developing at this stage and soon become the essential organs for the exchange of gases. Later, the internal gills will appear; these are markedly reduced in size.

As noted above, aerial respiration is essential to the Dipnoi. Coming regularly to the surface of the shaft to breathe, the larvae will there await the rising of the waters that inundate the swamp and frees them in the rainy season. Having terminated their metamorphosis, during which the external gills disappear, they are able to move about and feed on small organisms living on the surface of the mud or among the roots of grasses and papyrus.

In the swamps of the Stanley Pool, as we have seen, the lowest level remains saturated with underground water that normally extends to the river. After spawning, the females can return to open waters by this route. The males remain near the larvae in the channel, which leads to the air shaft, awaiting the rising of the waters. However, when the dry season is exceptionally early, long, and very severe, males may be trapped in their channels, from which the water progressively disappears.

What becomes of these lungfish when they are immobilized in a swamp undergoing pronounced desiccation? Are they capable of entering a state of torpor to await the coming inundation, which will free them? We tested this with an experiment. Two large barrels were filled two-thirds full of very soft mud, with a thin layer of water on the top. Two *P. dolloi*, which had been caught in the river, were placed on top of the mud, one in each barrel. They immediately buried themselves. After two months, the thoroughly dried mud was carefully removed. In each barrel, the lungfish was found to be in a state of torpor. When these two specimens were placed in water, they immediately regurgitated large bubbles of gas and, little by little, resumed normal activity. From this experiment, it may be concluded that *P. dolloi*, when conditions demand it, may remain buried in a state of torpor. In this state it awaits the next flood waters that will permit it to resume its normal, aquatic life.

It may therefore be concluded that *P. dolloi* is capable of entering a state of torpor when overtaken by the desiccation of the swamps; behavior that is known to be normal in the dry season for the other three species of this genus. When the water again rises, the latter three species awaken, leave their cocoons and enter an active phase that includes sexual reproduction. But the fourth - *P. dolloi* of the Stanley Pool - buries itself in the mud not to enter a state of torpor, but to lead an active life and reproduce there. If it incidentally enters a state of torpor, this is after reproduction and at a time when a long, pronounced dry season imprisons it.

At the start of this article, it was pointed out that the Dipnoi could not be the ancestors of the land vertebrates. If present-day Dipnoi share numerous similarities in development and organization with the amphibians, these similarities are attributable, in part, to common ancestry, however remote, and in part to convergent characteristics associated with a somewhat similar way of life. The dipnoans, as well as those lobe-finned fishes that gave rise to the amphibians, probably arose from a common ancestral stock at the beginning of the Devonian period or perhaps somewhat earlier. These two groups of fishes, however, evolved toward terrestrial life with unequal success. The swim bladders of ray-finned fish, the pulmonary sacs of Dipnoi, and the lungs of land vertebrates stem from a single organ: the pulmonary air bladder of the earliest higher bony fishes. The remarkable adaptability to environment exhibited by the living Dipnoi enables us to understand how they have survived with relatively little change until the present period.

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A GREEN DARNER EMERGES

Many insects do not deserve the common names that humans give them, but the dragonfly - boasting one of the most menacing faces seen in nature - would seem to be aptly labeled. Yet, despite its grotesque facial structure and predatory behavior, the dragonfly should be numbered among mankind's benefactors: it eats large numbers of mosquitoes and other harmful insects, and then is eaten in turn.

The fact is that the dragonfly long ago secured its role in the balance of nature. Giant ancestors of today's dragonflies - some attained wing spans of thirty inches on foot-long bodies - dominated the skies at a time before flying reptiles or birds existed, while fossil remains about the size of today's dragonflies have been found in rock some 260 million years old. Today's descendants include the 5,000 species of the Order Odonata. One of the largest, fastest, and most brilliantly colored is *Anax junius*, the green darner, familiarly known as the "darning needle". The darning needle is but one of 400 species of dragonflies and damselflies to be found in North America, and although there are numerous variations in the structure, habits, and cycles of these species, all have certain basic similarities.

When seen aloft, the darning needle is actually nearing the end of its life, the greater part of which has been passed as an aquatic insect. The female deposits her eggs in waterweeds below the surface by puncturing holes in the stem with her ovipositor. After about two weeks, the eggs hatch and the second and longest period of the dragonfly's life cycle begins.

This is the nymphal stage, during which the insect dwells on underwater vegetation or sunken logs, feeding on small forms of aquatic life - including other nymphs.

As the nymph feeds, it grows; and as it grows, it repeatedly bursts its outer skin. Sometimes there are as many as ten molts before the nymph attains full size.

At this stage, a more radical change occurs. The nymph has been breathing by means of an abdominal gill chamber, but now it must put its head and thorax above the water in order to breathe. Shortly thereafter, it climbs entirely out of the water to enter its third and final stage.

STRUGGLE TO SUNLIGHT

The final transformation from an ugly nymph to a shimmeringwinged, brightly colored dragonfly may be witnessed all over North America, especially during the warm months of late spring, by close observation of the vegetation at the edges of ponds and streams. The nymph remains quiescent for hours after emerging from the water, while crucial physiological changes occur within it. Then the nymphal skin splits for the last time. This time, a new head and thorax appear through the upper back. Now begins the "birth struggle" - a series of exertions and contortions as the adult dragonfly fights to extricate itself from its nymphal skin.

As it emerges, its body is seen to be divided into three parts: the long, slender, segmented abdomen; the thorax, to which are attached the legs and wings; and the head. It is this head that has earned the dragonfly its name: it is a bulging configuration, with antennae, oversized compound eyes, and flexible lower lip, or labium, with jagged-tooth jaws just visible.

The main pair of eyes, alone, would give the dragonfly an advantage in its brief existence. These huge organs are each composed of as many as 20,000 sight units,

while three other single eyes are situated on the upper surface of the head. Together, they allow the dragonfly to see in all directions at once and to detect motion as far as fifty yards away.

The wings of the dragonfly are its most spectacular feature. As they are pumped up, intricate patterns of veins are revealed - patterns sufficiently differentiated to enable us to distinguish and classify the various species. For the adult dragonfly, its wings represent life itself. Rain, wind, or clouds may occasionally drive it to shelter, but otherwise the green darner spends most of its life on the wing - darting and hovering, preying and eluding - the gauzy-winged insect known to us. Finally, the male and female will mate in flight, and after the female has deposited the eggs in some reed at the edge of a pond or stream, the dragonfly's life cycle will start in anew.

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THE LAST GREAT HERDS OF AFRICA

An aerial census of animals in the Serengeti
National Park

B. Grzimek

The native chiefs in Tanganyika co-operated in a population census several decades ago by turning over to authorities a variety of seeds representing their subjects. Long grass seeds represented boys; little round seeds indicated girls; thick black seeds symbolized men; and brown seeds represented women. The system was simple but effective. No such enviable simplicity was possible for myself and my late son, Michael, when in 1957 we were asked to

make a census of large animals in the Serengeti National Park in Tanganyika, British East Africa. Colonel Peter Molloy, then director of the National Parks of Tanganyika, requested the survey to determine accurately the extent of the animals' seasonal movements.

The Serengeti Park, which is the only national park in Tanganyika, was established for the protection of great plains animal herds and their environment. The enormity of the task that faced us may be imagined in view of the size of the park - 4,600 square miles - and the erroneous belief at the time that it sheltered some million animals or more within its borders.

Motivating the census was a government plan to reduce the size of the park and to alter the boundaries in favor of Masai tribesmen. The action was to be taken in connection with recommendations set forth in an official study made in 1957. However, this study, in regard to movements of large herds of plains animals including wildebeest (or gnu), zebra, and Thomson's and Grant's gazelles, had necessarily been based on assumptions by others and on brief observations. The census we had been asked to make was to be of particular importance, since the herds of Serengeti are presumably the last great herds of wild animals still surviving in Africa.

The immediate concerns of our census were twofold - both to establish the number of animals in the Serengeti National Park, and to discover whether the herds were actually protected by the proposed new boundaries. In view of the great area to be covered and the terrain involved, a survey by motor vehicle was impractical. Because the plain areas in Serengeti, and much of the mountainous part as well, are devoid of trees, we decided to count the animals from an airplane.

To accomplish this project, my son and I both learned to fly a plane. In December of 1957, we began a 6,000-mile flight from Germany to equatorial Africa in a single

engine Dornier 27. The Dornier, a refinement of the World War II Fieseler Storch observation plane, had been selected for the job because of the excellent visibility from its cockpit. An additional advantage of this craft was its ability to fly at very low speeds. In fact, it could remain aloft at just thirty miles an hour, which would be invaluable for making observations and would also permit the plane to operate from almost any flat area without being dependent on airfields and landing strips. The plane was painted with bold "zebra" stripes to make it easy to spot in case we were forced down.

Our original intention was to fly over the whole park area, photographing it with automatic cameras. However, we discovered that it would be necessary to fly at very low altitudes, about 2,400 feet, in order to identify reliably the different species recorded on the film. Our calculations, based on the results of previous aerial surveys by other workers, showed that, at that altitude, we would have to make more than 50,000 vertical exposures to cover the whole area. Economically, such a procedure was out of the question. Further, the absence of landmarks in much of the area to be covered would have made it impossible to join individual oblique photographs of adjacent areas. Our solution was to divide the area of the park into districts, or zones, and to fly over each of these in parallel sweeps, counting the animals of various types included within a specific angle of vision to each side of the plane.

In establishing these zones, we tried to take into consideration natural barriers - such as river valleys and mountain ranges - so that animals would not be able to shift easily from counted into uncounted districts, thus upsetting our totals. Test flights indicated that a 550-yard-wide strip to each side of the plane could be observed accurately. The plane would have to fly at a height between 150 and 300 feet. Results of the tests showed that

an observer could distinguish easily between antelope species and even classify them as adults or young at a distance of 1,500 feet. In areas where there were few animals and where scanning was easy, the strips were extended in width to 2,000 feet.

In flight the pilot navigated, and his was the responsibility of establishing the width of the strips and the sequence in which they were to be surveyed. The task was complicated by the absence of adequate maps for the area. The park had to be covered on the basis of incomplete sketches in which only large streams, rivers, parts of mountains, and a few pastures were shown. Flight courses had to be set using landmarks such as lone trees, rock outcroppings, water holes, and clusters of bushes. Sweeps were made by following compass courses almost exclusively in an east-west direction or the reverse. This heading was chosen to minimize drift: a strong easterly wind blew constantly during the whole survey period. While flying over a strip, the pilot would note landmarks along one edge to be used as guides for the edges of the adjacent strip to be surveyed on the next pass.

One thought we needed to consider about our aerial survey work was the reactions of various animals to the presence of the airplane. In practice, the reactions appeared to vary quite as much as the wildlife itself, and seemed to depend on many factors. Generally, lone animals reacted little to the plane overhead, even when it flew as low as thirty to sixty feet. This held true for both Thomson's and Grant's gazelles and also for zebras, kongonis, and topis. In fact, resting Thomson's gazelles did not even bother to stand up when the plane passed sixty feet above them. Small herds of from five to fifteen zebras or antelopes would run about one hundred yards from the plane's path, often dashing across its line of flight. They exhibit the same tendency to dash across the paths of autos in the Serengeti. Larger herds of fifty or more animals

reacted rather differently. Gnus especially, were very nervous. They would begin to race away even when the aircraft was at a height of six hundred feet, although lone specimens did not react at all. It seemed that a few particularly skittish animals would trigger escape reactions in a herd, and others would follow suit.

Large groups of gazelles showed a completely different reaction. The herd would stay calmly in place until the plane was directly overhead, then they would scatter in all directions in a rather confused fashion, but only for the few seconds it took for the airplane to pass over them. In contrast to this behavior, zebras took note of the aircraft even when it was gliding in for a landing, with the motor switched off, at heights of as much as 150 feet. Ostriches would run only when the Dornier was very close to them. Otherwise, they showed the typical "threat" posture, standing their ground with inflated feathers and spread wings.

Giraffes were difficult to start moving and fled only infrequently. Even then, they would run only 150 feet or so to the side. If they were standing beneath trees they did not bother to move at all. Baboons would always run immediately to nearby trees.

Although hyenas with prey fled while the plane was still some way off, specimens sleeping near a water hole could not be chased away. In extreme cases they might wake up, stand, and take a long look at the plane that was disturbing them. On the other hand, wart hogs fled promptly, and on one occasion, a wart hog was spotted taking cover in a nearby burrow.

Lions reacted in various ways. In the Ngorongoro Crater, we flew over and circled about an adult male. At first he showed little inclination to react. Finally, though, he began to walk away, gradually increasing his pace. Most of the time, however, lions would try to escape detection in the grass by pressing themselves close to the ground. Although we rarely saw cheetahs, the few we did encounter

simply sat where they were and showed no sign of fright. Our one leopard raced to a tree and climbed it.

Naturally, the approaching airplane occasionally caused animals to flee into strips that had already been counted. Most of the time, however, they did not penetrate the zone more than 100 to 200 yards. When conditions allowed, we flew high enough to avoid appreciable fleeing or we resorted to counting whole herds. Because of the flight reactions often exhibited by the herds, when we spotted one we would gain altitude in order not to spook the animals into a previously surveyed strip. Then we would circle and count the herd without disturbing it, disregarding completely the boundaries of the strips.

Of course, the problem of how to identify herds that had already been counted was one that arose. This was an important question not only because we did not wish to upset the census by recounting the same animals but also because we wanted to be able to trace herd movements from one part of the park to another, and further, to see if these herds were straying outside of the park's present and proposed boundaries.

Traditional methods of marking animals include dyeing or painting their hides, and putting metal clips in their ears. For our purposes, metal clips would be useless since they could not be seen from the air. Dyeing would not work at all on animals whose hair was black, and would not work well on animals with greasy hair. In any case, it was probable that neither dye nor paint had sufficient permanence and durability to mark these animals for the length of time we thought desirable. We finally settled on marking individual animals in the herds with brightly colored, plastic collars. The brilliant color of these collars was easily distinguished from the air. Made of several layers of synthetic material, they were also quite durable, and the smooth finish meant they would not irritate the animals that wore them. At first, we were concerned about the re-

ception a marked animal might receive from others in his herd. Fortunately, the marked animals seemed to be treated normally by their companions. The durability of the collars was proved by the fact that eighteen months after we had banded some animals, they were seen in the park still wearing their gay bands.

Putting collars on wild animals, however, is in one respect analogous to the classic recipe for rabbit stew that says to, first, catch the rabbit. In our case, we had to, first, catch our wild animal. This was no mean task. We had heard a great deal about a "miracle" gun manufactured in the United States, which shot a projectile containing drugs. In theory, hitting an animal with one of the needle-tipped bullets injected a narcotic and anesthetized the animal so that it might be approached safely.

We acquired one of the guns in the hopes that it would fulfil our requirements. The weapon was powered by compressed carbon dioxide, a puff of which shot the hypodermic-type projectile between sixty and one hundred feet. Behind the plunger of the projectile was a mixture of carbide and water, which produced gas to drive the plunger forward, injecting the narcotic solution into the target animal. Our first results with the device were rather disappointing.

For one, it was relatively inaccurate, and we could never be sure just how far the bullet would carry. Secondly, even when an animal was hit squarely, the performance of the bullets was erratic. Thirdly, the syringe projectiles were slow to use. The narcotic solution and the carbide and water mixture had to be loaded in the field immediately before firing. Clearly, we had to remodel the contraption to adapt it to our needs.

During a return to Frankfurt, Michael modified the weapon and tested it. The new power source was compressed air at a pressure of nearly three thousand pounds per square inch. Effective range of the weapon rose to 120 feet with

reasonable accuracy. The hypodermic bullets were also modified so that the impact of hitting the target was sufficient to drive home the plunger. This meant that a supply of the darts could now be loaded in camp and taken, ready to use, into the field. It also assured that the animal would receive the full dose in the bullet, whereas, with the previous system, only a partial dose was administered as often as not.

Finding the correct anesthetic for use on various animals proved a more difficult problem, and this took many months to resolve. The tolerances of different animals to a given drug varied greatly, and often, surprisingly. For example, a gnu shot with a dose per pound body weight less than that tolerated by an ordinary domestic goat was incapacitated overnight, during which time we had to watch him to see that he was unharmed by predators. However, the proper dose per pound body weight for gnus of the drug (nicotine salicylate) had no apparent effect on little Thomson's gazelles. We finally learned that they required a dose per pound five times as large as that used for the gnus. We also found that the Thomson's gazelle bucks had to be captured while lying down. While running at their speed of about thirty miles per hour, the slight effects of the drug disappeared.

Once correct dosages were ascertained for the various animals we wished to mark, the actual collaring became much simpler. The drugged animal could be approached and the plastic collar fitted to its throat. In a matter of minutes, the beast would regain its feet and, soon after that, would rejoin its companions. Only the zebras would never let us come close enough to use the "miracle" gun.

Zebras required an entirely different, more energetic - and dangerous - approach. In the beginning, when we had tried dyeing them with picric acid, we would chase them by car, while a member of our group sat on top of the vehicle holding a long pole with a rope noose at one end. By iso-

lating one animal from its herd, then driving alongside it, always keeping parallel to its line of flight, it would be possible to close the range until the man with the pole could slip the noose over the tiring animal's neck. The danger lay in the precarious position of the man with the noose, who had to handle the unwieldy pole while trying to maintain his seat on the roof of the bucking, swaying car. On one occasion, Michael was handling the pole when a lurch of the car caused the tip of the pole to catch in the ground. Immediately, the rear of the pole rammed back and hit Michael's throat, inflicting a serious wound that necessitated flying him to a hospital for an emergency operation. Despite this experience, Michael insisted upon rejoining the group almost immediately.

Later we modified this method for catching our zebras. We would race in the car alongside an animal and whoever was best located would reach out and grab the animal's tail. Naturally, this is much easier said than done, and it might be noted that a zebra's tail does not afford the most secure grip desirable under the circumstances. Despite the obvious difficulties involved, we became quite proficient at this method of capturing zebra. After subduing the animal, we would fit it with a collar and let it rejoin its herd.

Sad to say, one of the greatest threats to the safety of animals in Serengeti is posed by man himself. We were made painfully aware of this during a flight undertaken for the sheer joy of flying on a beautiful day. High above the plains spread below, Michael cut the motor of the plane and we glided in silence through the clear air. As we descended, a fine line across the ground caught our attention. Gliding still lower, we saw that the line was a fence of twigs and thorny branches punctuated by occasional gaps. The fence had been raised by native poachers, who slaughtered herds for meat and to provide the souvenir and curio market with teeth, hoofs, hides, and horns of

various beasts. In the gaps of the fence were wire snares that would entangle any animal trying to pass through. These fences were generally placed in intersect a migration route or trail commonly used by the herds.

The poachers were still near the fence and, as Michael touched the starter button and the engine roared to life, they dropped to the ground. We buzzed them in an effort to drive them away and, during one pass, some of them dropped to their knees and let fly at the airplane with poisoned arrows. From the safety of the cockpit their gesture appeared futile, but when we landed at our base some time later we saw an arrow protruding from the metal wing of the plane.

Aside from the obvious objections to the poachers' depredations against "protected" animals, we were infuriated both by the cruelty of the methods used, as well as by the enormous waste of the animals so slaughtered. When making auto trips where poachers had been at work, we often came across animals that had died by slow strangulation in wire nooses, or had been trapped in the snares and then dispatched by predatory animals. Often the victims would decay before the poachers arrived to take the meat. Occasionally an animal would be found minus its horns or paws, the only parts that the poachers wanted.

Eventually our indignation mounted to the point where we took part in a raid against a group of poachers. Two of the band were caught, and they naturally claimed that they had merely blundered into the poacher's camp. The camp itself, located in a small clearing within a wood, might have served as the backdrop for a scene from a Grand Guignol performance. Wherever one looked there were strips of raw meat hung to dry from poles arranged to form racks. The sunlight shining through the gory slabs gave a bloody, eerie glow to the camp. Tangible benefits of the raid included the capture of three truckloads of bows, poisoned arrows, and wire snares, all of which were destroyed or

tossed into a pit too deep to permit retrieval of them.

Unfortunately, both American and European tourists also complicate the situation through their hunting trips. It is not entirely reasonable to expect natives to accept the idea of being punished for hunting when they see the hunting parties of wealthy visitors roll through their villages in cars loaded with trophy animals. Furthermore, most African governments have diminished the value of preserves and parks by not appropriating sufficient funds to ensure that the animals in them are guarded adequately.

Before discussing the results of our aerial survey, it is desirable to pause to consider some of the sources of error inherent in making a game census under such unusual conditions. One factor that presumably could never be eliminated was the natural movement of animals from a counted strip to an uncounted one. The reverse situation also may have been encountered. We tried to minimize this problem by covering in one day areas that had no natural barriers separating them. In general, we tried to count consecutively adjoining areas.

Another possible source of error lay in the blind spot directly beneath the fuselage of our airplane. Mitigating this factor were the predominantly low altitudes at which we flew, which minimized the actual hidden area. Besides, most of the animals counted scattered to the side, out of this zone, so this was most likely not a major source of error.

More important perhaps were the long distances involved in flying to the study areas. Because of this, it was often necessary to count for more than two and one half hours at a time, a chore that led inevitably to exhaustion on the part of the counters and of the pilot, who had to rest for several hours after each trip.

The position of the sun also affected our counting. Because the strips to be surveyed were oriented principally in an east-west direction, at certain times of the day

sweeps in one direction or the other might be made directly into the sun. We noticed, for example, that we sighted fewer gazelles when flying toward the sun than when flying in the opposite direction. The amount of error this produced varied depending on the species being counted. More conspicuous animals, such as giraffes and rhinoceros, could hardly be overlooked. They could be seen at great distances and it was not likely that they might be missed. For the giraffe, rhinoceros, elephant, oryx, roan antelope, and probably for buffalo, our figures were likely to be very accurate. Elephants, rhinoceros, and buffalo occurring in rain forests, however, were not included, because they could not be seen from the air. It is also possible that there might have been some errors in the counts of larger herds of gnus, zebras, and gazelles, especially considering that some herds of two thousand or more were observed during our census flights.

In summary, while it is possible that a margin of error of twenty per cent exists in the total number of animals we counted, the error should certainly not exceed that figure.

The survey results were not entirely surprising to us. Preliminary counts had shown that the movements of several species were not limited by park boundaries. During some seasons, a great many animals leave the area of the park. However, the total count of large animals proved to be 366,980, or only a third of the number popularly estimated for this region. Regarding distribution of the animals, our findings raised a whole series of new questions.

Animals of a given species are not uniformly distributed over the entire area of the Serengeti Park but tend to form concentrations in certain places, while in other areas they may be entirely absent. Regarding giraffes, the reason is evident - they stay among trees or near them. Waterbucks were found only along riversides or in parts of the Ngorongoro Crater. Impala occurred only in heavy bush

and tree plains areas and were not seen on open plains. This also applied to the topi, but less strictly so. As to gazelles, the interpretation is more complicated, and the same is true for gnus. It is possible that soil types and, indirectly, the composition of the vegetation play a part. Gazelles could also be pushed from an area into a region with poor vegetation by population pressure of the closely associated gnus. Generally, the way in which one species fits into the openings left by other animal groups was conspicuous.

The upsetting fact that emerged from our survey was that every year the large herds moved far beyond the new borders proposed for the park. They remain outside this area for many months. We wanted to find out why. Michael landed in many different spots in the Serengeti to study the vegetation and take samples for analysis of the types eaten by the game and those spurned by them. The results of his research indicate that the preferred type of grazing grows, to a great extent, outside the future limits of the park during the rainy season. What grows within the future Serengeti is considered largely inedible by the animals during parts of the year. We have studied the nutritive content of the grasses and have tried soil analysis to find the reasons for the difference in distribution of various grasses. We concluded that the herds need the area that is to be taken away. Ironically, the land in the park - adequate for wild animals - would be inadequate to support the Masai's overly large herds of cattle. The big wild herds move over the central part of the Serengeti Plains in the rainy season in large circles, always returning to the same place periodically. The situation is like that on a modern dairy farm, where cows are driven daily to new areas, returning every few days to the same spots, eating only short, protein-rich grass.

In surrounding districts we saw that large herds of cattle - protected against infectious diseases - cause

soil erosion and can, in a few decades, change the land to desert. In contrast, wild herds live in a natural balance with the vegetation. Because the land around the Serengeti is more heavily settled by natives each year, I believe that if the new boundaries remain in effect, large parts of the great wild herds must surely die.

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MAN AGAINST THE COLD

A visit to the last of the Alakaluf shows their
adaptation to a subpolar climate

C.S. Coon

The "Gloria" is a "Barca", sixty feet of stout Chilean pine, as broad and as tough as a Hudson River tug. She has two short, thick masts, a stubby bowsprit, and a galley smokestack that telescopes when under sail. Below decks is a diesel engine that drives her through the turbulent, icy waters of Cape Horn at seven knots, or eleven with the help of sails and a following wind. Approaching the "Gloria" on the long dock at Punta Arenas, the world's most southerly seaport, the first living thing one hears or sees is Bua, the ship's dog - a tidy Scottish shepherd, friendly to man but unflinching foe to any dog that tries to come aboard.

I boarded the "Gloria" late in the summer of 1959 as the guest of a group of physiologists headed by Dr. T.H. Hammel, of the University of Pennsylvania Medical

School. In co-operation with the Department of Anthropology of the University of Chile at Santiago, Hammel's party of nine was in pursuit of the Alakaluf, a dwindling tribe of Fuegian Indians that possesses an unusual capacity to resist cold weather. Don Alberto Medina and Luis Strozzi, M.D., Represented the University of Chile. Per Scholander, from the Scripps Institute of Oceanography at La Jolla, was an old hand at physiological studies, as was K. Lange-Andersen, M.D., from Oslo. Robert V. Elsner was present from the University of Washington, Seattle, and Raymond J. Hock had come from the White Mountain Research Station of the University of California. Fred A. Milan, both anthropologist and physiologist, represented the Arctic Aero-Medical Laboratory at Ladd Air Force Base, Fairbanks, Alaska.

Hammel and Elsner, each of whom had conjured up such an expedition independently, had joined forces and assembled our party in Santiago in mid-August. Lange-Andersen brought with him from Norway a sort of landlocked bicycle that served to test muscular endurance - and many other queer-shaped package filled the plane that carried us to Punta Arenas.

Physiologists are gregarious folk who divide up segments of their job just as the organs of the body are divided in their functions. One will handle the rectal thermometers, another will watch a subject's oxygen intake and carbon dioxide output, and a third will check skin temperatures. What each physiologist in our group did on this trip is little known to me: they worked during the long nights and slept by day, while my business of physical measurements was conducted in the short, daylight hours of the subantarctic winter.

Whatever each of us did, the objective was the same. We had come to the Magellanic Islands to study the cold adaptation of the Alakaluf Indians. The U.S. Air Force, which footed most of the bill, wanted to know whether or not these Fuegians - among the ones described by Darwin

during the voyage of the "Beagle" - were really different from the rest of us in their ability to tolerate cold and, if so, how and why. In today's threats of global warfare, as well as in preparation for space travel, what a human organism can stand and how he stands it are items of strategic information.

When Magellan passed through the Strait that bears his name, he saw smoke rising from hundreds of fires on and near the shores of the great island to the south and the smaller, fringing islands. Hence the name "Fireland": Tierra del Fuego. The fuel for these fires was Nothofagus, an evergreen relative of the beech, which throws out great heat. Some of the smoke Magellan spied was leaking out of the roofs and doorways of domed huts, built of a framework of halfhoops covered with the skins of sea lions and sea otters; inside these huts, the temperature was sometimes as high as that of a New York hotel bedroom today. Other wisps of smoke came from the fires burning on clay hearths in skin or bark canoes.

Within the outer periphery of the campfire's radiation squatted a man, his wife (or wives), his children, and several brow-beaten dogs. Some of these folk were naked, although smeared with grease and ochre; others wore small robes of sealskin or sea otter skin over their backs. These were the Fuegian Indians.

Before the white men entered and ruined their lives, the Fuegian Indians were divided into four tribes. On the main island of Tierra del Fuego lived a hunting people called the Ona - Selknam in their own language. They killed the native guanaco with bows and arrows, and wore robes of guanaco skin. At the very tip of the main island was a small tribe called Haush: these people disappeared before anyone had a chance to study them, but the Haush were probably related to the Ona. All along the shores of the southern border of Tierra del Fuego and on the neighboring small islands as far south as Cape Horn lived the

Yaghan, or Yamana - so-called "Canoe Indians". It was they whom Darwin saw in Beagle Channel; Fuegia Basket and Jemmy Button were Yaghans; and it was among the Yaghans that the Rev. Thomas Bridges devoted his life to his work as a missionary.

The fourth tribe was the Alakaluf - Aweskar in their own language. They inhabited both sides of the Strait of Magellan and the shores of the fiords, channels, and sea-ways north to the Taito Peninsula, and covered a much larger territory than any of the other tribes. No one knows how many Alakaluf existed at their peak population, but six thousand is the figure sometimes given. The Alakaluf moved about a good deal. Their middens - the piles of clam, mussel, and other shells they left at temporary camp sites - are shallow: those left by the Yaghans are deeper, showing that they led a less nomadic life.

Alakaluf, or Alakalup, is a Yaghan word meaning "People who use quahog shells for knives." And so they did. With these shells they carved spear points and harpoon heads out of whalebone, and they also made fourtined spears out of cedar, with which they collected sea urchins. Their canoes were originally wooden frames covered with sea lion skin. When they got metal axes they made three-plank canoes and, finally, dugouts. Now the handful of surviving Alakaluf buy their boats from other people.

Until forty years ago, Alakaluf men wore their hair in a soupbowl bob. Now they have Western-style haircuts. Within the present century, photographs were taken on board ships of Alakaluf men now alive or recently dead, walking about naked. Going naked but for a coat of grease is much healthier in wet weather than wearing someone's castoff jacket and trousers, letting them get soaking wet, and keeping them on in a heated hut. The Alakaluf could stand cold, but not the white man's colds and tuberculosis.

Darwin saw a Fuegian woman suckling a naked baby in a snowstorm, and I have seen naked Fuegian babies walking

about in snow. Even today, Alakaluf women habitually go barefoot, wading in 40° F. water as they moor and cast off their boats, treading sleet and snow underfoot, and never seeming to mind the cold. Their feet and ankles seem built for this sort of treatment. Short toes; short, broad, square feet with a thick pad of fat on the arch; tubular ankles, three or four inches in diameter: these are designed to equip Alakaluf women for their amphibious, sub-antarctic lives.

But such observations of gross morphology are too crude for physiologists. They must have temperatures to read, and quanta of gases and liquids to measure in millimeters and cubic centimeters. Hence all the paraphernalia we transshipped from airfield to dock and loaded aboard the "Gloria". Such gear is strange to the field anthropologist: all that we need can often be loaded on a single mule. But we cannot study cold adaptation in such a way as to produce conclusive, scientific results. This is a task for a team of physiologists, with boxes full of metal, rubber, plastic, and glass gadgets for their various tests.

Like his crew of five, the Captain of the "Gloria" was a Chilote. The Chilotes are the inhabitants of the isle of Chiloe', off the southern end of the regularly inhabited coastal plain of Chile, and north of the myriad islands, steep-walled channels, and sea-reaching glaciers of Chile's almost uninhabited lower coast - the zone we were on our way to visit.

In early conquistador days, a company of noble folk from northern Spain settled in Chiloe, and established the foundation of a special human breed. First, the Spaniards absorbed the local Indians - Chona by name and probably related to the Alakaluf. Later, the product of this mixture absorbed an immigration of Araucanian Indians from the mainland - horsemen, cider-makers, and silversmiths. The result is a new subrace of man: short,

square, extremely muscular, black-haired, red-cheeked, energetic, enterprising, and bright. Some Chilotes look enough like Indians for this Mongoloid touch to be noticed, but most do not. Captain Delgado, master of the "Gloria", has no Indian features: he looks like a Basque - which probably many generations ago, his Spanish forebears had been.

The Chilotes have had a population explosion. Like Ireland, Chiloé is famous for potatoes, and its waters yield many fish. On a diet of potatoes, fish, and mutton, the Chilotes have bred rapidly, and have exported people. As this human product is cold-resistant, quick, and hard working, it now accounts for the majority of the population in the southern tip of South America, including both Magallanes Province in Chile, and Argentine Patagonia. In the latter, some 400,000 Chilotes retain Chilean citizenship.

The "Gloria's" cargo hold, a cavity thirty feet long, twenty feet wide, and some eight feet deep, was to be our quarters for the journey. In it, the day I first went aboard, a gang of **carpenters** was busy setting in **bunks** on the sides and aft, and installing a two-burner oil galley against the forward wall. Having seen the equipment and stores for the nine of us and our cook and cook's helper, I wondered where it could all be stowed, but the cook, who had also seen the gear, reassured us, and he was right. Somehow, he found room enough for the equipment, the canned goods, and dry rations, and ourselves: in fact, exactly enough room, with hardly space left over for a small mouse. Our fresh meat, in the form of half-carasses of beef and mutton, was slung in the rigging, where it teased the sea-gulls to near frenzy.

Our cook's name was Adalberto Carcamo, and we simply called him the jefe (chief). A short, fat, red-cheeked Chilote of enormous energy, he came along, he said, just for the pleasure of being on an expedition. He had been on many before. The jefe is a rich man, the owner of a bar

and restaurant at the foot of the Punta Arenas municipal pier. There he is both a ship's chandler and host to the transient seamen of many nations.

It was on a visit to the jefe's establishment that I saw my first Fuegian Indian, a Yaghan who had come in from Navarino Island as a sailor. Medina, Strozzi, and I bewildered the poor young man with unexpected attention, and he blinked anxiously as the strobes of our cameras flashed. This meeting with a live Yaghan was a thrill I had long awaited, almost as great as when I first saw an Australian aborigine or a Philippine Pygmy.

The second Fuegian I saw was an eleven-year-old Alakaluf girl named Maria Theresa. She had been carried from her island home to a hospital at Punta Arenas, suffering from spinal tuberculosis. In an iron cot she lay, striking her forehead with a clenched fist, slowly, rhythmically, and dramatically, her features drawn into a lugubrious frown. When Dr. Strozzi told her that we would try to see her relatives, her face brightened and her fist unclenched. Her skin was light brown, the palms of her hands were dead white and the hands large and well muscled, with beautifully formed nails. Her face was broad, her eyes set wide apart, and her features strikingly similar to those of an Ainu girl of the same age I had seen in Hokkaido two years before. Like that Ainu child, she had continuous hair from eyebrows to scalp on either side, and an exceedingly low hairline between. This hairy development left her little visible forehead. Her appearance, unusual for most American Indians, made me even more eager to see as many of the Alakaluf as I possibly could.

The "Gloria" left port on the morning of August 25 and headed south-west in the Straits of Magellan.

At 5:45 P.M. we dropped anchor in Bougainville Bay to check a leak in the fuel line. In this sheltered haven, near the tip of the continent, we saw cliffs behind a narrow, pebbly shore, and dense, almost tropical looking vege-

tation, with the false beech *Nothofagus* and a true cedar (related to the cedar of Lebanon but locally called cypress) as the dominant species, and with shrubs and ferns covering the ground. The scene was not unlike a miniature Japanese garden, exquisitely contrived and then magnified to a majestic scale. Hundreds of cormorants flew about, their speed exaggerated by their rapid wingbeat and craning necks. Among them Hock pointed out a loon.

The oil leak was fixed in short order and we were off again, passing tiny islands with storm-twisted trees, and leaving the snow-covered mountains of Tierra del Fuego in the background. This scenery continued to unfold all the next day until we were nearly exhausted by its beauty.

On the 26th, we passed a manned lighthouse - all the rest are automatic - between Manuel Rodriguez Island and the mainland. The lighthouse keeper waved warmly to us from the roof. A tanker passed us and we saw steamer ducks - those fat birds, incapable of flight, who propel themselves like side-wheel river boats by striking the water with their wings. A condor floated high overhead, and among the gulls glided an albatross. Before dusk we were visited by porpoises, which made everyone happy because Scholander is a world authority on their physiology and behavior, and he had just completed, in Punta Arenas, a letter to "Science" explaining how these brainy mammals ride, in defiance of dead body physics, on the bow waves of ships. This trick they proceeded to do for us almost as if they knew Scholander was aboard and wanted to entertain him.

At the end of the afternoon, we stopped in a cove to fetch fresh water, and there we found limpets, mussels, mandarin hats, and clams by the thousands, and collected a thousand or so mussels for supper. On the flatter parts of the shore, above high tide, stood the skeletons of Alakaluf huts and extensive middens, bearing witness that this was a favorite Indian camping place. The Alakaluf leave these

hut frames standing between visits and carry away only the skin covers. While the anthropologists in our party inspected the hut frames and middens, Scholander, who is a botanist among his other accomplishments, collected as many plant specimens as he had time for, including holly, magnolia, and something that looked like a tree cabbage.

Late that same day we passed a grim, watery Calvary of ships, where two freighters, freshly wrecked, had not yet settled. One stood on end, bow to the sky; the other pointing into the channel at a 45° angle. From here on, the navigation became somewhat tricky and Captain Delgado could frequently be seen standing in the bow, where, like a football umpire in a hotly contested game, he passed dramatic arm and hand signals to the man in the wheelhouse.

We arrived at Puerto Eden on Wellington Island, our destination, in the declining light of day on August 29. We anchored in front of the Chilean Air Force house, the only carpenter-built, firm building between the lighthouse we had passed and Rio Baker, a distance of over 625 miles. This house is a two-storied frame structure of about ten rooms, originally built as a hotel for seaplane passengers flying between Santiago and Punta Arenas. Before the hotel was ready for its first guests, the Argentine government had suddenly removed its ban against Chilean planes flying over Patagonia - the ban that had inspired the hotel in the first place. Then Puerto Eden became a Chilean Air Force base and, at the same time, a rallying point and last haven for what was left of the Alakaluf.

Many of these Indians stay at Puerto Eden most of the time, because the Chilean Air Force garrison feeds them when hungry, and gives them as much medical care as it is able. The medical orderly has, for example, eliminated venereal disease among the Alakaluf with penicillin injections. When an Indian needs hospitalization, he is sent on the next available ship to Punta Arenas. There is another advantage to this site, too. Puerto Eden is located

in the lagoon just south of Angostura Inglesa, the English Narrows. All ships of moderate draft that move north through this inland waterway - much calmer than the open Pacific - have to stop at Puerto Eden to await high tide, unless they arrive at that exact time. While waiting at anchor, these vessels are invaded by two or three boatloads of Alakaluf, mostly women and children, who swarm aboard to squat, mutely pathetic, by the doors and hatchway. They offer baskets and toy bark canoes (the latter modeled after those of the Yaghans and not their own) in exchange for clothing, food, cigarettes, and forbidden liquor. They also beg when barter fails.

When we first saw Puerto Eden, the beach was covered with mollusk shells, and on it were drawn up three or four dugout canoes, old and in poor shape. On the bank behind stood four newly built plank houses, covered with skins and seeping smoke, and behind the most distant house rested fifty-odd drums of high octane gasoline. A small, wooden pier reached the channel, and on it stood our reception committee, consisting of three of the four Chilean Air Force personnel at the base - a corporal, the cook, and the medical orderly. The commander, a sergeant, was in the house, on duty in the station's radio room.

These four men were to be our hosts for over a month. To Hammel and his fellow physiologists they turned over most of their quarters, in which work was to go on all night; they installed the jefe in their own kitchen, and let me measure the Alakaluf in their parlor, and never a murmur of discord or a grumble of hurt feelings was heard by any of our party.

Once ashore, we were disappointed to find only five adult males, out of a total population of forty-nine Alakaluf, in the camp. One, Pancho, was ancient and bedridden. Another, who called himself Alessandri after the current president of Chile (he had formerly been Alejandro), had tuberculosis. A third, Enrique, had suffered

a crippling injury to one hip and leg in his youth, by falling off a cliff while robbing birds' nests. Only two, Lucho (Luis) Molinari and Jose Lopez, were present and whole. Six other men were off in their longboats hunting sea otters, but exactly where no one knew.

Because these three men, Lucho, Jose, and, in a pinch, Enrique, were not an adequate sample, Hammel immediately applied by radio to the Chilean Navy for permission (duly granted) to search the fiords north of us for the otter hunters and to bring them back to Puerto Eden.

Hammel, Elsner, and the other physiologists set up their laboratory in the second story of the Chilean Air Force building. A tent, below, was connected to the lab by tubes and wires run through a window. Their first volunteer was Lucho, for he was needed to guide us to the other hunters. The physiologists' subject spent the night on a cot in the outdoor tent, under a light blanket and with a plastic "spaceman" hood over his head, a rectal thermometer in place, and eight thermocouples cemented to various spots on his skin. All night long the observers sat in their second-storey laboratory, reading gauges, mixing magic brews, and in general doing things as mysterious to me as to the Alakaluf.

Once they wired Lucho and had him swim for eight minutes in the icy water, recording his internal and external temperatures from instruments on the shore. He came out of the water dripping, but not shivering. Lange-Andersen got all his subjects to grind away on his stationary bicycle, and downstairs I eventually measured all the men except the bedridden Pancho, taking not only weight and the conventional anthropometric constants but also the dimensions needed for calculating skin surface area. Elsner, among other things, measured fat folds on various parts of the body.

Leaving the physiologists at work on the Alakaluf in camp, we boarded the "Gloria" a few days later and set out

northward through the English Narrows into a labyrinth waterway, watching every minute for the otter hunters. Clad in Chilean replicas of Mr. Frost's Gloucester oilskins, our Alakaluf guide, Lucho, stood like a rubber figurehead throughout the day, scanning the misty waters for any sight of the boats. Each night we anchored in tiny, breathless coves, some still unnamed, but known of old to Captain Delgado. In them we went ashore for water and rowed about in the ship's boat to shoot ducks. Everywhere the dense foliage - with ferns and bright red berries under the trees - gave the shore line - a look of the Tropics in temperatures only a degree or two above freezing, when not a degree or two below.

Each day, we cruised about a maze of inlets and channels between islands, in waters for which we had no charts. On September 5, we stopped at Vargas Island to pick up a one-eyed, half-Araucanian woodcutter who had been living alone with his dog, cutting "cypress". As he had spoken to no human being for seven months, he was naturally bubbling over with conversation. He came aboard at 4:30 P.M. and brought us luck. Less than an hour later, we rounded a cape of the same island to see two boats just leaving a shingly beach. They held six men, a woman, a boy, and nine dogs. Loud cheers rose from the deck of the "Gloria", and even Lucho smiled.

The otter hunters were wearing good Western clothing, including several pieces of formal attire, and were speaking to each other in Spanish as we approached. As soon as they saw Lucho's beaming face, they shifted to Alakaluf. One young man, Carlos, was obviously the leader and all but one of the other men were older. The woman - a small, elegant creature - had a curious visage. Her upper face, including her eyes, nose, and cheekbones, was small and delicate but her jaws, mouth, and teeth were very large. Her name was Lola and she had charge of the dogs. The boy of the party was Carlito. The other men were Carlos brother,

Virjilio, Manuel Lopez (Jose Lopez' brother), Manuel and Julio Tonko, and Francisco.

These men were younger and more vigorous than their tribesmen back at Puerto Eden. Except for Virjilio, they were wearing clothing bought new to fit them, instead of castoffs. Their vessels were two new clinker-built Chilote longboats, propelled by oars, from which rose the lively stench of ripe sea lion meat and other slightly putrid proteins that I could not identify. The hunt was over and the men were ready to go home.

We cast them a line and towed them into Rio Baker, the southernmost settlement of the Chilean mainland north of Magallanes Province. Except for Puerto Eden and a few woodcutters' huts, the intervening stretch is uninhabited. Here we spent the night, bought an ox to add to our meat supply, hung it high, hoisted the two longboats on deck - Lola and the dogs staying in one boat, away from Bua - and we were off, arriving at Puerto Eden with a following wind and tide, on the afternoon of September 7.

Down in the huts - during the next ten days - Medina and Strozzi and I, when I was able to join them, collected an Alakaluf vocabulary from various informants, particularly from Alessandri and from Margherita Canales, a one-eyed, middle-aged woman of great presence and charm, who sang ancient love songs for our tape recorders. Had we given them liquor, I was told, they might have forgotten the dreary present enough to have performed their ancient dances, imitating various birds and sea mammals with startling fidelity. But liquor is forbidden the Alakaluf by the Chilean government, and all we got was song.

The results of our investigations may be summarized under three headings: physiology, physical anthropology, and cultural anthropology.

Our physiologists found that their subjects are indeed cold-adapted. When they slept with little covering at 0° to 5° C., their metabolic rate remained high throughout the

night (their basal metabolism being 150-200 per cent of the Dubois basal metabolic rate for white men of their height and weight). The Alakaluf men not only maintained a normal internal body temperature but also radiated heat through their extremities. White men also lose heat through their extremities but suffer a lowering of core temperature under similar circumstances. Australian aborigines, also studied by Scholander, Hammel, and J.S. Hart of Canada, maintain their core temperatures but lose less heat than either Indians or whites through their extremities because of a heattransfer from arteries to veins in their upper arms and thighs.

From the physical anthropological point of view, this information indicates that ancestral American Indians, similar to the Alakaluf, could have walked from Asia to Alaska over the Bering land bridge at any time when the sea level was low enough and the land bridge climate was comparable to that of present-day Tierra del Fuego. All such Indians would have needed was fire, a crude cutting tool, and the ability to build simple huts. America could have been first invaded at any suitable phase of the Wisconsinian glaciation. When it actually was invaded must be settled by archeologists.

Racially the Alakaluf are fully sapiens Mongoloids. Some have heavy brow ridges, large teeth with five- and six-cusped molars, and very large hands, with long ring and shorter index fingers. Most have skins as light as Japanese or brunet Europeans, but they also have blue pigment spots on their backs above the sacrum and on their gums, as well as blue genitals. Their eyes are mostly light brown, their hair dark brown. The women's hair is usually red-brown, and probably bleached through diving. All of the men over twenty-five or so had beards, and some wore mustaches. Enrique had hair on his chest and back, and most of them had hair on their legs. The Alakaluf are about as hairy as the Japanese.

The mean weight of the men is 142 lbs., the mean height, 5'3". They have big bodies, short necks, long arms, and short legs. Their heads and faces are both long and large. In other words, they look about as the first Indians to reach America could have looked, particularly if a little of what later produced the Ainu was added on the way.

Culturally, there is less to say. Ethnographic field work takes more time than basal metabolism measurements or anthropometry. A report on the trip's cultural findings is Dr. Medina's share of the work. He and Dr. Strozzi collected a vocabulary of many hundreds of words, some of which - like Bushman and Hottentot words and like the neighboring Ona language - are pronounced with clicks.

The Alakaluf have different words for father's father and mother's father, but one word for both grandmothers, which suggests that the grandmothers were sisters or cousins. Who marries whom and who feeds whom - an important point in such food-gathering societies - I do not know, but it was clear that much remarriage took place after widowhood and divorce. Continence in the young was not deemed a virtue. Most deaths were caused either by drowning or by violence.

Of more immediate importance than these meager notes is the fact that the survival of the Alakaluf without mixture depends largely on the future of three young women. One of these was pregnant by a Chilean during our sojourn, while another, Theresa, had left her husband and showed no inclination for further marriage or great hope of reproduction.

Much more serious is the fact that Alakaluf culture - which cannot be studied in a few short weeks - will soon become extinct. To all intents and purposes, the fine details of this Fuegian culture will die with Alessandri and Margarita Canales one of whom has tuberculosis and the other one eye.

/Natural History, January 1, 1961, p. 56-68.

THE PLANT AS A MACHINE INCESSANTLY AT WORK

Chapter VIII

Feeding

In the chapter on evolution it is suggested that animals and plants have a common ancestor. It is only to be expected, therefore, that even to-day there should be certain resemblances between them. Except in the case of some few very simple organisms, all external resemblance is definitely lost, but the members of the two kingdoms still agree in so far as they carry out the same functions in the business of living - they feed, breathe, grow, respond to stimuli, and multiply on the face of the earth.

The actual way in which plants feed, however, is fundamentally different from the feeding process of animals. Plants, with some exceptions, build up their own food, using, in the manufacturing process, water, mineral salts, and carbon dioxide. They absorb the salts in solution from the soil or from the water of their habitat. They take carbon dioxide from the atmosphere, or from air dissolved in the water in which they live. Animals have no power of manufacturing food and are entirely dependent upon plants for their supplies. If, therefore, the "green things of the earth" died out, all life in the world would automatically end.

In this physiological difference lies the explanation of the fact that, generally speaking, plants are fixed in their habitat, whereas animals roam in search of food.

The ability of plants to obtain mineral salts depends upon osmosis. This is a process in which two liquids of different density, separated by a permeable membrane, have a mutual attraction for one another, the stronger exerting the more powerful pull.

If a thistle-funnel is handy, the attraction of a sugar solution for water can be readily demonstrated. A piece of pig's bladder or parchment must be tied tightly over the open end of the bulb of the funnel. The sugar solution is then poured down the tube until the bulb is full. In doing this the tube should be held in a slanting position, so that air may escape along the upper half of the tube as the syrup flows down the lower side.

The thistle-funnel is fixed so that its bulb is suspended in water in a glass. In a short time liquid rises up the stem. Obviously water has passed in through the membrane, having been attracted by the dense solution in the bulb. After a time the water in the glass tastes slightly sweet, because some of the sugar solution has passed outwards. The experiment can be varied by using other solutions - of salt or copper sulphate, for instance - and by reversing the liquids, so that water is in the thistle-funnel and the denser liquid in the glass.

In this experiment osmotic action is evident in non-living apparatus, and therefore no proof is given that it takes place in living cells. This may be demonstrated by using a large potato instead of a thistle-funnel. With the exception of the outside skin, a potato is entirely made up of living cells.

Two potatoes are used in the experiment, for one acts as a control. A small slice is cut off the end of each so that it stands on a flat base. As liquids cannot penetrate the corky skin, a narrow ring of this is peeled away at the base. Down the middle of each potato a pit is bored, stopping short within half an inch of the base. The potatoes are now put into a dish containing water to the depth of one inch.

The pit of one potato is left empty, and this is the control which serves for comparison. Into the other is put a little sugar, which dissolves in the moisture that escapes from the cut cells, forming a sugar solution

at the bottom of the pit. There is a rise in the level of the liquid here, as in the glass tube of the thistle-funnel. The solution first attracts water from the cells lining the pit; because of the loss of water, the sap in these particular cells becomes stronger, so that it, in its turn, attracts water from neighbouring cells farther away the pit; the sap of these cells therefore becomes stronger and exerts attraction; in this way a movement of water is started which ultimately affects the cells on the outside of the potato so that they, in their turn, attract water from the dish in which the potato stands. In quite a short time so much water rises in the pit that it overflows and trickles down the outside of the potato. In the control experiment there has been no such rise, and the pit is quite dry.

In the higher plants it is through the very delicate root-hairs that solutions are absorbed from the soil. The osmotic solutions are the cell-sap of the root-hair and the soil-water in which soluble salts from the soil are dissolved. The mineral solution is weaker than the cell-sap; if this were not the case, root-absorption by osmosis could not take place. The solutions are separated from one another by the cell wall, within which is a delicate protoplasmic lining which is semi-permeable - that is, it allows water to pass freely through it, but is not permeable to all the substances dissolved in the water.

The action of osmosis is difficult to understand. In the root-hair it is a vital process, regulated by the living membrane of protoplasm.

Because of this control by the protoplasmic membrane, root-hairs exercise a certain selective power in their work, with the result that some plants do not take in certain solutions that are freely absorbed by others. It is because of this selective power of roots that rotation of crops is the rule in agriculture. Hundreds of years

before there was any science of botany, tillers of the soil avoided growing the same crop on the same land in successive years.

It is, then, as a result of osmosis, controlled by living protoplasm, that plants obtain from the soil one class of raw materials for the manufacture of food. From the air leaves take in carbon dioxide, which is necessary for the manufacture of carbo-hydrates within the leaf. The essential conditions for this work are the presence of sunlight and of the green colouring matter, or chlorophyll, in the leaves. Certain chemical reactions take place within the leaves which result in oxygen(O_2), set free from the absorbed carbon dioxide (CO_2), being returned to the air, while the carbon (C) is kept in the leaf and unites with the elements of water (H_2O) to form sugar ($C_6H_{12}O_6$) and ultimately starch ($C_6H_{10}O_5$). That oxygen is evolved during this process can be proved by collecting and testing the bubbles of gas that are given off by a water plant, such as Canadian pondweed, when it is put in a good light. There is a simple arrangement for trapping the gas. The pondweed is contained in a funnel, immersed in water in a glass vessel. A testtube full of water is inverted over the stem of the funnel. Oxygen given off from the green leaves rises in the stem of the funnel, and displaces the water. When sufficient gas has been collected it can be tested by putting the glowing end of a splint into the test-tube. The splint then bursts into flame, thus proving that the collected gas is oxygen.

A simple experiment proves the presence of starch in green leaves; those of the lime alway give good results. Two or three leaves must be picked on a sunny afternoon and kept in methylated spirits for a day or two. The green colouring matter dissolves in the alcohol, and the leaves become white. If they are dipped in iodine they turn dark blue or brownish-black. This is a proof that starch is present, for it its only a starch that iodine has this effect.

The prove that light is necessary for the manufacture of starch, two or three leaves on the tree can have black paper pinned over them, so that both sides are covered. After a few days, if they are decolorized and tested with iodine, there will be no starch reaction except at the pin-holes where a little light has penetrated.

It is equally simple to prove that chlorophyll is essential, because on testing it is found that no starch is present in a white leaf of Ivy or Geranium and that it only occurs in the green patches of the variegated leaves of Japanese Maple.

Even in strong sunlight starch is not formed in green leaves if carbon dioxide is not present. This is proved by keeping a potted plant (a fuchsia, for example) in the dark for a few days, so that its leaves are free from starch. It is then placed under a large bell-jar which contains a dish of caustic potash. A tube that passes through the cork of the bell-jar is connected to a -tube which contains soda-lime. All air that enters the bell-jar thus passes through the soda-lime, which absorbs the carbon dioxide; the carbon dioxide already within the bell-jar is absorbed by the caustic potash, thus no carbon dioxide reaches the leaves of the plant. Under these conditions no starch is formed in the leaves even when the bell-jar is in full sunlight.

This particular manufacturing process of the green plant is sometimes called photosynthesis, because it depends on light (Greek, photos, light), and sometimes carbon assimilation, because carbon is the foundation of the manufactured substances.

In carbon assimilation, as in respiration, there is an interchange of oxygen and carbon dioxide; but the two processes are quite independent and must not be confused.

Respiration is an unceasing process which goes on every moment of the day and night. In it oxygen is taken in and carbon dioxide is given out. It is a destructive

progress of slow combustion in which energy is set free.

Carbon assimilation is a constructive process, in which the building up of food provides stores of potential. Unlike respiration it is intermittent, for it takes place only in the light. In this process carbon dioxide is taken in and oxygen is given out; in the day-time, therefore, green plants are lessening the carbon dioxide content of the air and increasing its oxygen content, because in the feeding process there is a greater exchange of gases than in respiration. As daylight fades carbon assimilation ceases and only respiration is active; the plants are then taking oxygen from and returning carbon dioxide to the outside world. It is for this reason that, in hospital wards, cut flowers and plants are removed before night falls.

In order that water in a kettle may boil, heat must be applied to it, and this is the force, or energy, that raises the temperature of the water to boiling point. The force upon which photosynthesis depends is light. When the ordinary white light of the sun passes through a glass paper-weight or a prism, it is split up into its several components - red, orange, yellow, green, blue, indigo, violet. A similar separation takes place, and a rainbow results, when the sun's rays pass through moisture suspended in the air.

Chlorophyll also causes the rays of light to separate, but whereas all the rays pass through a glass prism, some of them, the red rays in particular, are trapped and retained when light passes through chlorophyll. The radiant energy of such trapped sunlight is the force responsible for the building up of starch in green leaves, from the simple inorganic compounds of carbon dioxide and water. Today, in the burning of coal, the sunlight thus trapped millions of years ago is set free. The lightabsorbing property of chlorophyll explains why the continuation of all life on our planet is dependent upon the green plant.

It is obvious that an unlimited supply of starch can-

not remain in the leaves; it is reconverted into sugar and is transported to various parts of the plant. That which is not immediately needed is stored for future use - as in seeds, for instance, in readiness for their germination; in the potato, in readiness for its sprouting; near the bases of resting-buds, that they may have a ready supply of food when they open in the spring of the following year. As a rule when sugar reaches the various storage organs it is reconverted into starch, which is insoluble. Sometimes, however, the reserve, or some part of it, is actually stored as sugar, as in the case of the Garden Pea, Beetroot, and the Sugar-cane.

The formation of carbohydrates is the basic process in the green plant's manufacture of foods. Fats are not produced as a direct result of photosynthesis, but are formed from carbohydrates; they contain the same elements as the latter, but in different proportions. Proteins contain nitrogen and sulphur in addition to carbon, hydrogen, and oxygen; sometimes they contain phosphorus and other elements. All these additional elements are obtained from the soluble salts which the roots of a plant absorb with the soil-water. The energy needed for the building up of proteins is not obtained directly from the sun, as in photosynthesis, but from the breaking down of substances, chiefly carbohydrates, already formed.

As plants absorb their food-forming materials in a liquid or gaseous state, an elaborate digestive system like that of most animals is not required. Further, as a plant does not take in a great deal more than it uses, there is little waste, except in the case of water which is given off in transpiration. Other waste is got rid of in herbaceous plants when all the parts of the plant that are above ground die down at the end of its season. Most British shrubs and trees shed their leaves in autumn; those substances that are the by-products of the plant's metabolism, and that are no longer needed, are disposed of by being passed into the

leaves before they fall.

Teach Yourself

/M.E. Phillips, L.E. Cox, Biology, 1959,
p. 69-77/

ENZYMES

The study of enzymes is a subject which has a special interest, because it lies just on the borderline where the biological and the physical sciences meet. On the one hand, enzymes are of supreme importance in biology. Life depends on a complex network of chemical reactions brought about by specific enzymes, and any modification of the enzyme pattern may have far-reaching consequences for the living organism. On the other hand, enzymes, as catalysts, are receiving increasing attention from physical chemists. The mechanism of action of enzymes is in itself one of the most fascinating fields of scientific investigation being pursued at the present time.

Enzymology has become a large and rapidly developing subject, with ramifications in many directions and close connections with many sciences, especially biochemistry, physical chemistry, bacteriology and microbiology, genetics, botany and agriculture, pharmacology and toxicology, physiology, medicine and chemical engineering. It has in addition important practical applications to activities as diverse as brewing and industrial fermentation, pest control and chemical warfare.

Many research workers in various parts of the world

are now devoting their attention to such problems, institutes have been established specifically for enzymes studies, several journals of enzymology exist and the literature of the subject has now become very large.

/Сборник текстов на английском языке
БИОЛОГИЯ, Москва, 1964, p. 5/

COMPARATIVE ENZYME BIOCHEMISTRY

Although a great deal has been written about comparative biochemistry, little or no attempt has been made to develop comparative enzyme biochemistry as a separate subject. Yet many of the differences between one species and another, as well as the differences between the various tissues of a given organism, no doubt rest on enzymic differences, and this seems to us to be a subject which is capable of great and fruitful development.

We use the term "comparative enzyme biochemistry" to include two distinct fields of study, namely, on the one hand the comparison of the enzyme equipment of different organs and species, and on the other hand the comparison of pure preparations of a given enzyme obtained from different sources.

Comparison of Tissues

A comparison of variety of cells of widely different types shows remarkable similarities in the pattern of enzyme they contain. The same basic metabolic pattern seems

to be used throughout living organism; and differences in metabolic end-products result from the addition or deletion of an enzyme here and there rather than from a change in the whole pattern. The complicated systems of enzymes, coenzymes and carriers involve in carbohydrate metabolism, form with only minor modifications the main energy-producing mechanism in animals, plants, moulds, yeast and most other micro-organisms.

There are, however, undoubted differences in metabolism, chemical composition and structure between different tissues and different organisms. The differences in metabolism clearly reflect differences in the complement of enzymes present; the differences in chemical composition are also the result of differences in the enzyme present, especially of the biosynthetic enzymes. It is by no means improbable that the more obvious differences of structure and form may also be referred to differences in enzymic make-up. Structure and form are known to be controlled by genes, and genes control the production of enzymes, so that unless genes act in two quite different ways it seems likely that structural differences may be mediated through a control of the enzymes present. The form of organs, largely influenced by neighbouring tissues, is no doubt controlled by morphogenetic substances or "evocators", but these are themselves to be very largely under genic control.

The greatest enzyme differences between organism are probably to be found by comparing animals, plants and bacteria. Metabolically, animals show a fairly standard pattern, but plants and moulds and to some extent bacteria, produce in addition a vast array of specialized metabolic products, for example, the various pigments, alkaloids and other heterocyclic compounds.

The extraordinary variety of complex ring compounds produced by moulds has been particularly studied by Raistrick (1930). Many of these compounds are restricted to one or two species. Little is known of the enzymes in-

volved in their synthesis. As the enzyme steps become identified, a comparative study may help to relate these special end-products to the physiology of the cells concerned.

/Сборник текстов на английском языке БИОЛОГИЯ,
Москва, 1964, p. 28-29/

BIOCHEMISTRY OF THE CELL

The generalized plant cell is made up of a thin layer of protoplasm which surrounds the large vacuole and which is in turn surrounded by the characteristic cell wall. From the point of view of cell volume, the vacuole is all important. Viewed physiologically the vacuole is also doubtless of great significance, particularly as to its osmotic role in the water relations of plant. From the standpoint of dry weight, however, the vacuole is relatively insignificant since its contents are made up so largely of water. Metabolically also the vacuole is not of great interest since few if any important metabolic processes take place within the portion of the cell. The wall of the plant cell ordinarily makes up a much smaller portion of the total volume than the vacuole, although in certain cases very massive secondary walls may occupy the bulk of the cell lumen. Even in the generalized cell, however, the cell wall tends to make up a quarter to a half or more of the total dry weight, and is then the largest single item in the over-all cellular constitution. The remaining dry matter of the cell is shared among the components which go to make up the cytoplasm and its inclusions, the nucleus, starch grains, fat droplets, the various granules and particularly in the case of the cells of green leaves, the chloroplasts. What now

can we say about the chemical compositions and the metabolic functions of these different portions of the plant cell?

The cell wall consists primarily of polysaccharides and polysaccharide derivatives, and, although there are a few special cases in which the cell wall is made up largely of a single polysaccharide, still in the more usual case several distinct and different compounds are intimately intermingled in its structure. Pores in this structure permit the ready exchange of smaller molecules, and it is undoubtedly the protoplasmic membrane rather than the cell wall which constitutes the semipermeable barrier in the cell wall. Cell wall constituents are evidently formed by processes which take place in the protoplasm, although we have but little evidence on this point. In any case the cell wall once laid down is relatively inert and its constituents ordinarily re-enter the metabolism of the plant sluggishly if at all. The cell wall is, however, subject to at least two striking and important transformations, related respectively to cell elongation and to fruit ripening. In both of these cases as in cell wall growth itself, the secondary transformations of the wall constituents are undoubtedly mediated by metabolic processes carried out within protoplasm of the cell.

The non-aqueous constituents of the vacuole appear to consist principally of substances of low molecular weight including water soluble pigments and possibly other glycosides, in addition to inorganic ions, sugars and organic acids. Proteins, if they occur in the vacuole at all, are present only in small amounts, and enzymes have been located with certainty in the vacuole only in latex vessels, where vacuolar and protoplasmic contents are inextricably mixed.

The full complexity of the plant cell is achieved only in the protoplasm, of which proteins are the principal and characteristic components. Of the protoplasmic protein, which may constitute a fourth to one-half of the

total dry weight of a typical leaf cell, approximately one half goes to make up the soluble cytoplasmic fraction while the remainder half is contained in various particulate inclusions, the nucleus, chloroplasts, and other granules. Many different and chemically individual proteins are undoubtedly concerned in the composition of these different cellular components and further cytochemical differentiation between the various cellular structures is found in the distribution of still other materials. Thus chlorophyll and the carotenoid pigments are restricted in higher plants to the plastid, desoxyribonucleic acid to the nucleus and ribonucleic acid largely to the cytoplasm. This cytochemical differentiation is associated with important biochemical differentiation in metabolic function. Thus we know that the synthesis of certain proteins, the desoxyribonucleoproteins, occurs in the nucleus, and there are indications that the nucleus may also directly synthesize other proteins which are then liberated into the cytoplasm. It is probable also that the synthesis and degradation of the starch grains and of the fat droplets, which occur as particulate inclusions in the cytoplasm, are reactions which take place in or on the surface of these particles. It is the chloroplast, however, which most clearly carries on chemical processes quite different in kind from those of the cytoplasm in which the chloroplast is imbedded. Thus the typical reaction of photosynthesis, the light-induced splitting of water, is a process confined in the higher plant to chloroplasts. The terminal stages of chlorophyll synthesis, as well as the synthesis of the associated carotenoid pigments, appear also to occur only within the chloroplast structure. Recent work indicates that much of the active respiratory system of the plant cell may be included in the particulate structure. What then is left to cytoplasm proper by way of biochemical function? What synthetic and what degradative reactions are typically cytoplasmic processes? We cannot yet answer this with certain-

ty, although it seems probable that there are biochemical reactions which are cytoplasmic in occurrence, and which may include among other processes the formation and transformation of simple carbohydrates and the synthesis of particular amino-acids.

Сборник текстов на английском языке, Биология, Москва,
1964, стр. 33-34

INFORMATION TRANSFER AND THE NUCLEIC ACIDS

It is generally believed that DNA alone functions as the carrier of genetic information. This understanding is based upon the classic experiments of Avery, who discovered bacterial transformation that is the ability of purified DNA from one bacterial species to alter the metabolic characteristics of another bacterial species in an inheritable manner. This interpretation of DNA function was further strengthened by the demonstration by Hershey and Chase that DNA alone is the infective component and hence the carrier of genetic information in the bacterial viruses.

All cells of a given organism have the same DNA content. The only exception to this statement is to be found in spermatozoa and ova, where the DNA content is one-half of the normal amount.

Further, if one analyses the chemical composition of the DNA in all tissues of a given animal, it is found to be the same. Thus, it is believed that all cells contain the same set of DNA molecules. The DNA is located in the chromosomal material of the nucleus, and during cell division the DNA is replicated in some manner, so that an

equal amount is found in the two daughter cells and with the same chemical composition as that found in the parental cell. One of the goals of molecular structural work in the nucleic acid is to discover the fundamental interpretation for these phenomena.

Although the amount of DNA is the same in each cell of a given organism, the amount varies from species to species. In general, the more complex species have more DNA. A bacterial cell has the order of 10^8 nucleotides in its DNA, which would make a molecular strand about 2 cm in length. In mammalian species there are the order of 10^{10} nucleotides which correspond to a total molecular length of 1 to 2 m/cell. Thus, the actual length of the primary coding material in a living cell is in the range of macroscopic dimensions and is much longer than the metabolic machine (or cell) which it directs.

Сборник текстов на английском языке, Биология, Москва,
1964, СТР.14

PURE MUTANT CLONES INDUCED BY ULTRAVIOLET
LIGHT IN THE GREEN ALGA, CHLAMYDOMONAS
REINHARDS

Auxotrophic mutants have been obtained in Chlamydomonas Reinhardt by irradiating vegetative cells in liquid medium and plating them on complete agar medium or else plating the cells to be treated on complete agar medium and then irradiating them. After the irradiated cells have formed distinct colonies they are replica-plated to minimal medium and to complete medium. The colonies which are unable to grow on minimal medium but which do grow on complete

medium, are presumed to be auxotrophs and are then tested for their biochemical requirement. Eversole has varied this method by allowing the irradiated cells to undergo two divisions in liquid complete medium prior to plating them on complete agar medium for growth and replica-plating. The difference between the method used by Eversole, which allows cellular division prior to the plating of irradiated cells, and the first method, which does not, is important for the following reason. If cells are plated to an agar medium immediately following irradiation, two classes of mutants might be expected.

The first class would consist of cells which only give rise to mutant progeny and thus to a pure clone of mutant cells. The second class of mutants would be composed of cells which give rise to colonies containing both prototrophic and auxotrophic progeny. Mixed clones of this type would not be evident on replica-plating to minimal medium since the prototrophic cells in the clone would overgrow the auxotrophic cells and the clone would appear to be wild-type. Such clones would be detected only if they were broken up into their component cells at some time prior to replica-plating and if the clones resulting from these progeny cells were those replica-plated to minimal medium.

In order to determine whether or not mutants of the second class were induced, cells were irradiated and plated immediately following irradiation. After several cell divisions had taken place, the colonies on a portion of the plates were broken up while on the remaining plates they were left undisturbed. On replica-plating the resulting colonies in the two series of plates, one of two results was to be expected. First, if mutants occurred only as pure clones then the ratio of plates bearing mutants to plates lacking mutants would be the same in both "spread" and "unspread" series. Second, if mutants occurred in mixed clones as well as in pure clones, the ratio of plates bearing mutants to plates lacking mutants would not be the same in the

two series. A larger proportion of the plates in the spread series would have mutant colonies. The possibility that mutants occurred only in mixed clones is eliminated, because the first method described in this communication has been used with success in obtaining auxotrophic mutants.

Сборник текстов на английском языке, Биология, Москва,
1964: стр. 62-63

CAUSES OF VARIABILITY

Ch. Darwin

When we compare the individuals of the same variety or subvariety of our older cultivated plants and animals, one of the first points which strikes us is, that they generally differ more from each other than do the individuals of any one species or variety in a state of nature. And if we reflect on the vast diversity of the plants and animals which have been cultivated, and which have varied during all ages under the most different climates and treatment, we are driven to conclude that this great variability is due to our domestic productions having been raised under conditions of life not so uniform as, and somewhat different from, those to which the parent species had been exposed under nature. There is, also, some probability in the view propounded by Andrew Knight, that this variability may be partly connected with excess of food. It seems clear that organic beings must be exposed during several generations to new conditions to cause any great amount of variation; and that, when the organisation has once begun to vary, it generally continues varying for many generations. No case is on record of a variable organism ceasing to vary under

cultivation. Our oldest cultivated plants, such as wheat, still yield new varieties: our oldest domesticated animals are still capable of rapid improvement or modification.

As far as I am able to judge, after long attending to the subject, the conditions of life appear to act in two ways, - directly on the whole organisation or on certain parts alone, and indirectly by affecting the reproductive system. With respect to the direct action, we must bear in mind that in every case, as Professor Weismann has lately insisted, and as I have incidentally shown in my work on "Variation under Domestication", there are two factors: namely, the nature of the organism, and the nature of the conditions. The former seems to be much the more important; for nearly similar variations sometimes arise under, as far as we can judge, dissimilar conditions; and, on the other hand, dissimilar variations arise under conditions which appear to be nearly uniform. The effects on the offspring are either definite or indefinite. They may be considered as definite when all or nearly all the offspring of individuals exposed to certain conditions during several generations are modified in the same manner. It is extremely difficult to come to any conclusion in regard to the extent of the changes which have been thus definitely induced. There can, however, be little doubt about many slight changes, - such as size from the amount of food, colour from the nature of the food, thickness of the skin and hair from climate, etc. Each of the endless variations which we see in the plumage of our fowls must have had some efficient cause; and if the same cause were to act uniformly during a long series of generations on many individuals, all probably would be modified in the same manner. Such facts as the complex and extraordinary outgrowths which variably follow from the insertion of a minute drop of poison by a gall-producing insect, show us what singular modifications might result in the case of plants from a chemical change in the nature of the sap.

Indefinite variability is a much more common result of changed conditions than definite variability, and has probably played a more important part in the formation of our domestic races. We see indefinite variability in the endless slight peculiarities which distinguish the individuals of the same species, and which cannot be accounted for by inheritance from either parent or from some more remote ancestor. Even strongly marked differences occasionally appear in the young of the same litter, and in seedlings from the same seed-capsule. At long intervals of time, out of millions of individuals reared in the same country and fed on nearly the same food, deviations of structure so strongly pronounced as to deserve to be called monstrosities arise; but monstrosities cannot be separated by any distinct line from slighter variations. All such changes of structure, whether extremely slight or strongly marked, which appear amongst many individuals living together, may be considered as the indefinite effects of the conditions of life on each individual organism, in nearly the same manner as the chill affects different men in an indefinite manner, according to their state of body or constitution, causing coughs or colds, rheumatism, or inflammation of various organs.

With respect to what I have called the indirect action of changed conditions, namely, through the reproductive system of being affected, we may infer that variability is thus induced, partly from the fact of this system being extremely sensitive to any change in the conditions, and partly from the similarity, as Kölreuter and others have remarked, between the variability which follows from the crossing of distinct species, and that which may be observed with plants and animals when reared under new or unnatural conditions. Many facts clearly show how eminently susceptible the reproductive system is to very slight changes in the surrounding conditions. Nothing is more easy than to tame an animal, and few things more difficult

than to get it to breed freely under confinement, even when the male and female unite. How many animals there are which will not breed, though kept in an almost free state in their native country! This is generally, but erroneously, attributed to vitiated instincts. Many cultivated plants display the utmost vigour, and yet rarely or never seed! In some few cases it has been discovered that a very trifling change, such as a little more or less water at some particular period of growth, will determine whether or not a plant will produce seeds. I cannot here give the details which I have collected and elsewhere published on this curious subject; but to show how singular the laws are which determine the reproduction of animals under confinement, I may mention that carnivorous animals, even from the tropics, breed in this country pretty freely under confinement, with the exception of the plantigrades or bear family, which seldom produce young; whereas carnivorous birds, with the rarest exceptions, hardly ever lay fertile eggs. Many exotic plants have pollen utterly worthless, in the same condition as in the most sterile hybrids. When, on the one hand, we see domesticated animals and plants, though often weak and sickly, breeding freely under confinement; and when, on the other hand, we see individuals, though taken young from a state of nature perfectly tamed, longlived and healthy (of which I could give numerous instances), yet having their reproductive system so seriously affected by unperceived causes as to fail to act, we need not be surprised at this system, when it does act under confinement, acting irregularly, and producing offspring somewhat unlike their parents. I may add, that as some organisms breed freely under the most unnatural conditions (for instance, rabbits and ferrets kept in hutches), showing that their reproductive organs are not easily affected; so will some animals and plants withstand domestication or cultivation, and vary very slightly - perhaps hardly more than in a state of nature.

Some naturalists have maintained that all variations are connected with the act of sexual reproduction; but this is certainly an error; for I have given in another work, a long list of "sporting plants", as they are called by gardeners; - that is, of plants which have suddenly produced a single bud with a new and sometimes widely different character from that of the other buds on the same plant. These bud variations, as they may be named, can be propagated by grafts, offsets, etc., and sometimes by seed. They occur rarely under nature, but are far from rare under culture. As a single bud out of the many thousands, produced year after year on the same tree under uniform conditions, has been known suddenly to assume a new character; and as buds on distinct trees, growing under different conditions, have sometimes yielded nearly the same variety - for instance, buds on peach-trees producing nectarines, and buds on common roses producing moss-roses - we clearly see that the nature of the conditions is of subordinate importance in comparison with the nature of the organism in determining each particular form of variation; - perhaps of not more importance than the nature of the spark, by which a mass of combustible matter is ignited, has in determining the nature of the flames.

/Ch. Darwin, The Origin of Species. Chicago,
1963, p. 31-34/

COMPLEX RELATIONS OF ALL ANIMALS AND PLANTS TO
EACH OTHER IN THE STRUGGLE FOR EXISTENCE

Ch. Darwin

Many cases are on record showing how complex and unexpected are the checks and relations between organic beings which have to struggle together in the same country. I will give only a single instance, which, though a simple one, interested me. In Staffordshire, on the estate of a relation, where I had ample means of investigation, there was a large and extremely barren heath, which had never been touched by the hand of man; but several hundred acres of exactly the same nature had been enclosed twenty-five years previously and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable, more than is generally seen in passing from one quite different soil to another: not only the proportional numbers of the heath-plants were wholly changed, but twelve species of plants (not counting grasses and carices) flourished in the plantations, which could not be found on the heath. The effect on the insects must have been still greater, for six insectivorous birds were very common in the plantations, which were not to be seen on the heath; and the heath was frequented by two or three distinct insectivorous birds. Here we see how potent has been the effect of the introduction of a single tree, nothing whatever else having been done, with the exception of the land having been enclosed, so that cattle could not enter. But how important an element enclosure is, I plainly saw near Farnham, in Surrey. Here there are extensive heaths, with a few clumps of old Scotch firs on the distant hilltops: within the last ten years large spaces have been enclosed, and self-sown firs are now springing up in multitudes, so close together that all cannot live. When I ascertained

that these young trees had not been sown or planted, I was so much surprised at their numbers that I went to several points of view, whence I could examine hundreds of acres of the unenclosed heath, and literally I could not see a single Scotch fir, except the old planted clumps. But on looking closely between the stems of the heath, I found a multitude of seedlings and little trees which had been perpetually browsed down by the cattle. In one square yard, at a point some hundred yards distant from one of the old clumps, I counted thirty-two little trees; and one of them, with twenty-six rings of growth, had during many years tried to rise its head above the stems of the heath, and had failed. No wonder that, as soon as the land was enclosed, it became thickly clothed with vigorously growing young firs. Yet the heath was so extremely barren and so extensive that no one would ever have imagined that cattle would have so closely and effectually searched it for food.

Here we see that cattle absolutely determine the existence of the Scotch fir; but in several parts of the world insects determine the existence of cattle. Perhaps Paraguay offers the most curious instance of this; for here neither cattle nor horses nor dogs have ever run wild, though they swarm southward and northward in a feral state; and Azara and Rengger have shown that this is caused by the greater number in Paraguay of a certain fly, which lays its eggs in the navels of these animals when first born. The increase of these flies, numerous as they are, must be habitually checked by some means, probably by other parasitic insects. Hence, if certain insectivorous birds were to decrease in Paraguay, the parasitic insects would probably increase; and this would lessen the number of the navel-frequenting flies - then cattle and horses would become feral, and this would certainly greatly alter (as indeed I have observed in parts of South America) the vegetation: this again would largely affect the insects; and this, as we have just seen in Staffordshire, the insectivorous birds

and so onwards in ever-increasing circles of complexity. Not that under nature the relations will ever be as simple as this. Battle within battle must be continually recurring with varying success; and yet in the long run the forces are so nicely balanced, that the face of nature remains for long periods of time uniform, though assuredly the merest trifle would give the victory to one organic being over another. Nevertheless, so profound is our ignorance, and so high our presumption, that we marvel when we hear of the extinction of an organic being; and as we do not see the cause, we invoke cataclysms to desolate the world, or invent laws on the duration of the forms of life!

I am tempted to give one more instance showing how plants and animals remote in the scale of nature, are bound together by a web of complex relations. I shall hereafter have occasion to show that the exotic *Lobelia fulgens* is never visited in my garden by insects, and consequently, from its peculiar structure, never sets a seed. Nearly all our orchidaceous plants absolutely require the visits of insects to remove their pollenmasses and thus to fertilise them. I find from experiments that humble-bees are almost indispensable to the fertilisation of the heartsease (*Viola tricolor*), for other bees do not visit this flower. I have also found that the visits of bees are necessary for the fertilisation of some kinds of clover; for instance, 20 heads of Dutch clover (*Trifolium repens*) yielded 2,290 seeds, but 20 other heads protected from bees produced not one. Again, 100 heads of red clover (*T. pratense*) produced 2,700 seeds, but the same number of protected heads produced not a single seed. Humble-bees alone visit red clover, as other bees cannot reach the nectar. It has been suggested that moths may fertilise the clovers; but I doubt whether they could do so in the case of the red clover, from their weight not being sufficient to depress the wing petals. Hence we may infer as

highly probable that, if the whole genus of humble-bees became extinct or very rare in England, the heartsease and red clover would become very rare, or wholly disappear. The number of humble-bees in any district depends in a great measure upon the number of field-mice, which destroy their combs and nests; and Col. Newman, who has long attended to the habits of humble-bees, believes that "more than two-thirds of them are thus destroyed all over England". Now the number of mice is largely dependent, as every one knows, on the number of cats; and Col. Newman says, "Near villages and small towns I have found the nests of humble-bees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice". Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district!

In the case of every species, many different checks, acting at different periods of life, and during different seasons or years, probably come into play; some one check or some few being generally the most potent; but all will concur in determining the average number or even the existence of the species. In some cases it can be shown that widely-different checks act on the same species in different districts. When we look at the plants and bushes clothing an entangled bank, we are tempted to attribute their proportional numbers and kinds to what we call chance. But how false a view is this! Every one has heard that when an American forest is cut down a very different vegetation springs up; but it has been observed that ancient Indian ruins in the Southern United States, which must formerly have been cleared of trees, now display the same beautiful diversity and proportion of kinds as in the surrounding virgin forest. What a struggle must have gone on during long centuries between the several kinds of trees each annually scattering its seeds by the thousand; what

war between insect and insect - between insects, snails, and other animals with birds and beasts of prey - all striving to increase, all feeding on each other, or on the trees, their seeds and seedlings, or on the other plants which first clothed the ground and thus checked the growth of the trees! Throw up a handful of feathers, and all fall to the ground according to definite laws; but how simple is the problem where each shall fall compared to that of the action and reaction of the innumerable plants and animals which have determined, in the course of centuries, the proportional numbers and kinds of trees now growing on the old Indian ruins!

The dependency of one organic being on another, as of a parasite on its prey, lies generally between beings remote in the scale of nature. This is likewise sometimes the case with those which may be strictly said to struggle with each other for existence, as in the case of locusts and grass-feeding quadrupeds. But the struggle will almost invariably be most severe between the individuals of the same species, for they frequent the same districts, require the same food, and are exposed to the same dangers. In the case of varieties of the same species, the struggle will generally be almost equally severe, and we sometimes see the contest soon decided: for instance, if several varieties of wheat be sown together, and the mixed seed be resown, some of the varieties which best suit the soil or climate, or are naturally the most fertile, will beat the others and so yield more seed, and will consequently in a few years supplant the other varieties. To keep up a mixed stock of even such extremely close varieties as the variously-coloured sweet peas, they must be each year harvested separately, and the seed then mixed in due proportions otherwise the weaker kinds will steadily decrease in number and disappear. So again with the varieties of sheep; it has been asserted that certain mountain-varieties will starve out other mountain-varieties, so that they can-

not be kept together. The same result has followed from keeping together different varieties of the medicinal leech. It may even be doubted whether the varieties of any of our domestic plants or animals have so exactly the same strength, habits, and constitution, that the original proportions of a mixed stock (crossing being prevented) could be kept up for half-a-dozen generations, if they were allowed to struggle together, in the same manner as beings in a state of nature, and if the seed or young were not annually preserved in due proportion.

/The Origin of Species. Chicago, p. 80-84/

NATURAL SELECTION; OR THE SURVIVAL OF THE FITTEST

Ch. Darwin

How will the struggle for existence, briefly discussed in the last chapter, act in regard to variation? Can the principle of selection, which we have seen is so potent in the hands of man, apply under nature? I think we shall see that it can act most efficiently. Let the endless number of slight variations and individual differences occurring in our domestic productions, and, in a lesser degree, in those under nature, be borne in mind; as well as the strength of the hereditary tendency. Under domestication, it may be truly said that the whole organisation becomes in some degree plastic. But the variability, which we almost universally meet with in our domestic productions, is not directly produced, as Hooker and Asa Gray have well remarked, by man: he can neither originate varieties, nor

prevent their occurrence; he can preserve and accumulate such as do occur. Unintentionally he exposes organic beings to new and changing conditions of life, and variability ensues; but similar changes of conditions might and do occur under nature. Let it also be borne in mind how infinitely complex and close-fitting are the mutual relations of all organic beings to each other and to their physical conditions of life; and consequently what infinitely varied diversities of structure might be of use to each being under changing conditions of life. Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occurred that other variations useful in some way to each being in the great and complex battle of life, should occur in the course of many successive generations. If such do occur, can we doubt (remembering that many more individuals are born than can possibly survive) that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favourable individual differences and variations, and the destruction of those which are injurious, I have called Natural Selection, or the Survival of the Fittest. Variations neither useful nor injurious would not be affected by natural selection, and would be left either a fluctuating element, as perhaps we see in certain polymorphic species, or would ultimately become fixed, owing to the nature of the organism and the nature of the conditions.

Several writers have misapprehended or objected to the term Natural Selection. Some have even imagined that natural selection induces variability, whereas it implies only the preservation of such variations as arise and are beneficial to the being under its conditions of life. No one objects to agriculturists speaking of the potent effects of man's selection; and in this case the individual differences

given by nature, which man for some object selects, must of necessity first occur. Others have objected that the term selection implies conscious choice in the animals which become modified; and it had even been urged that, as plants have no volition, natural selection is not applicable to them! In the literal sense of the word, no doubt, natural selection is a false term; but who ever objected to chemists speaking of the elective affinities of the various elements? - and yet an acid cannot strictly be said to elect the base with which it in preference combines. It has been said that I speak of natural selection as an active power or Deity; but who objects to an author speaking of the attraction of gravity as ruling the movements of the planets? Every one knows what is meant and is implied by such metaphorical expressions; and they are almost necessary for brevity. So again it is difficult to avoid personifying the word Nature; but I mean by Nature, only the aggregate action and product of many natural laws, and by laws the sequence of events as ascertained by us. With a little familiarity such superficial objections will be forgotten.

We shall best understand the probable course of natural selection by taking the case of a country undergoing some slight physical change, for instance, of climate. The proportional numbers of its inhabitants will almost immediately undergo a change, and some species will probably become extinct. We may conclude, from what we have seen of the intimate and complex manner in which the inhabitants of each country are bound together, that any change in the numerical proportions of the inhabitants, independently of the change of climate itself, would seriously affect the others. If the country were open on its borders, new forms would certainly immigrate, and this would likewise seriously disturb the relations of some of the former inhabitants. Let it be remembered how powerful the influence of a single introduced tree or mammal has been shown to be. But in the

case of an island, or of a country partly surrounded by barriers, into which new and better adapted forms could not freely enter, we should then have places in the economy of nature which would assuredly be better filled up, if some of the original inhabitants were in some manner modified; for, had the area been open to immigration, these same places would have been seized on by intruders. In such cases, slight modifications, which in any way favoured the individuals of any species, by better adapting them to their altered conditions, would tend to be preserved; and natural selection would have free scope for the work of improvement.

We have good reason to believe, as shown in the first chapter, that changes in the conditions of life give a tendency to increased variability; and in the foregoing cases the conditions have changed, and this would manifestly be favourable to natural selection, by affording a better chance of the occurrence of profitable variations. Unless such occur, natural selection can do nothing. Under the term of "variations", it must never be forgotten that mere individual differences are included. As man can produce a great result with his domestic animals and plants by adding up in any given direction individual differences, so could natural selection, but far more easily from having incomparably longer time for action. Nor do I believe that any great physical change, as of climate, or any unusual degree of isolation to check immigration, is necessary in order that new and unoccupied places should be left, for natural selection to fill up by improving some of the varying inhabitants. For as all the inhabitants of each country are struggling together with nicely balanced forces, extremely slight modifications in the structure or habits of one species would often give it an advantage over others; and still further modifications of the same kind would often still further increase the advantage, as long as the species continued under the same conditions of life and

profited by similar means of subsistence and defence. No country can be named in which all the native inhabitants are now so perfectly adapted to each other and to the physical conditions under which they live, that none of them could be still better adapted or improved; for in all countries, the natives have been so far conquered by naturalised productions, that they have allowed some foreigners to take firm possession of the land. And as foreigners have thus in every country beaten some of the natives, we may safely conclude that the natives might have been modified with advantage, so as to have better resisted the intruders.

As man can produce, and certainly has produced, a great result by his methodical and unconscious means of selection, what may not natural selection effect? Man can act only on external and visible characters: Nature, if I may be allowed to personify the natural preservation or survival of the fittest, cares nothing for appearances, except in so far as they are useful to any being. She can act on every internal organ, on every shade of constitutional difference, on the whole machinery of life. Man selects only for his own good: Nature only for that of the being which she tends. Every selected character is fully exercised by her, as is implied by the fact of their selection. Man keeps the natives of many climates in the same country; he seldom exercises each selected character in some peculiar and fitting manner; he feeds a long and short beaked pigeon on the same food; he does not exercise a long-backed or long-legged quadruped in any peculiar manner; he exposes sheep with long and short wool to the same climate. He does not allow the most vigorous males to struggle for the females. He does not rigidly destroy all inferior animals, but protects during each varying season, as far as lies in his power, all his productions. He often begins his selection by some half-monstrous form; or at least by some modification prominent enough to catch

the eye or to be plainly useful to him. Under Nature, the slightest differences of structure or constitution may well turn the nicely balanced scale in the struggle for life, and so be preserved. How fleeting are the wishes and efforts of man! how short his time! and consequently how poor will be his results, compared with those accumulated by Nature during whole geological periods! Can we wonder, then, that Nature's productions should be far "truer" in character than man's productions; that they should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship?

It may metaphorically be said that natural selection is daily and hourly scrutinising, throughout the world, the slightest variations; rejecting those that are bad, preserving and adding up all that are good; silently and insensibly working, whenever and wherever opportunity offers, at the improvement of each organic being in relation to its organic and inorganic conditions of life. We see nothing of these slow changes in progress, until the hand of time has marked the lapse of ages, and then so imperfect is our view into long-past geological ages, that we see only that the forms of life are now different from what they formerly were.

In order that any great amount of modification should be effected in a species, a variety when once formed must again, perhaps after a long interval of time, vary or present individual differences, of the same favourable nature as before; and these must be again preserved, and so onwards step by step. Seeing that individual differences of the same kind perpetually recur, this can hardly be considered as an unwarrantable assumption. But whether it is true, we can judge only by seeing how far the hypothesis accords with and explains the general phenomena of nature. On the other hand, the ordinary belief that the amount of possible variation is a strictly limited quantity is like-

wise a simple assumption.

Although natural selection can act only through and for the good of each being, yet characters and structures, which we are apt to consider as of very trifling importance, may thus be acted on. When we see leaf-eating insects green, and hawk-feeders mottled-grey; the alpine ptarmigan white in winter, the red-grouse the colour of heather, we must believe that these tints are of service to these birds and insects in preserving them from danger. Grouse, if not destroyed at some period of their lives would increase in countless numbers; they are known to suffer largely from birds of prey; and hawks are guided by eyesight to their prey - so much so, that on parts of the Continent persons are warned not to keep white pigeons, as being the most liable to destruction. Hence natural selection might be effective in giving the proper colour to each kind of grouse, and in keeping that colour, when once acquired, true and constant. Nor ought we to think that the occasional destruction of an animal of any particular colour would produce little effect: we should remember how essential it is in a flock of white sheep to destroy a lamb with the faintest trace of black. We have seen how the colour of the hogs, which feed on the "paint-root" in Virginia, determines whether they shall live or die. In plants, the down on the fruit and the colour of the flesh are considered by botanists as characters of the most trifling importance: yet we hear from an excellent horticulturist, Downing, that in the United States, smooth-skinned fruits suffer far more from a beetle, a *Curculio*, than those with down; that purple plums suffer far more from a certain disease than yellow plums; whereas another disease attacks yellow-fleshed peaches far more than those with other coloured flesh. If, with all the aids of art, these slight differences make a great difference in cultivating the several varieties, assuredly, in a state of nature, where the trees would have to struggle with other

trees, and with a host of enemies, such differences would effectually settle which variety, whether a smooth or downy, a yellow or purple fleshed fruit, should succeed.

In looking at many small points of difference between species, which, as far as our ignorance permits us to judge, seem quite unimportant, we must not forget that climate, food, etc., have no doubt produced some direct effect. It is also necessary to bear in mind that, owing to the law of correlation, when one part varies, and the variations are accumulated through natural selection, other modifications, often of the most unexpected nature, will ensue.

As we see that those variations which, under domestication, appear at any particular period of life, tend to reappear in the offspring at the same period; - for instance, in the shape, size, and flavour of the seeds of the many varieties of our culinary and agricultural plants; in the caterpillar and cocoon stages of the varieties of the silkworm; in the eggs of poultry, and in the colour of the down of their chickens; in the horns of our sheep and cattle when nearly adult; - so in a state of nature natural selection will be enabled to act on and modify organic beings at any age, by the accumulation of variations profitable at that age, and by their inheritance at a corresponding age. If it profits a plant to have its seeds more and more widely disseminated by the wind, I can see no greater difficulty in this being effected through natural selection, than in the cotton-planter increasing and improving by selection the down in the pods on his cotton-trees. Natural selection may modify and adapt the larva of an insect to a score of contingencies, wholly different from those which concern the mature insect; and these modifications may effect, through correlation, the structure of the adult. So, conversely, modifications in the adult may affect the structure of the larva; but in all cases natural selection will ensure that they shall not be injurious: for if they were so, the species would become extinct.

Natural selection will modify the structure of the young in relation to the parent, and of the parent in relation to the young. In social animals it will adapt the structure of each individual for the benefit of the whole community; if the community profits by the selected change. What natural selection cannot do, is to modify the structure of one species, without giving it an advantage, for the good of another species; and though statements to this effect may be found in works of natural history, I cannot find one case which will bear investigation. A structure used only once in an animal's life, if of high importance to it, might be modified to any extent by natural selection; for instance, the great jaws possessed by certain insects, used exclusively for opening the cocoon - or the hard tip to the beak of unhatched birds, used for breaking the egg. It has been asserted, that of the best short-beaked tumbler-pigeons a greater number perish in the egg than are able to get out of it; so that fanciers assist in the act of hatching. Now if nature had to make the beak of a fullgrown pigeon very short for the bird's own advantage, the process of modification would be very slow, and there would be simultaneously the most rigorous selection of all the young birds within the egg, which had the most powerful and hardest beaks, for all with weak beaks would inevitably, perish; or, more delicate and more easily broken shells might be selected, the thickness of the shell being known to vary like every other structure.

It may be well here to remark that with all beings there must be much fortuitous destruction, which can have little or no influence on the course of natural selection. For instance a vast number of eggs or seeds are annually devoured, and these could be modified through natural selection only if they varied in some manner which protected them from their enemies. Yet many of these eggs or seeds would perhaps if not destroyed, have yielded individuals better adapted to their conditions of life than any of

those which happened to survive. So again a vast number of mature animals and plants, whether or not they be the best adapted to their conditions, must be annually destroyed by accidental causes, which would not be in the least degree mitigated by certain changes of structure or constitution which would in other ways be beneficial to the species. But let the destruction of the adults be ever so heavy, if the number which can exist in any district be not wholly kept down by such causes, - or again let the destruction of eggs or seeds be so great that only a hundredth or a thousandth part are developed, - yet of those which do survive, the best adapted individuals, supposing that there is any variability in a favourable direction, will tend to propagate their kind in larger numbers than the less well adapted. If the numbers be wholly kept down by the causes just indicated, as will often have been the case, natural selection will be powerless in certain beneficial directions; but this is no valid objection to its efficiency at other times and in other ways; for we are far from having any reason to suppose that many species ever undergo modification and improvement at the same time in the same area.

/The Origin of Species. Chicago, 1963,
p. 87-93/

MECHANICS OF SPECIES SURVIVAL

Roaches' hidden egg cases exemplify protective adaptation

F.A. McKittrick, T. Esiner, H.E. Evans

One of the basic observable facts of nature that led Darwin to formulate his theory of natural selection was that the offspring of most species, in the early stages of

their existence, greatly outnumber their parents. Despite this tendency to geometrical increase, Darwin noticed that the numbers of a given species actually stay rather constant. From this he correctly reasoned that, since more young are produced than actually survive, there must be competition for survival. This competition is usually referred to as the struggle for existence.

Prolific reproduction, then, is one basic requirement for the continued existence of most species. But just how prolific must a species be in order to survive? During its life span a codfish or a tapeworm, for instance, may produce eggs by the millions. Similarly, a solitary orchid flower may produce millions of seeds. But, clearly, a high reproductive rate is not the only key to survival, since many successful species - including man - have what is in fact a remarkably low rate of reproduction. Evidently the young of such species must be specially adapted to face and outlast the hazards of the struggle, or must somehow be protectively sheltered from them. Mechanisms for protecting offspring and increasing their chances of attaining maturity are commonplace evolutionary acquisitions among both animals and plants. It is our purpose here to call attention to such mechanisms as they occur in a wellknown, if poorly regarded, insect group - cockroaches.

Remarkable as it may seem, the behavior of cockroaches has only recently come under careful study, despite the fact that for centuries many of their kind have been man's constant domestic companions, and that these sturdy insects have for years been chosen as subjects in his physiological laboratories. But cockroaches are active primarily at night: for this reason alone some of their most interesting habits have remained almost undetected.

Several years ago, one of us (Evans), while camped one spring night at Highlands Hammock State Park in the central part of Florida, noticed a group of cockroaches engaged in a most peculiar kind of activity. The species

was *Eurycotis floridana* (Walker), a large reddish-brown roach, native and quite common to the area. All of the individuals were mature, gravid females, each having a fully formed egg case protruding in characteristic fashion from the rear of its abdomen. The roaches were on sandy terrain, and they were digging. As it turned out, each was preparing a small hole into which it then deposited the egg case, covering it with sand and finally smoothing over the surface so as to leave virtually no markings that might betray its activity.

Eurycotis, we have found, does well in the laboratory. During its nocturnal egg-laying it is remarkably oblivious to outside disturbance. This has made it easy for us to study the animal's behavior at close range in all its fascinating detail. In the laboratory we keep the roaches on sand, in glass enclosures that prevent their escape and in which they can be watched and photographed with ease.

The first sign of the impending onset of egg-laying is the appearance of the egg case, which is slowly extruded from the genital chamber of the female. When it first emerges, the egg case is white and soft, but it gradually hardens over a period of several hours and becomes tanned to a dark brown. Egg cases are quite characteristic of roaches, but the number of eggs per case varies in different species. That of *Eurycotis* holds about twenty eggs, neatly arranged in two parallel rows within the packet.

With the completed egg case projecting from its rear, the roach now actively seeks out a place to begin digging. It ambles about at a leisurely pace, pauses occasionally to "inspect" the ground with its mouthparts, and then resumes wandering once more. Suddenly, it makes its first attempt to dig. The head is brought forward, is pressed into the sand, and is then pulled back abruptly in a rapid stroke that rakes a small heap of sand to the rear. This initial stroke may represent no more than one of the several false starts that the roach usually makes before set-

ting on a definitive site. Once such a final location has been chosen - and we are still quite ignorant as to the specific environmental clues that the roach relies upon in making its choice - the digging proceeds without interruption, at the rate of a stroke every few seconds. Deeper and deeper the hole is carved, until eventually it reaches down about a centimeter below the surface. In dry sand the entire procedure lasts about thirty minutes.

At this point the hole is more or less irregularly funnelshaped, and does not at all conform to the configuration of the egg case. But the roach remedies this by shifting to a totally new kind of activity. It dribbles saliva onto the sand in the hole, and with the mouthparts picks up a few grains at a time, removing them from one place and pressing them into another, until finally the hole is molded into a narrow, elongate trough, shaped quite precisely to hold the egg case. The molding of this trough is not a rapid procedure: it may take the roach up to an hour to complete the job. It is interesting to note that the width of the head is about the same as the width of the egg case, suggesting that the head itself might provide the gauge on which the roach relies while shaping the hole.

Now comes the main event - the laying of the egg case. This act is simple, and is completed within seconds. The roach lifts its head out of the hole and assumes a position directly above it, then arches its body upward and drags the rear of its abdomen, with the egg case, forward into the hole. Once lowered into place, the egg case is released from the genital armature. At this point, the positioning of the egg case usually still requires some adjustment. The roach turns round, grasps the saw-toothed keel of the egg case with its mandibles, and, by a process of pulling and tugging, maneuvers it so that it fits perfectly within the trough.

The egg case is now ready to be covered. Using its

mouthparts, the roach picks up sand grains from the margins of the hole, thoroughly moistens them with saliva, and then sticks them onto the egg case. The entire exposed surface of the egg case is roofed in this way with a dense, pasted layer of sand, and completely disappears.

The final operation is a general smoothing over of the entire region of activity. Again using its mouthparts, the roach simply picks up sand from one place and deposits it in another, eventually, leveling out all major irregularities. It spends considerable time - often more than an hour - at this operation. The female's job is now completed, and she simply wanders off. Her major concern, for at least a brief period of time, will be the search for food. But within a few days - usually about eight - a new egg case will have matured in her body, and once more she will bury it and conceal it in the same elaborate way.

One of the remarkable things about this egg-laying behavior is its adaptability to different environments. When we collected *Eurycotis* in Florida, we noticed that one of the habitats in which it was commonly found was dead, decaying logs. Within these logs, the roaches scurry about by the dozens, living in an internal labyrinth. We also found egg cases in these logs. But, instead of lying freely exposed within the passages, they were always hidden from view under small piles of shredded wood. We have since seen how *Eurycotis* lays its egg case in this type of habitat. It first carves a hole by chewing on the wood, using its powerful mandibles to tear away small pieces, one at a time. It then deposits the egg case in the carved-out depression and covers it with small wood shreds that are glued to the surface with saliva. Finally, the entire site is camouflaged with a loose cover of larger pieces of wood taken from the surroundings.

We must now ask ourselves about the function of this behavior. The first thing that comes to mind, obviously, is protection. But protection from what? Oddly, one of

the main natural enemies may be *Eurycotis* itself. When we kept roaches in aluminum cages, we saw that many of their egg cases - which were now exposed conspicuously on the bottom of the cage - were eagerly devoured by the roaches, even when a surplus of other food was available to them. This kind of cannibalism could be almost completely prevented by transferring the roaches to sand or dead wood in which their egg cases could be buried. We say "almost completely", because even under these conditions, and especially when overcrowded, roaches at times chew away at each other's egg cases while these are protruding from the genital chamber.

But roaches are not their own sole enemies. Ants, carabid beetles, and small rodents, to mention only a few, are each in their own ways potent menaces in the habitats frequented by *Eurycotis*. Burying the egg cases must help reduce the toll that would otherwise be taken by such predators. Then there are the egg parasites. Tiny wasps, for instance, lay their own eggs in roach egg cases, and the larvae undergo their entire development in them. It would be interesting to experiment with such wasps to determine if, when given a choice between exposed and concealed egg cases, the wasps are unable to locate the ones that have been buried.

Finally, there is the possibility that the buried egg cases are better protected against water loss. One might think offhand that the hard shell of the egg case is in itself an adequate shield against desiccation, but this is not so: the egg case that is exposed to the air loses water quite rapidly at continuing low humidities.

After working with *Eurycotis*, it occurred to us that it might be worth while investigating some other species of roaches. We wanted to know, first of all, how widespread this burying habit is and how it varies from one species to another. One most interesting possibility was that by studying the egg-laying on a comparative ba-

sis - including for study both generalized and more advanced species - one might be able to piece together the sequence of events that spelled the evolution of this behavior.

We have now worked on more than twenty species from many areas of the world, including representatives of most known families. Our hopes are being realized. Not only is the burying habit rather widespread, but it is also variable. Some of this variability is interesting in itself, even without going into the detailed evolutionary implications. For instance, some roaches dig with their forelegs rather than with the head, others use both head and forelegs. Some completely omit shaping the hole with wet sand, and simply drop the egg case into the unmolded pit. One common native species, *Parcoblatta virginica* (Brunner), constructs an oblique tunnel instead of the usual open hole. Even the very act of laying is subject to variation. Some, like *Eurycotis*, lay the egg case from above while straddling the hole; others turn round to lay, sliding the egg case into place by backing into the pit. There are even a few species that simply drop their egg cases or glue them on an exposed surface, constructing no shelter whatever for their protection.

One should mention that there are some cockroaches that never even lay their egg cases. As with the mammals among the vertebrates, they incubate the developing eggs within their own bodies. When the young are born, they are free-living, miniature versions of the adults.

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V o c a b u l a r y

A

- abdomen /æb'doumən/ - allkeha, kõht
- abnormal /æb'nɔ:məl/ - ebanormaalne, anormaalne
- aborigine /æb' rɪdʒɪn/ (pr. aborigines / b r'id ini:z/) - (maa) põliselanik
- abound /ə'baund/ - külluses esinema või olema
- abrasion /ə'breɪʒ(ə)n/ - kraapimine, marrastus
- abruptly /ə'brʌptli/ - järsult, äkitselt
- abscess /æb'ses/ - mädandama
- absorb /əb'sɔ:b/ - neelama, imama
- absorbent /əb'sɔ:bənt/ - neelav, imav
- abstract /'æbstrækt/ - abstraktne, mõtteline, mõisteline
- abundance /ə'bʌndəns/ - küllus, ohtrus, rohkus
- access /æ'kses, æk'ses/ - juurde- e. ligi- või sisse-
pääs
- accidentally /æksi'dentəli/ - juhuslikult, kogemata
- accommodate /ə'kɒmədeɪt/ - varustama
- accomplish /ə'kɒmplɪʃ / - täide saatma, lõpule viima,
teostama
- accomplishments - võimed, oskused
- accord with /ə'kɔ:d/ - kooskõlas olema
- account /ə'kaunt/ - seletus, aruanne; jutustus; kasu;
tähtsus; lugema, arvestama; ära sele-
tama

accumulate /ə'kju:mjuleit/ - koguma, kuhjama

accuracy /'ækjʊrəsi/ - täpsus

acid /'æsid/ - hape

acetic /ə'si'tik/ acid - äädikhape

acidity /ə'siditi/ - happesus

acorn /'eikɔ:n/ - (tamme) tõru

acquire /ə'kwaiə/ - omandama, saama

acquisition /ækwi'ziʃ(ə)n/ - omandamine, saavutus

adapt /ə'dæpt/ - kohastama, kohandama

adaptation /ædæp'teiʃ(ə)n/ - kohastumine; kohastamine

adequate /'ædikwi:t/ - täiesti vastav, adekvaatne

adhere to /əd'hia/ - millegi külge jääma

adhesive /əd'hi:siv/ - hõlpsasti külgejääv, kleepuv

adjacent /ə'dʒeis(ə)nt/ - külgnev, lähedane; naabruses
olev

adjustment /ə'dʒʌstmənt/ - kohandamine

administer /əd'ministə/ - välja jagama, andma

adobe /ə'doubi/ - adoob (päikese käes kuivatatud) põle-
tamata telliskivi või sellistest tel-
listest hoone

adrenal /əd'ri:nəl/ - neerupealis, neerupealne nääre

adult /ə'dʌlt, 'ædʌlt/ - täiskasvanud, -ealine

advantage /əd'vɑ:ntidʒ/ - paremus, eelis; edutama,
aitama

aerial /'ɛəriəl/ - õhu-

aero- /ɛəro, e(i)əro/ - õhu-, aero-

affect /ə'fekt/ - mõjustama, mõju avaldama; kahjustama

affinity /ə'fɪnɪti/ - hõimlus, sugulus; afiinsus, (elementide) tung üksteisega ühineda

afford /ə'fɔ:d/ - lubama, võimaldama

afield - kaugele, väljale, ära

afore /ə'fɔ:/ - eespool, ees

aft /a:ft/ - ahtris(se), laevapäras(se)

agar /'eɪgə:/ - agar

agar medium - agari sööde

agent /'eɪdʒənt/ - toimur, agens

aggregate /'ægrɪɡɪt/ - koondis, kogumik; koondunud, koondatud, kuhjunud

agitate /'ædʒɪteɪt/ - segama (vedelikku)

agreement - sobivus, leppivus, kokkulepe

in agreement as to - (mingis küsimuses) üksmeeles, ühel arvamisel

albatross /'ælbətrɒs/ - albatross

alcohol /'ælkəhɒl/ - alkohol, viinapiiritus

alga /'ælgə/ (pl. algae /'ældʒi:/) - vetikas

alimentary /æli'mentəri/ - toitev; toite-

alimentary tract - seedetrakt

alkalinity /ælkə'lɪnɪti/ - leelisus, alkaalsus

alkaloid /'ælkəloɪd/ - alkaloid

allegedly /ə'ledʒɪdli/ - nagu väidetakse

alleviate /ə'li:vieɪt/ - kergendada, leevendada

aloft /ə'lo:(t)ft/ - kõrgel(e), üle(ev)al, üles

alpine /'ælpain/ - alpi

alter /'ɔ:ltə/ - muutama

altitude /'æltitju:d/ - (geograafiline) kõrgus

gain altitude - kõrgemale tõusma

aluminium /ə'ljʊ:mi:nəm/ - alumiinium

amberggris /'æmbəɡri(:)s/ - (hall) ambra (vahajas healõhnaline aine)

amble - küliskäigul liikuma, kergel sammul kõndima

amino-acid - amiinhape

amount /ə'maunt/ - kogus, hulk

amphibian /æm'fibiən/ - amfiib, kahepaikne (loom)

amphibious /æm'fibiəs/ - amfiibne, kahepaikne

ample - avar, küllane, rohke

analogous /ə'næləɡəs/ - analoogiline, samalaadne

anatomy /ə'nætəmi/ - anatoomia

ancestor /'ænsistə/ - esivanem, -isa

ancestral /æn'sestrəl/ - esivanemlik

ancestry /'ænsistri/ - esivanemkond

anchor /'æŋkə/ - ankur

anchorage /'æŋkəridʒ/ - ankurumine, ankrusolemine

anchoveta /æntʃou'vetə/ - kohalik peruu sardiin

ancient /'einʃ(ə)nt/ - vana, muistne, põline; (auväärt) rauk

anesthetize /ə'ni:sθətaiz/ - tuimastama

anew /ə'nju:/ - uuesti, jälle, taas

angle - nurk

ankle - pahkluu, sääre alumine osa

annals /'æn(ə)lz/ - annaalid, aastaraamatud

annual /'ænjuəl/ - aasta kestev, üheaastane

ant - sipelgas

antelope /'æntiloup/ - antiloop

antenna /æn'tenə/ (pl.-ae /-i:/) - tundel, katsesarv

anterior /æn'tiəriə/ - eelnev, eelkäiv; eespoolne, ees-
mine

anther /'æneə / - tolmukapea

anthropogeneous /ænθərə'pɒdʒinəs/ - antropogeenne

anthropology /ænθərə'pɒlədʒi/ - antropoloogia, inimese-
teadus

antropometric /ænθərə'pɒmitrik/ - antropomeetriline

anthropomorphic /ænθrupə'mɔːfik/ - antropomorfe, ini-
mesekujuline

antiquity /æn'tikwiti/ - antiikaeg, vana-aeg

anxiously /'æŋ(k)ʃəslɪ/ - murelikult, rahutult, ärevalt

aperture /'æpətʃʊə/ - avaus, auk

apex /'eɪpeks/ (pl. apices /'eɪpisiːz, 'æp-/ , apexes
/'eɪpeksɪz/ - tipp, haripunkt

aplanospore - liikumatu eos, aplanospor

apparently /ə'pærəntli/ - ilmselt, nähtavasti

applicable /'æplɪkəbl/ to - kohaldatav

application /æpli'keɪ(ə)n/ - rakendamine, tarvitamine

apply to /ə'plai/ - pöörduma (kellegi poole), kehtima,
käima millegi kohta, juurde või peale
või külge panema

appreciable /ə'priːʃəbl/ - märgatav, hinnatav

appropriate /ə'prəʊpriɪt/ - sobiv, vastav, kohane, sün-
nis; rahasummat määrama

aptly - sündsalt, sobivalt

aquarium /ə'kwɛəriəm/ - akvaarium

aquatic /ə'kwætɪk/ - vee-, vesi

aqueous /'eɪkwɪəs/ - vesine, veeline, vee-

arborescent /a:bə'resnt/ - puukujuline, -taoline

arch /a:tʃ/ - võlv, kurv, lookjas kõverjoon

archaic /a:'keɪɪk/ - arhailine, muistne, vanaaegne

archeologist /a:ki'ɔ:lədʒɪst/ - arheoloog

archipelago /a:ki'peləgou/ - arhipelaag, saarterikas meri

Argentine /'a:dʒ(ə)ntaɪn, ti:n/ - argentiina, argentiinlane

arid /æɪd/ - kuiv

aridity /ə'ɪdɪti/ - kuivus, põad(sus), vihmavaesus

arise - tõusma, esile tulema või kerkima, tekkima

armature /'a:matʃuə/ - raamistik

array /ə'reɪ/ - reastus, rida, väljapanek (näitamiseks)

artery /'a:təri/ - arter, tuiksoon

ascent /ə'sent/ - ülesminek, tõus

ascertain /æ.sə'teɪn/ - kindlaks tegema

asexual /ə'seksjuəl, ei's, -kʃuəl/ - aseksuaalne, sugutu

assemblage /ə'semblɪdʒ/ - kogumine, kogunemine

assert /ə'sə:t/ - väitma, kinnitama

assertion /ə'sə:ʃ(ə)n/ - väitmine, kinnitamine; väide

assess /ə'ses/ - hindama, takseerima

associate /ə'souʃiɪt/ - kaaslane, liitlane

-"- /ə'souʃiɪt/ - ühinema, liituma

association /səusi'eɪʃn/ - assotsiatsioon

assume /ə'sju:m/ - omandama; eeldama, endastmõistetavaks
pidama; enesele võtma

assumption /ə'sam(p)ʃ(ə)n/ - eeldamine, eeldatav asi

assuredly /ə'ʃʊrɪdli/ - kindlasti

attach - külge kinnitama

attachment /ə'tætʃmənt/ - kinnistus, side; kinnitumine;
seadis

attain /ə'tein/ - saavutama, kätte saama

attend /ə'tend/ to - tähele panema, hoolt kandma, hoolit-
sema

attendant /ə'tendənt/ - saatev, kaasaskäiv

attire /ə'taɪə/ - riided, rõivastis

attribute /ə'tribju(:)t/ - omistama, omaks andma või omaks
lugema

automatically /ɔ:tə'mætɪkəli/ - automaatselt

autopsy /'ɔ:təpsi, ɔ:'təpsi/ - koolnuvaatlus, lahang

auxotroph /'ɔ:ksətrɔ:f/ - auksotroofne organism

auxotrophic /ɔ:ksə'trofik/ - auksotroofne

availability /əveɪlə'bɪlɪti/ - kasutatavus, kättesaadavus

available /ə'veɪləbl/ - kättesaadav

average /'ævərɪdʒ/ - keskmine arv, näitaja; keskmine;
keskmiselt ulatuma või olema

awesome /'ɔ:səm/ - kohutav, hirmuäratav

awry /ə'raɪ/ - viltu, kõverdi, valesti

axil /'æksɪl/ - lehe- või oksakaenal

axis /'æksɪs/ (pl. axes /'æksɪz/) - telg

baboon /bə'bu:n/ - paavian e. koerapeaahv

back - toetama

backdrop - foon

bacteriological /bəktiəriə'lɒdʒikəl/ - bakterioloogiline

bacteriology /bəktiəri'ɒlədʒi/ - bakterioloogia

bacterium /bək'tiəriəm/ (pl. bacteria /bək'tiəriə/) -
bakter, mikroob

bait /beɪt/ - sööt(-da), peibutis

balance /'bæləns/ - tasakaalustama; tasakaal

baleen - whalebone

ban - keeld

band - pael, lint, side; organiseeritud salk(kond), jõuk,
kamp

bar - baar, joomisruum

bare - paljas, tühi, lage

barefoot - paljajalu

barely - vaevalt

bark - (puu)koor

barrier /'bæriə/ - barjäär, tõkepuu; takistus, tõke

barrel - vaat, tünn

barren /bær(ə)n/ - sigimatu, viljatu; kasutu

barren heath - metsatu nõmm

barter - vahetuskaubitsus, -kaup

basal /beɪs(ə)l/ - basaalne, põhimikuline

base - (keem.) alus e. baas, leelis

basin /beɪsn/ - bassein; (jõe) vesikond; vaagen, kauss;
sulglohk

Basque /baːsk/ - bask (teatava rahva liige)

bay /bei/ - laht

beach - mererand, supelrand

beagle /biːgl/ - jahikoer

beak /biːk/ - nokk

beam - kiirgama, särama, lahkelt naeratama

bean - uba

bear - kandma; kannatama, taluma

bear down upon - järsult rõhuma

bear in mind - meeles pidama

bear witness - tunnistama, tunnistajaks olema

beast - loom

beast of prey - röövloom

bedridden - haigevoodis lamav, põdev, vigane

beech /biːtʃ/ - pöök(puu)

beef - loomaliha

beer - õlu

beetle - mardikas; põrnikas e. sitikas

carabid beetle - jooksiklane

beetroot - peet

bell-jar - klaaskuppel

belt - vöö, vööt; (Am.) vööde

beluga - beluuga

benefactor /'benɪfæktə/ - kasutoov, kasulik, soodus

benefit /'benɪfɪt/ - kasu, tulu

be of benefit - kaasa aitama, soodustama

betray /bi'trei/ - reetma
bewilder /bi'wildə/ - hämmeldama, segadusse viima
bible /baibl/ - piibel
bill - arve
bind, bound, bound - siduma
biochemistry /baɪə'kemistri/ - biokeemia
biological /baɪə'lɒdʒɪk(ə)l/ - bioloogiline
biological supply houses - bioloogiliste uurimisobjek-
 tidega varustamise jaamad
biotic /baɪ'ɒtɪk/ - biootiline
birch /bɜ:tʃ/ - kask
bizarre /bi'zɑ:/ - veider, pentsik
bladder - põis; vill, rakk
blade - lehelaba
bleach - pleegitama, valastama; pleekima, valastuma
blink - silmi pilgutama, silmi pilgutades vaatama
bloody /'blʌdi/ - verine; verejanuline, julm
blowhole - vaala (pealael asetsev) ninasõõre
blunder - komistama, ekslema
blunt - tömp
blunt pointed - tõmbiotsaline
boa /bo(u)ə/ - boa (hiiglamadu)
boast /bəʊst/ - hooplema, kiitlema
bob - lühikeseks lõigatud hobusesaba või juuksed
border - külgnema, piiridega kokku puutama; äär, piir
bore - puurima
bother /'bɒðə/ - muretsema, endale tüli tegema

bow /bou/ - vibu; laevarind, -nina
bowhead /'bouhed/ - grööni vaal, põhjavaal
bowsprit /'bousprit/ - bugspritiit e. raapuu
brackish /'brækɪʃ/ - soolakas, riim
brackish waters - riimveed
brainy - nupukas, nutikas
branched - haruline
breaker - murdlaine
breathless - elutu, surnud
breed, bred, bred - sigitama, tekitama, kasvatama, (loomi)
aretama, paljunema, siginema; tõug,
sugu, sugukond
breeding ground - pesitsuseala
brevity /'breviti/ - lühidus
brew /bru:/ - pruulis, keede
brewing /bru:iŋ/ - pruulimine
brig - brikk (kahemastiline purjekas)
brighten - elavamaks, lõbusamaks muutuma
bring about - põhjustama
broadcast - laialt külvama
browbeat /'braubi:t/ - (kurja pilgu või kärkimisega)
heidutama, araks tegema
browse /brauz/ - lehti ning noori võrseid närima
brunet /bru:'net/ - brünett
brush /brʌʃ/ - võsa, võserik,
bubble - kihama, vulisema; mull, vull
buck - (hüplevalt sõidukilt) maha viskama; metssikk, isane hirv või põder

bud - pung; idupung

buffalo /'bʌfələu/ - pühvel; (Am.) piison

bulb - (mugul) sibul, mugul; (elektri) pirn

bulge /bʌldʒ/ - möhn, kühn, väljaulatuv kumerus; kumeralt
välja ulatuma

bunk - (laeva)koiku, magamisase

burial /'berial/ - mattumine, matmine

burlap /'bɜ:læp/ - teatav jäme kotiriie

burrow /'barou/ - urgas, urg; (rebase või kodujänese)
koobas

bury /'beri/ - matma

busket /'bʌskit/ - vanik

but - peale

button - nõõp, nupp

buzz /bʌz/ - sumisema, surisema, põrisema, (elektri) su-
mistil signaliseerima

C

calcareous /kæl'kɛəriəs/ - lubjane, lupja sisaldav

calcareous soil - lubjane pinnas või muld

calm /ka:m/ - rahulik, vaikne, tasane

Calvary /'kælvəri/ - Kolgata

camera lucida /'kæmərə 'lju:sidə/ - kujutist suurendav
kaamera

camouflage /'kæmʌflə:ʒ/ - kaitsevärvi abil varjama,
(kaitseks) maskeerima

can - konserveerima (toitu)

Canadian /kə'neidiən/ - Kanada

canoe /kə'nu:/ - süst; kanuu

cape - neem, maanina

Capricorn /'kæpriko:n/ - Kaljukits (tähtkuju)

capsule /'kæpsju:l/ - kupar; kapsel, kihn

captivity /kæp'tiviti/ - vangistus

capture /'kæptʃə / - tabama, vangistama

carbide /'ka:baid/ - karbiid (metalli ja süsiniku ühend)

carbohydrate /'ka:bou'haidreit/ - süsivesik

carbon dioxide /'ka:bən 'dai:ksaid/ - süsihappegaas

carcass /'ka:kəs/ - (tapetud) looma kere; korjus, laip

carelessness - hooletus

carex, (pl. carices) - tarn

carnivorous /ka:'nivərəs/ - karnivoorne, lihasööja

carotenoid /kə'rəti:nɔid/ - karotinoid

carpenter /'ka:pintə/ - puusepp

carrion /'kæriən/ - raibe

cartilaginous /ka:ti'lædʒinəs/ - kõhreline, kõhrjas

carve /ka:v/ - lõikama, nikerdama

case - kast, karp, tupp; kapsel, kest

cast, cast, cast - viskama, heitma; (sarvi, nahka jne.)

ajama

castoffs - vanad riided

cataclysm /'kætəklizm/ - kataklüsm, uputus; vapustav
muutus

catalyst /'kætəlist/ - katalüsaator

caterpillar /'kætəpɪlə/ - röövik, tõuk

cathin /'kæθɪn/ - (paju-, kase- jne) urb

caustic potash /'kɔːstɪk'pɒtæʃ/ - kaaliumhüdrokssiid
e. sööbekaalium

cavity /'kævɪti/ - õõnsus, õõs, koobas

cedar /'siːdə/ - seeder

cell - rakk

cello /'tʃeləʊ/ - tsello

cellular /'seljʊlə/ - raku-, rakuline

cellulose /'seljʊləʊz/ - tselluloos

cement /si'ment/ - tsement

census /'sensəs/ - tsensus, loendus

cetacean /si'teɪʃ(ə)n, -ʃɪən, -siən/ - vaalaline

chain /tʃeɪn/ - ahel

chandler /'tʃaːndlə/ - poodnik, kaupmees

ship's chandler - laevavarustaja

channel /tʃæ n(ə)l/ - kanal

chaotic /keɪ'ɒtɪk/ - kaootiline, segaduses olev

character /'kærɪktə/ - tunnus

characteristics - tunnused

charge - hool, hoolitsus

to have charge of - kellegi, millegi eest hoolitsema,
vastutav olema

charm - võlu

chart - merekaart

chase away - minema kihutama

check - pidurdus, tõkestus; pidurdav asjaolu; (äkiline)
seisak; kontrollima

cheer /tʃiə/ - (hea) meeleolu, (hea) tuju, rõõmsameelsus
cheetah /tʃi:tə/ - tšitah, (India) jahileopard
chestnut /'tʃesnat/ - kastan
chew /tʃu:/ - närima
Chilean /'tʃili:n/ - tšiili, tšiililane
chill - ebameeldiv külmus, jahedus
Chilote - Chiloe saare elanik
chlorophyll /'klɔ:rəfil/ - klorofüll
chloroplast /'klɔ:rəplæst/ - kloroplast
chore /tʃɔ: / - töö(d)
Christ /kraist/ - Kristus
Christian /'kristʃən/ - ristiusu, kristlik
Christmas /'krisməs/ - jõulud, jõulupühad
chromosomal /'kroumɔ'souməl/ - kromosoomne
chromosomal material - kromosoomi aine, kromosoomid
cider /saɪdə/ - (harilikult käärinud) õunamahla jook,
õunakali, -vein
circumstance /'sɜ:kəmstəns/ - asjaolu, seik
under the circumstances - antud tingimustes või asja-
oludel
cite /saɪt/ - tsiteerima, näitena mainima
citizenship /'sɪtɪznʃɪp/ - kodanikuõigus, -olukord
clad - riietama
claim - nõudlema, nõudma, väitma; väide
native claim - kohalik väide, kinnitus
clam - sõõdav rannakarp
clay - savi

clear - koristama, korda seadma
clearing - metsaraismik või -lahk
clench - (hambaid, rusikat jne.) kõvasti kokku pigistama
click - klõps, plõks(atus), naks(atus)
climax /'klaɪmæks/ - kõrgeim aste, haripunkt
clinker-built - (paadi või laeva kohta) klinkerehitusega
clip - kirja klamber, näpits
clone /kloun/ - kloon
close-fitting - kitsalt ümberolev (rõivaste kohta)
clout /klaʊt/ - paik, lapp; koputus
clover /'klouvə/ - ristikhein, ristik
clue /klu:/ - (saladuse) võti; juhtiv lõng; (jutu või mõttekäigu) juhtjoon
clump (puude) salk, (metsa)tukk
cluster /'klʌstə/ - kobar, salk
coastal /'koust(ə)l/ - ranna-, ranniku
coat - katma, pealistama, katteks olema
coaxial /kou'æksɪəl/ - koaksiaal e. ühtelangev
coccus /'kɒkəs/ (pl. cocci /k'ksai/) - kokk, kerakujuline mikroorganism
cockpit - lenduriruum lennuki keres
cockroach = roach
cocoon /kə'ku:n/ - kookon, putuka (eriti siidiussi) nuku tupp
code - (sõnumit) kokkuleppekeelde tõlgitsema
codfish - tursk, tursakala
coffee-bean - kohviuba
cogent /'koudʒənt/ - sundivalt veenev, uskumasundiv

- coincidence /ko(u)'insid(ə)ns/ - kokkusattumus; ühtimine
- colds - külmetushaigused; nohu
- collar - krae, rõngas, võru
- colloid /'kɒlɒɪd/ - kolloid, kolloidne aine
- colonize /'kɒlənaɪz/ - asundama
- colossal /kə'lɒs(ə)l/ - kolossaalne, hiiglasuur
- comb /koum/ - kärg
- combine /kəm'bain/ - kombineerima, ühendusse astuma
- combustible /kəm'bʌstɪbl/ - põletatav, süttiv
- combustion /kəm'bʌst(ə)n/ - põlemine, põletamine, põletus
- come across - sattuma (millelegi), juhuslikult kohtama
- command - käskima, käsutama
- commerce /'kɒmə(:)s/ - kaubandus
- common - üldine, tavaline; laialt levinud
- commonplace - liiga tavaline
- communication /kə'mju:ni'keɪ(ə)n/ - side, ühendus
- community /kə'mju:nɪti/ - kogukond, ühiskond
- plant community - taimekooslus
- comparative /kəm'pærətɪv/ - võrdlev
- comparison /kəm'pærɪsn/ - võrdlemine, võrdlus
- complement /'kɒmplɪmənt/ - komplement, täiendus; (laeva meeskonna) komplekt, koguarv
- complex /'kɒmpleks/ - komplitseeritud, keeruline; kompleksne, liit-
- complexity /kəm'pleksɪti/ - komplitseeritus, keerukus
- component /'kəm'pəʊnənt/ - koostisosa

composition /kɔmpə'zi(ə)n/ - koosseis, koostis
compound /'kɔmpaund/ - ühend; koosnev; liit-
comprehension /kɔmpri'hen(ə)n/ - arusaamine, taip
beyond comprehension - üle mõistuse
concede /kən'si:d/ that - mõnna, järele andma, nõus olema
concentration of substrate /kɔnsen'trei(ə)n əv 'sʌbstreit/
- sõõtme kontsentratsioon
concept /'kɔnsept/ - mõiste, üldmõiste
concern /kən'sə:n/ - mure, hool; suhtuma, (millesegi,
kellesegi) puutuma, (millegi) kohta
käima
concern in - ennast segama (millesegi)
be concerned - tegemist olema
conclude /kən'klu:d/ - järeldama; lõpetama, lõppema
conclusion /kən'klu:ʒ(ə)n/ - järeldus
conclusive /kən'klu:siv/ - lõplik, otsustav
conclusively /kən'klu:sivli/ - põhjalikult, ammendavalt
concomitant /kən'kɔmitənt/ - saatev, kaaslev
concur /kən'kə:/ - kaasa töötama, ühtima, ühtuma
condor /'kɔndɔ:, -də/ - kondor (Lõuna-Ameerika) hiigla-
raisakull
cone /koun/ - käbi; koonus; koonusekujuline
confidence /'kɔnfidəns/ - usaldus
confidently /'kɔnfidəntli/ - usalduslikult
configuration /kənfigju(ə)'rei(ə)n/ - kujukond, (osade)
suhteline paigutus,
konfiguratsioon

confine /kən'fain/ - kitsendama, (millegi) piirides pidama
confinement /kən'fainmənt/ - vangistus; piiramine, kitsen-
dus

confirm /kən'fə:m/ - kinnitama
conform /kən'fɔ:m/ - kohandama, kohastama; ühtlustama,
ühtima, ühtuma

confuse /kən'fju'z/ - ära segama, segi ajama

confused - segane, hämune

congregate /'kɔŋgrigeit/ - salka koguma või kogunema

conjure /'kændʒə/ - lausuma, manama, nõiduma

conquer /'kɔŋkə/ - vallutama, võitma

conqueror /'kɔŋkərə/ - vallutaja

consecutively /kən'sekjutivli/ - järgnevalt

consequently /'kɒnsikwəntli/ - järelikult, niisiis

conservation /kɒnsə(:)'vei ʃ(ə)n/ - alalhoidmine, säilita-
mine, säilitus

consideration /kɒnsidə'rei ʃ(ə)n/ - vaatlemine, kaalutle-
mine, kaalutus, arves-
tus; tähelepanu; arves-
tusväärne asjaolu, tegur

take into consideration - (midagi) arvestama, arvesse
võtma

conspicuous /kɒns'pikjuəs/ - silmatorkäv, selgesti nähtav,
tähelepanдав

consternation /kɒnstə:'nei ʃ(ə)n/ - jahmatus, kokkumushäm-
meldus, masendus

constituent /kəns'titjuənt/ - koostusosa, osis

constructive /kəns'traktiv/ - ülesehitav, jaatav

consumption /kən'sʌmp(ə)n/ - tarbimine, äratarvitamine
contain /kən'teɪn/ - sisaldama
contaminate /kən'tæmineɪt/ - reostama, rüvetama
contamination /kəntæmi'nei(ə)n/ - saastumine, nakatus
content /'kɒntent, kən'tent/ - sisaldus, maht
contest /kən'test/ - võitlema, võistleva
continence /'kɒntinəns/ - loobumus, keeldumus, kasinus;
 (suguline) karskus
contingency /kən'tɪndʒ(ə)nsi/ - võimalikkus
contortion /kən'tɔ:(ə)n/ - väändus, käänustus, moodustus
contract /kən'trækt/ - kokku tõmbuma
contralto /kən'træltou/ - kontra-alt e. kontralto (mada-
 laim naishääl või selle laulja)
contraption /kən'træp(ə)n/ - (veider) masinavärk või
 seadis
contrast /'kɒntrə:st/ - kontrast, vastand
contribute /kən'tribju(:)t/ - toetama, kaasa aitama
contrive /kən'traɪv/ - leiutama, välja mõtlema, sepsitama,
 plaanitsema
convenience /kən'vi:njəns/ - otstarbekus
convergence /kən'və:dʒ(ə)ns/ - konvergens, ühtekalduvus,
 lähenevus, koonduvus
convergent /kən'və:dʒ(ə)nt/ - konvergentne, ühtekalduv
conversely /kən'və:slɪ/ - vastupidiselt
convert (into) /kən'vɜ:t/ - (millekski) muutuma; ümber
 töötama, väärindama
copper - vask

copper sulphate /'kɒpə'sʌlf(e)ɪt/ - vasesulfaat, silmakivi

coral /'kɒr(ə)l/ - korall

core /kɔː/ - tuum, südamik

core temperature - kehasisene temperatuur

corkscrew motion /'kɔːkskruː'moʊ / - kruvikujuline,
spiraalne liikumine

cormorant /'kɔːm(ə)r(ə)nt/ - kormoran (teatav sõudjala-
line lind)

corporal /'kɔːp(ə)r(ə)l/ - kapral

correlation /kɒri'lei / (ə)n/ - seos, suhtumus, korrelat-
sioon

cot - kerge voodi, häll, koiku, koi

cotyledon /kɒti'liːd(ə)n/ - iduleht

count /kaunt/ - loendus, arvutus, üldarv

counter - loendaja, lugeja

couple /kʌpl/ - seostama, siduma

course /kɔːs/ - jooks, käik, kulg; (laeva) kurss, koos;
suund

cove - kurm(u), väike merelaht, sopp

crack - mõra, pragu

craft - õhusõiduk, õhusõidukid

crane - (kaela) välja sirutama, käänama

crater /'kreɪtə/ - kraater (tulemäe või mürsuplahvatuse)
purskeava

creature /'kriːtʃə / - olend

credible - usutav

credit - au, tunnustus

crew /kru:/ - (laeva-, paadi-) meeskond
crimson /'krimzn/ - karminpunane
cripple - sandistama, vigastama, vigaseks tegema
crop - saak
crowding - umbrohistumine
crucial /'kru:ʃ(ə)l/ - otsustav, kriitiline, tähtis
'cruck' /krʌk/ - siin: tarbepuit
crude /kru:d/ - toores, tahumata
cruelty /'kru(:)ilti, 'kruəl-/ - julmus, halastamatus,
karmus; julm tegu
cruise /kru:z/ - ristlema, vahelduva kursiga sõitma
crumb /krʌm/ - raas, raasuke; pala; iva
crumble /'krʌmbəl/ - pudenema, tükki l lagunema
crustacea /krʌs'tei ʃjə/ - koorikloomad
crustacean /krʌs'tei ʃ(ə)n, - ʃiən/ - koorikloom (vähk)
crustose /'krʌstəs/ lichen - kooriksamblik
cubical /'kju:bik(ə)l/ - kuubikujuline
culinary /'kju:linəri/ - kulinaarne, köögisse või koka-
kunstisse puutuv
cult /kʌlt/ - kultus
cultivated plants - kultuurtaimed
culture /'kʌltʃə/ - kultuur, pisikute kunstlikult kas-
vatamine
cure /kjʊ/ - ravima, arstima, terveks tegema
current /'kʌr(ə)nt/ - käibiv, käibelolev, kehtiv; vool,
voolus
cushion /'ku ʃ(ə)n/ - polsterdama

curio /'kjuəriou/ - haruldus, haruldane ese
curl up - kokku rulluma
cusp /kʌsp/ - tipp, teravik
cycle /saikl/ - tsükkel
cylindrical /si'lindrik(ə)l/ - silindrikujuline
cypress /'saipris/ - küpress
cytoplasm /'saitouplæzm/ - tsütoplasma

D

dairy farm /'dɛəri 'fa:m/ - karjafarm
Dalmatian /dæl'mei (ə)n/ - dalmaatsia
damsel fly /'dæmzəlflai/ - vesineitsik
darner /'da:nə/ - sukanõeluja; siin: = dragonfly
dart - sööstma, tormama; viskeoda, -nool
dashing - sööstmine, sööst
deal - kuuse või männipuit
a good deal - hulk, jagu, osa
debris /'debri:/ - jäänused
vegetable debris - taimsed jäänused
decade /'dekəd, 'dekeid/ - kümmekond, aastakümme
decay /di'kei/ - kõdunema, mädanema; lagunema
decline /di'klaɪn/ - allapoole kalduma, kahanema
decolorize /di:'kʌləraɪz/ - dekoloriseerima
deem - arvama, pidama
defiance /di'faɪəns/ - väljakutse, trots
in defiance of - hoolimata
definite /'definit/ - määratud, kindel, selge

degeneration /di'dʒənə'reiʃ(ə)n/ - degeneratsioon, mandu-
mine

degradation /degrə'deiʃ(ə)n/ - degradatsioon, lagunemine

degradative /degrə'deitiv/ - lagunemis-

degree /di'gri:/ - aste; kraad

dehydrate /di'haidreit/ - dehüdreerima

Deity /'di:ti/ - jumalus

deletion /di(:)'li:ʃ(ə)n/ - kustutamine, hävitamine

delicacy /'delikəsi/ - maiuspala, hõrgutis, delikatess

delicate /'delikit/ - õrn, peen

delightful - ülimeeldiv, -mõnus, õnnestav

delimit /di:'limit/ - piiristama, piire tõmbama

delta /deltə/ - delta, (jõe) suudmema

demarcation line /dima:'keiʃ(ə)n/ - piiristus- e. demar-
katsioonijoon

denote /di'nout/ - näitama, märgitsema

dense - tihe

density - tihedus

depart /di'pa:t/ - kõrvale kalduma

dependency /di'pendənsi/ - sõltuvus

dependent on - sõltuv (millestki, kellestki)

deposit /di'pɒsit/ - sade, sadestus, sadestunud lademik,
sete; hoiule panema

depredation /depri'deiʃ(ə)n/ - röövimine, rüüstamine;
pl. hävitus

derelict /'derilikt/ - mahajäetud

derivative /di'rivətiv/ - derivaat, tuletis

- descendent /di'sendənt/ - järglane, järeltulija
- descent /di'sent/ - põlvnemine
- desert /di'zə:t/ - maha jätma, hülgama
- design /di'zain/ - kavandama, määrama
- desirable /di'zaiərəbl/ - soovitav
- desolate /'desoleit/ - laastama; valusasti kurvastama
- desolation /desə'lei (ə)n/ - mahajäetus
- destination /desti'nei (ə)n/ - sihtkoht
- destruction /dis'træk (ə)n/ - hävitus; deformeerimine,
purustamine
- destructive /dis'traktiv/ - hävitav, destrukttiivne
- detect /di'tekt/ - avastama, leidma; tabama
- detection /di'tek (ə)n/ - avastamine, avastus
- deviation /di:vi'ei (ə)n/ - kõrvalekaldumine
- device /di'vəis/ - plaan, väljamõeldis, leiutis;
seadeldis, seadis
- devil /'devil/ - kurat, kurivaim
- devoid of - tühi, lage, ilmaolev (millestki)
- Devonian /di'vouniən/ - devoni (eriti ajastu või ladestu
kohta)
- devour /di'vauə/ - õgima, (ahnelt) sööma
- diagnostic /daɪəg'nɒstik/ - diagnoosi-
- diameter /dai'æmitə/ - diameeter, läbimõõt
- diatom /'daɪətəm/ - ränivetikas
- diatomaceous oozes - ränihlib, ränimuld
- dichotomous /di'kɒtəməs/ - dihhotoomne, kahenev, kaheks
harunev

diet /daiit/ - toit, toitumiskord, dieet

digestive /dai'dʒestiv/ - seede -

diminutive /di'minjutiv/ - väike, pisike, diminutiivne

dinoflagellate /dina'flædʒilit/ blooms - vaguviburvetikate õied

dip - sisse kastma

diplococcus /diplo'k)kəs/ (pl. diplococci /diplo'k)ksai/ - diplokokk

directions - juhtnöörid, juhised

disappoint /disə'p)int/ - (kellelegi) pettumust valmistama

disaster /di'za:stə/ - (suur) õnnetus

discernible /di'zə:nibl/ - tajutav, märgatav, eristatav

discord /'disk)ɔ:d/ - lahkeli; vastuolu

discrimineit /dis'krimineit/ - vahet tegema, eraldama

discriminate against - eelistama, eelistavalt soodustama

disease /di'zi:z/ - haigus

dispatch /dis'pætʃ/ - (lühikest) lõppu tegema, ära tapma; nahka panema, (kiiresti) ära sööma.

displace /dis'pleis/ - (vett) välja suruma

display - näitama

disposal /dis'pouz(ə)l/ - korraldamine, paigutus; eemaldamine, kõrvaldamine; lagundamine; lagundamine

dispose of - kõrvaldama, hävitama

disposition /dispə'zi(ə)n/ - kalduvus, eelsoodumus

disregard /disri'ga:d/ - mitte hoolima, tähelepanemata
jätma

disruption /dis'rʌp ʃ(ə)n/ - lõhastus, lõhustus; lõhang

disseminate /di'semineit/ - levitama, (laiali) külvama

dissimilar /di'similə/ - ebasarnane, teistsugune

dissolve /di'zɒlv/ - lahustama, lahustuma

distinct /dis'tiŋkt/ - selge, selgesti tajutav; erisugune, erinev

distinction /dis'tiŋk ʃ(ə)n/ - distinktsioon, eristatavus

distinguish /dis'tiŋg wi ʃ / - eristama, vahet tegema

distribution /distri'bju: ʃ(ə)n/ - jaotamine, jaotus;
levik

district /'distrikt/ - distrikt, ringkond, piirkond

disturbance /dis'tə:bəns/ - rahurikkumine

diver - sukelduja

diverse /d(a)i'və:s/ - mitmesugune, erisugune

diversity /d(a)i'və:siti/ - mitmekesisus

division /di'vi ʒ(ə)n/ - jagamine

divorce /di'vɔ:s/ - (abielu) lahutus

DNA = desoxyribonucleic acid = desoksüribonukleinhape

division /di'vi ʒ(ə)n/ - jagamine

docile /'dɒsil/, 'dous-, Am. 'dɒsil/ - sõnakuulelik

dolphin /'dɒlfɪn/ - delfiin e. pääsuvaal

dome - kuppel

domestic /də'mestik/ - kodune, kodu-

domestic productions - inimese poolt arendatud vormid,
kodustatud tõud, koduloomade tõud,
kodustatud organismid

domesticate /də'mestikeit/ - kodustama

domestication /dəmesti'kei/ (ə)n/ - kodustus, domestikat-
sioon

dormant /'dɔ:mənt/ - magav, uinuv, puhkav

dorsal - dorsaalne, selgmine

dosage /'dousidʒ/ - doseerimine, annus

dose - doseerima, annusekaupa andma; doos, annus

doubly /'dʌbli/ - kahekordselt, dopelt

down /daun/ - ebemed, udemed

draft - süvis, laeva veesistumise sügavus

dragonfly - kiil (putukas)

drain - drenima, vett kõrvaldama, maad kuivendama

drastic - drastiline, tugevasti mõjuv; järsk, käre

drawing - tõmbamine, vedamine; venitamine; nihutatav

dreary /driəri/ - sünge, õudne, morn, kurb

drizzle - ila tilgutama

drift - triivimine, triiv; triivima

drip - tilkuma, nõrguma

drive, drove, driven - ajama: sundima

drive home - (naela) jne. sisse lööma

driver - kütt

drought /draut/ - põud, kuivus

drought-resistant - põuale vastupidav

drown /draun/ - uppuma; uputama

to be drowned - uppuma

drug - rohi, arstim, -aine, une e. uimastusrohi

drum - trummel

dubious /'dju:biəs/ - kahtlane, ebakindel, -selge

due - vastav; kohane, õigusega kuuluv

be due to - tingitud olema, tagajärjeks olema

dugout /'dʌgaut/ - õõnestatud pautüvi paadina

duly - (nõudeile) vastavalt

durable /'djuərəbl/ - kestev, vastupidav

durability /djuərə'biliti/ - kestvus, vastupidavus

durmast oak - kivitamm

dust - tolm

dwell - elama, elutsema

dwindle - kahanema, vähenema

dye - värvima

dynamic /dai'næmik/ - dünaamiline

E

earthworm /'ə:əwə:m/ - vihmauss

ebb - mõõn, mõõna-aeg

ecologic /ekə'lɒdʒik/ - ökoloogiline

ecologist /i(:)'kɒlədʒist/ - ökoloog

edifice /'edifis/ - ehitis, (suur) hoone

eel - angerjas

erie /'iəri/ - kummaline, imelik, jube

effect /i'fekt/ - täide viima, teostama; efekt, toime,
mõju(avalduis)

in effect - tegelikult

effectually /i'fektjuəli/ - mõjusalt, tagajärjekalt

efficient /i'fi(ə)nt/ - tõhus

eject /i(:)'dʒekt/ - välja heitma või viskama

elective /i'lektiv/ - valitav, valiv

elegant /'eligənt/ - elegantne, maitsekas, peen

ellipsoidal /ilip'soid(ə)l/ - ellipsoidi kujuline

elongate /'i:lɔŋgeit/ - pikendama, pikenema

elongated /'i:lɔŋgeitid/ - piklik, pikaks veninud

elongation /'i:lɔŋ'gei(ə)n/ - pikendamine, pikendus

elude /i'ljʊ:d/ - kõrvale põiklema

embrace /im'breis/ - enesesse haarama, sisaldama

emergence /i'mə:dʒ(ə)ns/ - üleskerkimine, esiletulek,
väljumine, emergents

emergency /im'ə:dʒ(ə)nsi/ (äkki esilekerkiv) häda, (ette-
nägematu) ohtlik juhtum

empire /'empaia/ - impeerium, (suur)riik

employ /im'pli/ - rakendama, tarvitama

enclose /in'klouz/ - tarastama; sulustama; ümbritsema

enclosure /in'klouz/ - tarastus; tarandik

encounter /in'kauntə/ - kohtama, kokku põrkama, (millele-
gi) sattuma

encourage /in'karidʒ/ - julgustama, ergutama

encrust /in'krast/ - koorikuga katma või kattuma, koor-
duma

endocrine glands /'endo(u)krain/ - endokriinsed, sisenõ-
ristuslikud näärmed

endurance /in'djuərəns/ - talumisvõime, kannatus, vastu-
pidavus
enforcement /in'fɔːsmənt/ - pealesundimine, maksmapanek
engraver /in'greivə/ - graveerija
engraving /in'greiviŋ / - gravüür, vaselõige
enormity /in'ɔːmiti/ - hiiglaslikkus, tohutu suurus
enormously /in'ɔːməsli/ - tohutult
ensue /in'sjuː/ - järgnema
entangle /in'tæŋgl/ - sisse mässima, sassi ajama, se-
gastama
enterprising /'entəpraiziŋ / - ettevõtlik, hakkaja, julge
entertain /entə'tein/ - lõbustama, meelelahutust pakkuma
enviable /'enviəbl/ - kadestatav, kadestusväärne
environment /in'vaiə(ə)nmənt/ - keskkond
environmental /invaiə(ə)n'mentəl/ - keskkonna-
enzyme /'enzaim/ - ensüüm, ferment
enzymic /en'zaimik/ - ensümaatiline, fermetatiivne
enzymology /enzai'mɒlədʒi/ - ensümolooogia
ephemeral /i'femə(ə)l/ - efemeerne, ühepäevane, üürike,
lühiajaline
epidermal /epi'dəːm(ə)l/ - epidermiline
epidermis /epi'dəːmis/ - epidermis, marrasknahk
equate /i'kweit/ - võrdsustama, võrdsena võtma
equator /i:'kweitə/ - ekvaator
equatorial /ekwə'tɔːriəl/ - ekvatoriaalne
era /'iərə/ - ajastik, aegkond, ajaarvamine
Erebus /'eribəs/ - Erebos, allilma pimedus personifit-
seeritult

erect /i'rekt/ - püstine, sirge, sirgelt seisev
erratic /i'rætik/ - ebakindel, muutlik
erroneous /i'rouniəs/ - ekslik, väär
error /'erə/ - eksitus, viga, eksimus
escarpment /is'ka:pmənt/ - järsk nõlvak, järsak
esophagus = oesophagus /i:'sɒfəɡəs/ - söögitoru
essential /i'sen / (ə)l/ - oluline, olulise tähtsusega
establish /is'tæbli / / - kindlaks tegema
establishment - rajamine, asutamine; kindlakstegemine;
 majapidamine
estate /is'teit/ - mõis
esteem /is'ti:m/ - lugu pidama, austama, hindama
ethnographic /eθnə'græfik/ - etnograafiline
Eubacteriales /ju:bækti:ri'eili:z/ - (Lad. k.)
evaluation /ivælju'ei / n/ - hindamine
event /i'vent/ - sündmus
in the event of - puhul
evergreen - igihaljas
evidence /'evid(ə)ns/ - tõend, tõendis, tunnistus
evident /'evid(ə)nt/ - ilmne
evocator /'i:vəkeitə/ - esilekutsuja, indutseerija
evolution /i:və'lju: / (ə)n/ - evolutsioon, arenemine
evolve /i'vɒlv/ - välja kiirgama; arenema
exaggerate /igz'ædʒəreit/ - liialdama
excavate /'ekskəveit/ - välja kaevama
excavation /ekskə'vei / (ə)n/ - väljakaevamine, õonestamine
exceed /ik'si:d/ - ületama

- excess /ik'ses/ - liigmäär, liialdus
- excessively /ik'sesivli/ - ülemääraselt
- exclusively /iks'klu:sivli/ - ainuselt, eranditult
- exemplify /ig'zemplifai/ - näidet tooma või näiteks olema
- exert /ig'zə:t/ - tarvitama, esile tooma, (mõju) avaldama
- exertion /ig'zə:ʃ(ə)n/ - tarvitamine; jõupingutus
- exhaustion /ig'zɔ:stʃ(ə)n/ - kurnamine; ärakurnatus,
nõrgestus
- exhaustive /igz'ɔ:stiv/ - (tühjaks) ammutav, põhjalik
- exhibit /ig'zibit/ - esitama, välja panema, näitama
- exit /'eksit/ - väljapääs, väljapääsutee
- exogenous /iks'ɔ:dʒinəs/ - eksogeenne, väline
- exotic /ig'zɔ:tik, ek's-/ - eksootiline, vöörapärane
- expand /iks'pænd/ - laiuma, avarduma
- expel /iks'pel/ - välja heitma või ajama, või tõukama
- expense /iks'pens/ - kulutus, kulu
- at the expense of - (millegi) arvel, kulul
- explosion /iks'plouʒ(ə)n/ - plahvatus; pahvatus, purse
- explosive /iks'plousiv/ - lõhkeaine
- expose /iks'pouz/ - paljastama; paljandama; paljanduma
- exposed rock - paljas, paljandunud või veest väljaaula-
tut kivi või kalju
- be exposed to certain conditions - teatud tingimustes
elama või viibima
- be exposed to drying - kuivale jääma
- be exposed to the air - õhu käes, veest väljas
- exposure /iks'pouʒ/ - (fot.) valgustus, säritlus; pal-
jandumine; paljandamine

exquisite /'ekskwizit/ - peen, hõrk, ilus, oivaline

extend /iks'tend/ - ulatuma, küündima

extension /iks'ten ʃ(ə)n/ - väljasirutus, pikendus

extent - ulatus, määr

to a limited extent - piiratud määral, ulatuses

extermination /ikstə:mi'nei ʃ(ə)n/ - ärahävitamine, välja-
juurimine

external /iks'tə:n(ə)l/ - väline, välispidine

extinct /iks'ti ŋ(k)t/ - väljasurnud

extinction /iks'ti ŋ(k) ʃ(ə)n/ - väljasuremine, häving

extract /iks'trækt/ - välja tõmbama, esile tooma

extreme /iks'tri:m/ - äärmus

extremities /iks'tremitiz/ - jäsemed

extricate /'ekstrikeit/ - lahti mässima

extrude /iks'tru:d/ - välja tõukama või suruma

eyebrow /'aibrau/ - silmakulm

F

face - kindlalt vastu astuma

facial /fei ʃ(ə)l/ - näo-, näosse puutuv

fade - närtsima, tuhmuma, vaibuma

fairy /fɛəri/ - haldjas, fee

familiarity /fæmili'æriti/ - tutvus, asjaga tuttav või
kursis olema

fancier /'fænsiə/ - (mingi asja, eriti looma-, taime-)
harrastaja, kasvataja või müüja

fascinate /'fæsineit/ - paeluma, võluma

fastigate /fæs'tidʒieit/ - samakõrgune, ühekõrgune
fatal /'feɪtəl/ - saatuslik, surmaga lõppev
fatigue /fə'tiːg/ - väsimus
favor /feɪvə/ - soosima, soodustama
favor a possibility - mingi võimaluse e. oletuse poolt
 rääkima
favorable /'feɪv(ə)rəbl/ - soodus
feat /fi:t/ - kangelastegu, vägitükk
feather /feðə/ - sulg
features /'fi:tʃəz/ - näojooned
feeding - toitumine
feline /'fi:lain/ - kassi-, kassile omane
female /'fi:meɪl/ - emane, emas-
fence - tara, tarastis, aed, hekk
feral /'fiər(ə)l/ - metsik, kodustamata (looma kohta)
fermentation /fə:men'teiʃn/ - käärimine, fermentatsioon
fern - (maarja-)sõnajalg
ferret /'ferɪt/ - küüliku e. jahituhkur
fertile /'fɜ:taɪl/ - viljakas
fertile egg - viljastatud muna
fertilise /'fɜ:tilaɪz/ - viljastama
fertility /fɜ:'tɪlɪti/ - viljakus
fertilization /fɜ:til(a)i'zeɪʃn/ - viljastus
fertilizer /'fɜ:tilaɪzə/ - väetis
fidelity /fai'delɪti/ - truudus, ustavus
figurehead - (laevaninas asetsev) ilustiskuju
filament /'fɪləmənt/ - filament, horm, kiud; tolmukaniit

filamentous /filə'mentəs/ - kiudjas, niitjas

file - rida, rivi

film - kile

filter - kurn, filter

fin - (kala) uim

ray-fin - kiiruimeline

lobe-fin - sagaruimeline

fine-grained - peene toime e. koetusega

finish - viimistlus

fiord /fjɔ:d/ - fjord, lõhang (laht)

first-hand - otsesest allikast (saadud)

fission /fi } n/ - raku pooldumine

fist - rusikas

fit - kohastuma; sobiv, sünnis, kõlblik; sobima, kõlbama,
sobitama, sobivaks tegema

fit with - varustama (millegagi)

fittest - enam kohastunu

fix - fikseerima, kinnistama

flagellum /flə'dʒeləm/ - (pl. flagella /flə'dʒelə/ -
- vibur, flagelo

flank - külg

flash - välgatama, sähvatama

flat - lame, lausik; laugmadalik

flatten /'flætən/ - lamestama

flatworm /flætwa:m/ - lameuss

flavor /'fleivə/ - aroom, meeldiv lõhn

fledgling /'fledʒliŋ/ - noor (parajasti suled saanud)
lind

flee, fled, fled - põgenema
fleeting - põgus, kiiresti mööduv
flexible - painduv
flexuous - keerlev, looklev, kurd-
fling, flung, flung - viskama, heitma, paiskama
float /flout/ - ujuma, veepinnal kandma
flock - kari, hulk, salk; parv (linde)
flood /flʌd/ - üleujutus
floristic /flɔˈrɪstɪk/ - floristiline, (taime) liigiline
fluctuate /ˈflʌktʃueɪt/ - (üles-alla) kõikumine
flyblown - reostatud, rikutud
foe - vaenlane
fold - kurd, volt
foliage /ˈfəʊliɪdʒ/ - lehestik; okaspuul okkad
foliose /ˈfəʊliəʊz/ - lehelaadne
foliose lichen - lehelaadne samblik
folk /fouk/ - rahvas; inimesed
follow out - (eeskirjadest) täpselt kinni pidama
follow suit - (eeltehtut) järele tegema, sama tegema
foot - arvet kinni maksmine
forbid, forbad, forbidden - keelama
forcefully - jõuliselt
forcibly - vägivaldselt
forebears - esivanemad
foregoing - eelnev, ennemainitud
forest - mets
virgin forest - põlismets
forester - metsakasvataja

forestry - metsandus
formation - moodustamine; moodustumine, kujunemine
formidable /'fɔːmɪdəbl/ - kohutav, hirmuäratav; raske
fort - fort, kindlustus, kants
fortify /'fɔːtɪfaɪ/ - (väidet) kinnitama
fortress - kindlus
fortuitous /fɔː'tjuːɪtəs/ - juhuslik
forward - laeva vööris (ninaosas) asetsev

fossil /'fɒs(i)l/ - kivistis, fossiil
fossilized /'fɒsɪlaɪzd/ - fossiilne
fourtined - neljajaharuline
fowl /faʊl/ - (kukk või) kana, (kanaliste seltsi) kodu-
lind, sulgloom
fraction - murdosa, tükk
fracture /'fræktʃə/ - murduma; purustama, murdma
fragmentation /frægmən'tei(ə)n/ - killustumine
frail - nõrk, õrn, habras
framework - raamistik, toestik
freighter /'freɪtə/ - prahilaev
frenzy /'frenzi/ - meeleetus, raev(us)
frequency /'friːkwənsi/ - sagedus, tihedus
frequent /friː'kwent/ - tavaliselt asuma; sagedasi või
alaliselt käima või külastama
fringe - ääriseks olema
frog - konn
frown /fraʊn/ - kulmukortsutus, kuri pilk

frugal /'fru:gəl/ - kokkuhoidlik, vähenõudlik, lihtne
fuchsia /'fju:ʃə/ - fuksia (lill)
Fuegian /'fju:dʒiən/ - tulemaalane
fuel /fju:il/ - põletus- või kütteaine
fuel line - kütetoru
functional /fʌŋk(ə)n(ə)l/ - funktsionaalne, talitus-
 lik, toimeline
fungus /'fʌŋɡəs/ (pl. fungi /fʌŋɡai/) - (madalam) seen
funnel /fʌn(ə)l/ - lehter, trehter, torn
furrow /fʌrou/ - kortsutama, vaostama
fuse - kokku, ühte sulatama, sulama
fuselage /'fju:zilidʒ/ - lennukikere
futile /'fju:tail/ - kasutu, asjatu

G

gadget /'gædʒɪt/ - masinavärgi seadis, masinaosa
Gaelic /geilɪk, gælɪk/ - gaeli, Šoti kõrgmaa (kelti
 päritolu) elanikesse puutuv
gain - saavutama
gain altitude - kõrgemalè tõusma
gall /gɔ:l/ - sapp
galley /'gæli/ - laevakööök
two-burner oil galley - kaheauguline või -kohaline õli-
 küttega pliit
game - uluk, jahiloom, -lind, -saak
gang - salk, jõuk, grupp
gap - auk; tühe, lõhe

gape - sund pärani ajama, haigutama
garland /'ga:lənd/ - lille- või lehevanik
garua - kohalik paduvihm
gasoline /'gæsoli:n/ - gasoliin, bensiin
high octane gasoline - kõrge oktaanarvuga bensiin
gasp - õhku ahmima, hingeldama
Gaucha /'gaut(ə) ou, 'gɔ:/ - gautšo (hispaania indiaani
 segarahva liige L.Ameerikas);
 ratsakarjane
gauge /geɪdʒ/ - mõõteriist
gauzy /'gɔ:zi/ - gaasriide- või looritaoline
gay - lõbus, ere, kirev
gazelle /gə'zel/ - gasell, põderkits
gear /giə/ - seadis, masinavärk; varustis, majariistad
gelatin /dʒelə'ti:n/ - želatiin
gene /dʒi:n/ - geen
generalize /'dʒen(ə)rəlaɪz/ - üldistama, üldmaksvusele
 viima
generously /'dʒen(ə)rəsli/ - heldelt, ohtralt, rikkali-
 kult
genetic /dʒi'netɪk/ - geneetiline, tekkeline
genetics /dʒi'netɪks/ - geneetika, pärilikkuseõpetus
genic /'dʒenɪk/ - geeni-
genitals /'dʒenɪtəlz/ - genitaalid, (välised) suguelun-
 did
gentle /'dʒentl/ - leebe, õrn
genus /'dʒi:nəs/ (pl. genera /'dʒenərə/ - perekond,

genus; (üldse) liik, sort

geological /dʒio'liɔʒik(ə)l/ - geoloogiline

geranium /dʒi'reiniəm/ - kurereha (taim); (toalillena)
geraanium e. pelargoonium

germinate /'dʒə:mineit/ - idanema, tärkama

gesture /'dʒestʃə/ - žest, väljendusliigutus

'get ahead' - siin: võimust võtma

gigantic /dʒai'gæntik/ - hiiglaslik

gills /gilz/ - (kala) lõpused

giraffe /dʒi'ra:f/ - kaelkirjak

girth /gə:θ/ - ümbermõõt

give way - taanduma, järele andma; kokku varisema

glacial /'gleisiəl/ - (i)al, 'glæ-/ - jää-, jää-
aegne

glaciation /glæsi'eɪʃən/, gleisi-/ - jää(liustikuga)
kattumine

glacier /'glæsiə, 'gleɪʃiə/ - jääliustik

glide - libisema, liuglema

glisten /glɪsn/ - sätestama, särama

glow /glou/ - hõõguma, õhetama; hõõgus, õhetus

glue /glu:/ - kleepima

glycoside /'glikousaid/ - klükosiid

gnarled /'na:ld/ - pahklik; okslik

gnu /nju:, nu:/ - gnuu, (Aafrika) pühvelhobu

goat /gout/ - kits, sikk, sokk

goldfinch - ohakalind e. tiglits

gorge /gɔ:dʒ/ - kuristik, mäekuru

gory /'gɔ:ri/ - vesine
Gothic /'gɔθik/ - gooti
grab - kahmama, krapsama
graft /gra:ft/ - pookoks
grandeur /'grændʒə, -dʒə/ - suurus, suursugusus
granule /'grænju:l/ - terake; granuul
grant - rahuldama, täitma palvet
grasses - kõrrelised
gravid - rase (= pregnant)
graze - (karjamaal) rohtu sööma
grease /gri:s/ - (looma) rasv; sularasv, määre
greasy /'gri:zi/ - rasvane, määrdeline, õline
gregarious /gri'gɛəriəs/ - karjana elav, ühiskondlik,
 seltsi armastav
grim - vali, karm, vihane, rõõmuta
grind, ground, ground - hõõruma; hõõrduma; väntama
grip - haare
gross /grouz/ - lopsakas; kogusummaline; jäme
grotesque /gro(u)'tesk/ - groteskne, kentsakas, veider
grove - metsasalu, hiis
grumble - nurin, urin, torin
guahog - söödav ümmargune merekarp P. Ameerika Atlandi
 ookeani rannikult
guanaco /gwa'na:kou/ - guanaako
guanay /gwa'nai/ - kohalik röövkala L. Ameerikas
guano /'kwa:nou/ - guaano, (mere)linnusõnnik
guarantee /gʌr(ə)n'ti:/ - garanteerima, tagama, kind-
 lustama

guard /ga!d/ - valvama, kaits(e)ma
guide /gaid/ - juhatama
gulp - kugistama, alla neelama
gum - ige(med)
gummy /'gʌmi/ - liimjas; kummitaoline
gut - sool, soolikas

H

habitat /'hæbitæt/ - (taime või looma) looduslik asu-
 miskoht, leiukoht
habitual /hə'bitjuəl/ - harjumuslik, harjumuspärane
habitually /hə'bitjuəli/ - harilikult, tavaliselt
haft /ha:ft, hæft/ - (noa, mõõga jne.) käepide
harbor /'ha:bə/ - sadam
hardy - tugev, vastupidav
harmful /'ha:mful/ - kahjulik
harmless /'ha:mlis/ - kahjutu
harpoon /ha:'pu:n/ - harpuun (kisuline viskeoda)
hatch /hæt/ - hauduma
hatchway - luugiava (eriti laevadekis)
haul /hɔ:l/ - tassima, tõmbama, vedama
haven /heivn/ - sadam
haw /hɔ:/ - viigipuumari
hawk /hɔ:k/ - kull
hawthorn /'hɔ:θɔ:n/ - (okas)viirpuu
hazard /'hæzəd/ - oht
haze - uduseks või häguseks tegema

head - suunduma, liikuma
heading - lahter, rubriik
heal - tervistama, ravima, parandama
hearth /ha:θ/ - kolle; tulease
heartsease /'ha:tsi:z/ - käoorvik
heath /hi:θ/ - nõmm
barren heath - metsatu nõmm
heather /heʒə/ - kanarbik
hedgerow /'hedʒrou/ - hekipõõsastik
herb - rohttaim, rohi
herbaceous /hə:'beɪʃəs/ - rohttaime-, rohu-
herbaceous plant - rohttaim
herbiage /'hə:biʒ/ - rohttaimed
grassy herbiage - kõrrelised rohttaimed
herd - kari
plains animal herds - lauskmää loomakarjad
hereditary /hi'redɪtəri/ - päritud, pärilik
heterocyclic /het(ə)ro'saiklik/ - heterotsüklikiline
hide - (looma karvane) nahk (toorelt või pargitult);
 peidupaik
hiker - matkaja, jalgsi rändaja
hindrance /'hɪndr(ə)ns/ - takistus, tõke
hip - puus
hog - siga; nuumsiga
hoist - heiskama, üles tõmbama
hold - (dekialune) laeva kaubaruum
hold true for - paika pidama, õigusega millegi, kelle-
 gi kohta käima .

hollow /'hɔləu/ - õõnestama
holly - astelpõõsas, iileks
honey-bee /'hʌnibi:/ - (tavaline taru-)mesilane
honorary /'ɔn(ə)rəri/ - auavalduseks antud või auametina
 peetav
homogeneous /hɒmo'dʒeɪəs, -'dʒi:n / - ühtlik, homo-
 geenne
homologous /hɒ'mɒləgəs/ - samandlik, homoloogne
hood /hud/ - kapuuts, kotitaoline peakate
hoof /hu:f/ - kabi
hoop - vits, võru
hoopoe /'hu:pu:/ - laanekukutaja, toone- e. vainukägu
horn - sarv, sarvollus
horny - sarvjas
horticulturist /hɔ:ti'kʌlt(ə)rist/ - aiaviljur
host - (parasiidi) peremees; makroorganism; kõrtsi- või
 võõrastemaja peremees
host of - suur hulk midagi
hover /'hɒvə, 'hʌvə/ - hõljuma
hug - kaisutama, embama; ligi hoiduma (kaldale)
humble-bee - kimalane e. kumalane
humid /'hju:mid/ - niiske
humidity /hju:'miditi/ - niiskus
humus /'hju:məs/ - humus
hutch /hʌt()/ - (kodujänete-) kuut
hybrid /'haibrid/ - hübriid, värd
hydrogen sulphide /'haɪdrədʒən 'sʌlfaid/ - väävelvesi-
 nik

hydrophilic /haɪdrə'fɪlɪk/ - hüdrofiilne, niiskuslembene

hydrophyte /'haɪdrəfaɪt/ - hüdrofüüt

hyena /ha(i)'i:nə/ - hüään

hypodermic /haɪpə'dɜ:mɪk/ - nahaalune, naha alla süstitav

hypothesis /h(a)i'pəθɪsɪs/ (pl. -theses /-θɪsi:z/) -

hüpotees

hypothetical /h(a)ɪpə'θetik(ə)l/ - hüpoteetiline, oletus-
lik

hysteria /his'tɪərɪə/ - hüsteeria

I

identical /aɪ'dentɪk(ə)l/ - samane, identne

identifiable /aɪ'dentɪfaɪəbl/ - eraldatav, äratuntav;
samastatav

identify /aɪ'dentɪfaɪ/ - määrama, kindlaks tegema; ära
tundma; identifitseerima, samas-
tama

ignite /ɪg'nait/ - süütama

image /'ɪmɪdʒ/ - kuju, kujutis

imbed - sängitama, mingisse ainesse sisendama

immemorial /ɪmɪ'mɔ:riəl/ - igiammune, -vana

immerse /ɪ'mɜ:s/ - sisse kastma

immigrate /'ɪmɪgreɪt/ - sisse rändama

immobilize /ɪ'məʊbɪlaɪz/ - liikumatuks tegema

immune serum /ɪ'mju:n 'siərəm/ (pl. sera /'siərə/ -
immuunseerum

impact /'imp ækt/ - kokku või vastupõrge
impala - impala (liik antiloope)
impart to - edasi andma
impend - üle või kohal rippuma; tulekul või eel olema;
 ähvardama
impervious /im'pə:viəs/ - läbimatu, läbipääsematu
implement /'implimənt/ - tööriist
implication - sissemääsimine, asjasse segamine, kaasa-
 arvamine
imply /im'plai/ - vihjama, osutama
impractical = unpractical - ebapraktiline
impregnate /im'pregneit/, 'imp- / - immutama; eostama
imprint /'imprint/ - jälg, jäljend, märk, tempel
imprison - vangistama
improbable /im'prɒbəbl/ - ebatõenäoline
inaccurate /in'ækjuri:t/ - ebatäpne
inadvertence /inəd'vɜ:təns/ - tähelepanematus, hooletus
Inca /'iŋkə/ - inka (L. Am. endise indiaani suguharu
 liige, selle suguharu valitseja)
incapacitate /inkə'pæsiteit/ - (tegu)võimetuks tegema
inch - toll (2,54 cm)
incidentally /insi'dentəli/ - juhuslikult; muuseas, mui-
 de, möödaminnes
inclination /inkli'nei (ə)n/ - kalduvus; kalle, kald,
 kaldumine
incline - kallutama, painutama
inclosure /in'klouzə/ - tarastus

include /in'klu:d/ - endasse mahutama
inclusion /in'klu: ʒ(ə)n/ - sisaldis
inclusion bodies - sulunduskehakesed
incombustible /inkəm'bʌstibl/ - põletamatu, põletuskõlbamatu
incomparable /in'kɒmp(ə)rəbl/ - võrreldamatu
incomplete /inkəm'pli:t/ - ebatäielik, puudulik
incomprehensible /inkɒmpri'hensibl/ - arusaadamatu, arusaamatu
inconsistency /inkən'sistənsi/ - vastuolulisus
incubate /'inkjubeit/ - hauduma
incubation /inkju'bei ʃ n/ - inkubatsiooni periood; kultiveerimine, (bakterite) kasvatamine
index /'indeks/ - näitaja
index finger - esimene sõrm
indicate /'indikeit/ - osutama, näitama, viitama
indication /indi'kei ʃ (ə)n/ (tunnus)märk
indignation /indig'nei ʃ (ə)n/ - põlastav meelepaha, nõrdimus, püha viha
indigo /'indigou/ - indigo (sinine värvaine)
indiscriminate (indis'kriminit/ - vahettegematu
indispensable /indis'pensəbl/ - hädavajalik
individual /indi'vidjuəl/ - indiviid, isend
induce /in'dju:s/ - esile kutsuma; põhjustama; mõjustama; indutseerima
inedible /in'edibl/ - mittesöödav, söömiskõlbmatu
inert /in'ɜ:t/ - inertne, loid, tegevusvõimetu

inevitable /in'evitəbl/ - vältimatu
inexhaustible /inɪg'zɔːstɪbl/ - ammendamatu
inextricable /in'ekstriːkəbl/ - lahutamatu
infective /in'fektɪv/ - nakatav
infer /in'fəː/ - järeldama
infestation /ɪnfes'teɪʃ(ə)n/ - kahjustamine
infinitely /'ɪnfɪnɪtli/ - lõpmatult, piiritult, määratult
inflammation /ɪnflə'meɪʃ(ə)n/ - põletik
inflate /in'fleɪt/ - täis puhuma
inflict /in'flikt/ - tekitama (haava, valu)
inflorescence /ɪnflɔ'rens/ - õisik
informant /ɪn'fɔːmənt/ - teadeteandja, informeerija
infra - allpool-, all-
infuriate /ɪn'fjuəriət/ - raevustama, maruvihaseks tegema
ingest /ɪn'dʒest/ - neelama
inherent /ɪn'hɪərənt/ - kaasasündinud, omane; kaasas-
 käiv
inheritable /ɪn'herɪtəbl/ - päritav
in an inheritable manner - pärilikult
inheritance /ɪn'herɪtəns/ - pärand, pärandus
inject /ɪn'dʒekt/ - süstima
injurious /ɪn'dʒuəriəs/ - kahjustav, kahjulik
injury /'ɪndʒ(ə)ri/ - vigastus, kahjustus
inkling - märguande, vihje; aim, aimdus
inoculate /ɪn'ɔkjuleɪt/ - külvama, inokuleerima
inroad - röövretk; sissetung, üle- või sissehaaramine
insect /'ɪnsɛkt/ - putukas
wood-boring insect - ürasek

insectivorous /insek'tivarəs/ - putukasööja
insensibly /in'sensibli/ - märkamatu, vähehaaval
insertion /in'sə: (ə)n/ - sisse- või vahelepanek
insist - rõhutama, toonitama; peale käima, kindlasti nõudma
insolation /insju'lei n/ - eraldatus, isolatsioon
insoluble /in'sɒljubl/ - lahustamatu
install /ins'tɔ:l/ - (masinaid, elektrivalgustust jne.)
 üles seadma; installeerima, monteerima
instance /'instəns/ - väide, näidis; (eri) juht
institute /'ɪnstɪtju:t/ - asutama, sisse seadma, ellu
 kutsuma
insurance /in') uərəns/ - (varanduse, elu-) kindlustus
intelligent /in'telɪdʒənt/ - arukas, taibukas, intelli-
 gentne
intend - kavatseda, mõtlema
intent /in'tent/ - kavatus
to all intents and purposes - niisamahästi kui, peaaegu
intergrade (with) /ɪntə'greɪd/ - vahepealne (vorm jne.)
 olema
interior /in'tiəriə/ - sise-
interior joinery - siseruumi kujundus, interjööri
interlace /ɪntə:'leɪs/ - kokku või läbi põimima; kokku
 või läbi põimima
intermediate /ɪntə'mi:djət/ - vahepealne, vahemine
intermingle /ɪntə(:)'mɪŋgl/ - kokku segama, segunema
intermittent /ɪntə:'mɪt(ə)nt/ - vahetevahel peatuv;
 vahelduv

interpret /in'tə:prit/ - tõlgendama, tõlgitsema
interpretation /intə:pri'tei/ (ə)n/ - tõlgitsus, tõlgendus
intersect /intə'sekt/ - (läbi) lõikama
intertidal /'intə'taidəl/ - (merevee) tõusu-ja mõõnavahe-
line
intertwine /intə:'twain/ - läbi põimima või põimuma
intervall /'intəvəl/ - (ruumi-, aja-) vahemik, vahemaa, vaheaeg
intervene /intə'vi:n/ - vahele tulema; vahele astuma
intestinal /in'testinaəl/ - soole-
intimate /'intimit/ - sisim, lähim
intimately /'intimitli/ - lähedalt, intiimselt
intoxication /intɒksi'kei/ (ə)n/ - mürgistus, intoksikatsioon
intrepid /in'trepid/ - kartmatu, kohkumatu
intricate /'intrikit/ - keerukas
intruder /in'tru:d / - sissetungija
inundate /'inʌndeit/ - üle ujutama
invaluable /in'væljuəbl/ - hindamatu, hindamatu
invariably /in'vɛəriəbli/ - muutumatult
invert /in'vɜ:t/ - ümber või vastupidi pöörama
invertebrate /in'vɜ:tibrit/ - selgrootu
investigation /investi'gei/ (ə)n/ - uurimine
invoke /in'vouk/ - tunnistajaks kutsuma; appi hüüdma
involuntarily /in'vɒlənt(ə)rili/ - tahtmatult
involution /invɔ'lu: / (ə)n/ - taandareng; involutsioon

involve in - asjasse segama

iodine /'aɪdaɪn/ - jood

ion /'aɪɒn/ - ioon

iridescent /iri'desnt/ - sillerdav

irradiate /i'reɪdi'eɪt/ - kiiritama

irrigation works - niisutusseadeldis

irritate /'ɪriteɪt/ - ärritama, pahandama

islet /'aɪlɪt/ - väike saar, saareke, laid

isolation /iso'lei(ə)n/ - eraldamine, eraldumine

issue /'ɪʃuː, 'i(j)uː/ - väljuma, välja voolama

item /'aɪtəm/ - (eeskava, loetluse) punkt, üksikpunkt,
-asi; teade, sõnum

J

jackal /'dʒækəl/ - šaakal

jag - sakk, täke

Japanese /dʒæpə'niːz/ - jaapani

joinery /'dʒɔɪnəri/ - tiseritöö

interior joinery - siseruumi kujundus, interjöö

joint - ühine

judge /dʒʌdʒ/ - otsustama, hindama, järeldama

jungle /'dʒʌŋɡl/ - džungel

justification /dʒʌstifi'keɪ(ə)n/ - õigustus

K

- keel - (laeva) kiil, (laeva) emapuu, andur
- kelp - kelp (suur merevetikas; selle tuhk, millest saadakse joodi jne.)
- kettle /ketl/ - katel, pada
- kingdom - kuningriik; riik
- knot /nɔt/ - sõlm; pähk oks; mer. sõlm (laeva kiirus-ühik = 1 meremiil = 6080 jalga = 1853 m tunnis)
- knotty /'nɔti/ - sõlmeline; okslik/
- kongonis - kongonis-antiloop

L

- label /leibl/ - iseloomustavalt tähistama
- labium = lip
- labyrinth /'læbərɪnθ/ - labürint, keerustik
- lack - puuduma; puudus, ilmaolek
- lactic /'læktɪk/ - piima-, piim-
- lagoon /lə'gu:n/ - laguun (madal laht, mis on merest leetseljakuga või korallirahuga lahutatud)
- lamina /'læminə/ (pl. -ae /-i:/) - lehtmoodustis, õhuke kiht
- lamprey /'læmpri/ - silm e. sutt e. nõgenool (kala)
- landfall - (laeva) maandumine, randumine
- landlocked bicycle - stendjalgratas

landmark - piiri- e. rajakivi

lapse - (aja) möödumine

larch /'la:t(/ - lehɪs

larva /'la:və/ (pl. -ae /-i:/) - (putuka) vastne, tōuk,
larv

larval /'la:vəl/ - vastseline, larvaalne

lash - piitsutama

late - hiljutisurnud, kadunud

latex /'leiteks/ vessels - piimasooned

latitude /'lætɪtju:d/ - (geogr.) laius, laiuskraad

layer /lɛə / - kiht

layman /'leimən/ - vōhik

lb = pound - nael (kaaluühik)

leak - lekkimiskoht (pragu, lõhe, mille kaudu immitseb vett laeva sisse); lekkima, sisse või välja immitsema

lean /li:n/, leant /lent/, leaned - nōjatama

lean away from prevailing wind - valitsevatest tuul-
test längu painutatud

leech /li:t/ - kaan

leisurely /'leʒəli/ - mitteruttav, aeglane

leopard /lepəd/ - leopard

lessen /lesn/ - vähenema, vähendama

liable /'laɪəbl/ to - kergesti alistuv, kalduv

liana /li'a:nə/ - liaan (troopikaline ronitaim)

lichen /'laiken, -kin/ - samblik

lift - tõstma, kergitama

frost lift - külmakerge
lighthouse - tuletorn
lightning /'ləɪtnɪŋ/ - välk
likely - tõenäoline
likewise /'laɪkwəɪz/ - samuti
lime - lubi
limit - piirama, piiriks olema, kitsendama
limit oneself - piirduma
limpet /'lɪmpɪt/ - liudkodlane, limune
line - vooderdama, voodriks olema
linear /'liːniəl/ - sirgjooneline, joonetaoline, pikiulatuslik
linger /'lɪŋgə/ - püsima
lion /laɪən/ - lõvi
liquid /'lɪkwɪd/ - vedelik
liquor /'lɪkə/ - alkoholine e. joovastav jook
literal /'lɪt(ə)r(ə)l/ - sõna-sõnaline
literally /'lɪt(ə)r(ə)li/ - täht-tähelt, sõna tõsisest mõttes, liialdamatult
litter - pesakond (kutsikaid, pörsaid jm.); sasina katma
littoral /'lɪtərə(ə)l/ - ranna, rannavöötmeline, litoraalne, litoraal
liver /'lɪvə/ - maks
lizard /'lɪzəd/ - sisalik
llama /'laːmə/ - laama (L. Ameerika lammaskaamel/
load - koormama, lastima, laadima
loam - savimuld

lobe - (lehe) hõlm; sagar, lott

lobe-fin - sagaruimeline (kala)

locate /lou'keit/ - asetama, paigutama; asukohta kind-
laks määrama

location /lo(u)'kei (ə)n/ - koht, asukoht

locomotion /loukə'mou (ə)n/ - kulgemine, liikumine

locust /'loukəst/ - rändav rohutirts

log - (puu)palk; puuront

lone - üksik, üksildane

longevity /lɒn'dʒeviti/ - pikaeealisus, pikk eluiga

loon /lu:n/ - jääkaur

loose /lu:s/ - lahtine, vaba

'lords of creation' - looduse isandad

lugubrious /lju:'gju:brɪəs/ - kaeplik, kurb

lumen /'l(j)u:men/ - (pl. -mina /minə/) - valendik,
luumen

lungfish - kopskala

lurch /'lɜ:t/ - äkiline küljelekaldumine, vaarumine

M

M.D. = Doctor of Medicine

magic /'mædʒɪk/ - nõia-, maagiline

magnify /'mægnɪfaɪ/ - suurendama

magnitude /'mægnɪtju:d - suurus; aste; ulatus; tugevus

magnolia /mæg'nouliə/ - magnoolia

maiden tree - pügamata puu

majestic /mə'dʒestɪk/ - majesteetlik, ülev

major /'meɪdʒə/ - suurem, ülem

make good - (lootust) täitma, heastama

make good one's escape - end päästa õnnestuma

make-up - koostus, koosseis; loomus, laad; moodustama

malaria /mə'liəri/ - malarial, hallitõbi

male - isane, isas-

mammal - imetaja

mammalogist /mæ'mælədʒɪst/ - mammaloloog

mammalian /mæ'meɪliən/ - imetaja-

man - inimesega varustama

mandarin /'mændərɪn/ - mandariin (puuvili)

mandible - suis (suisse)

maneuverable /ma'nu:vərəbl/ - manööverdamisvõimeline

mania /'meɪniə/ - hullus, maania

manifest /'mænɪfest/ - ilmutama, avaldama

manifestly /'mænɪfestli/ - ilmselt

manioc /'mæniək/ - maniokk e, kassava (troopilisest

L. Am-st pärinev põõsastaim piimalil-
leliste sugukonnast, kasvatatakse
suurte tärgliserikaste mugulate
pärast)

manipulation /mənɪpju'leiʃ(ə)n/ - käsitsus, menetlus

manual /'mænjuəl/ - käsiraamat

manufacture /mænju'fæktʃə/ - valmistama

maple /meɪpl/ - vaher

margin /'ma:dʒɪn/ - äär, serv

marginal /'ma:dʒɪn(ə)l/ - ääre-

marked /ma:kt/ - märgatav, silmatorkav, tunduv
marking - märkimine, tähistus, märgistus
marvel /'ma:v(ə)l/ - imestlema
marvelous /'ma:v(i)ləs/ - imestamisväärne
mast /ma:st/ - tammetõrud (sigade jne.) nuumtoiduks
masthead - mastitipp
mate - paari minema, paarima
mature /mə'tjuə/ - küps, valminud; küpsema, valmima
maturity /mə'tjuəriti/ - küpsus
maze - keerdkäigustik, labürint
meager /'mi:gə/ - kõhetu, kõhn; kehv, vähene, napp
mean - alatu, madal, tähtsusetu
no mean task - raske, tähtis ülesanne
measure /'meɜ:/ - mõõt; vahend, abinõu; kriteerium,
hindamismõõdupuu; mõõtma
mechanics /mi'kæniks/ - mehhaanika
mediate /'mi:diəit/ - vahendama, vahetalitajaks olema,
sobitama
medicinal /mi'disin(ə)l/ - arstiv, raviv, tervendav
medieval /medi'i:v(ə)l/ - keskaegne
Mediterranean /meditə'reiniən/ - Vahemere(-)
medium /'mi:diəm/ (pl. media /mi:diə/) - keskkond; toi-
tekeskkond,
sööde; keskmine,
mõõdukas
membrane /'membrein/ - kile, membraan
menace /'menəs/ - ähvardama; hädahoht, ähvardus

mere /miə/ - paljas, aihult

mesas - (Hisp. k.) platoo

mesophyte /'mesəfait/ - mesofiit

metabolic /metə'bɒlik/ - ainevahetuse

metamorphosis /metə'mɔːfəsis, -mɔː'fousis/ - moone, meta-
morfoos

metaphorical /metə'fɔːrɪk(ə)l/ - metafoorne, piltlik

methodical /mi'θə'dɪk(ə)l/ - metoodiline, kavakindel

methyated spirits /'meθiːleɪtɪd/ - metüülpiiritus

microbiologist /maɪkrəʊbaɪ'ɒlədʒɪst/ - mikrobioloog

microbiology /maɪkrəʊbaɪ'ɒlədʒi/ - mikrobioloogia

micrometer /maɪ'krɒmɪtə/ - mikromeeter

midden /mɪdn/ - sõnniku- või jäätmehunnik

midrib - (lehe)keskrood

migration /maɪ'greɪ(ə)n/ - ränne, rändamine

miniature /'mɪniətʃuə, -nɪtʃuə, -tʃə/ - miniatuurne,
pisimõõduline

minus /'maɪnəs/ - maha arvatud, ilma, miinus

minute /maɪ'njuːt/ - pisike, pisitilluke

miracle /'mɪrəkl/ - ime, imetegu

miraculous /mi'rækjʊləs/ - imetaoline

misapprehend /mɪsəpri'hend/ - vääriti mõistma

misnomer /mɪs'nəʊmə/ - väärnimetus, valenimetus

miss - vahele või välja jätma

missionary /'mi(ə)n(ə)ri/ - misjonär

mitigate /'mɪtɪgeɪt/ - pehmdama, mahendama

mobile /'məʊb(a)ɪl/ - liikuv

moderate /'mɒdəraɪt/ - mõõdukas, paras
modification /mɒdɪfɪ'keɪʃn/ - muutmine, modifikatsioon
modified /'mɒdɪfaɪd/ - muundunud, erikuju omandanud,
 modifitseerunud
modify /'mɒdɪfaɪ/ - muutma, modifitseerima
moisture /'mɔɪstʃə/ - niiskus
molar /'məʊlə/ - puri-, (toidu)puremis-
mold /mould/ - hallitus; hallitusseen; kujundama, vormi-
 ma
mole - mutt
mollusc /'mɒləsk/ - mollusk, limune(loom)
molt /moult/ = moult - sulgimine
monastic /mɒ'næstɪk/ - munga-, kloostri-
monstrosity /mɒns'trɒsɪti/ - koletuslikkus
monstrous /'mɒnstɹəs/ - koletislik, peletislik
moor /muə/ - (paati, laeva) kaldale kinnitama (kõie või
 keti abil)
moribund /'mɔ(:)rɪbʌnd, -bænd/ - suremas haige
morphology /mɔ:'fɒlədʒi/ - morfoloogia
morsel /'mɔ:s(ə)l/ - suutäis, tükike, pala
mosquito /mɒs'ki:tou/ - moskiito, sääsklane
moss-rose - sammalroos
moth /mɔ(:)θ/ - siin: koilaste hulka kuuluv putukas
motile /'məʊtaɪl/ - liikuv, liikumisvõimeline
motility /məʊ'tɪlɪti/ - motiilsus, liikumisvõime
motivate /'məʊtɪveɪt/ - põhistama, motiveerima
mottled-grey - hallilaiguline

mould /mould/ - hallitus
mound /'maund/ - muldvall; künigas, kühm
mount /mʌunt/ - tõusma, kerkima, kuhjuma
mucilaginous /mju:si'lædʒɪnəs/ - limane
mucus /'mju:kəs/ - lima
mule /mju:l/ - muul
multiplication /mʌltipli'keɪ(ə)n/ - paljundamine,
 paljunemine
multiply /'mʌltiplaɪ/ - paljundama, paljunema
multitude /'mʌltɪtju:d/ - paljus, rohkus, arvurikkus
municipal /mju(:)'nɪsɪp(ə)l/ - linna, omavalitsuse
murmur /'mɜ:mə/ - ümin, pomin; nurin
muscle /mʌsl/ - muskel
muscular /'mʌskjʊlə/ - muskulaarne, lihase-
mussel /'mʌs(ə)l/ - meri- või jõe- või konnakarp
mustache = moustache /mʌs'ta:ʃ/ - vurrud, vuntsid
mutant - mutant
mute /mju:t/ - tumm, hääletu, sõnatu
mutton /mʌtn/ - lambaliha
mutual /'mju:tʃu(ə)l/ - vastastikune, mõlemapoolne
myriad /'mɪrɪəd/ - müriaad, musttuhat, lõpmata suur arv
myth /miθ/ - müüt

N

nail /neɪl/ - küüs
naked /'neɪkɪd/ - alasti, paljas, katmata
naked eye - paljas silm

Napoleonic /nə'pəʊli'ɒnik/ - Napoleoni, napoleonlik
narcotic /nɑ:'kɒtɪk/ - uimastusvahend
narwhal /'nɑ:w(ə)l/ - sarv-vaal e. narval
nasal /'neɪz(ə)l/ - nina-
natural /'næt(ə)r(ə)l/ - looduslik, loomulik
natural selection - looduslik valik
naturalise /'næt(ə)rəlaɪz/ - naturaliseerima, (võõ-
 rast looma, taime jne.)
 kodustama
nature - iseloom, laad
naturalized productions - naturaliseerunud organismid
navel /'neɪv(ə)l/ - naba
navigate /'nævɪgeɪt/ - (laeva jne.) juhtima
navigator /'nævɪgeɪtə/ - meresõitja
necessitate /ni'sesɪteɪt/ - hädavajalikuks või tingimata
 tarvilikuks tegema
necessity /ni'sesɪtɪ/ - paratamatus, hädavajalikkus
of necessity - paratamatult
nectar /'nektə/ - mesi e. õiemahl
nectarine /'nekt(ə)rɪn/ - nektariin (teatav karvkatteta
 virsikusort)
needle - nõel, okas
neolithic /ni(:)əu'liθɪk/ - neoliitiline
netting - võrgustik, võrk
nicotine /'nikəti:n, nɪkə'ti:n/ - nikotiin (tubakas si-
 salduv mürkaine)
nitrify /'nɪtrɪfaɪ/ - nitreerima, nitroühendiks muutma

nitrogen /'naitridʒən/ - lämmastik
noble /'noubl/ - suursugune
nocturnal /nɔk'tə:n(ə)l/ - öine, öösine
nomadic /no'mædɪk/ - rändrahvalik
nonetheless /nənðə'les/ - sellest hoolimata
noose /nu:s/ - silmus, püünis
Norwegian /nɔ:'wi:dʒ(ə)n/ - norra
notochord /'noutəkɔ:d/ - keelik
noxious /'nɔks/ - kahjulik, ebatervislik, mürgine
nuclear /'nju:kliə/ - tuuma-
nucleotide /'nju:kliətaɪd/ - nukleotiid
nucleus /'nju:kliəs/ (pl. nuclei /'nju:kliə/) - tuum
nurture /'nɜ:tʃə/ - üles kasvatama, toitma
nutrient /'nju:triənt/ - toit(e)aine, toitev aine
nutritive /'nju:tritɪv/ - toitev, toidu- toitmis-
nymp /nimf/ - nümf e. neidis (teatavate putukate vast-
 ne)

0

oak /ouk/ - tamm

pedunculate /pɪ'dʌŋkjulɪt/ oak - harilik tamm

oar /ɔ:/ - aer (aeru)

object /əb'dʒekt/ to - vastu väitma või rääkima

objection /əb'dʒekʃ(ə)n/ - vastuväitmine, -väide; mit-
 tesallimine, pahakspanek

oblige /ə'blaɪdʒ/ - kohustama, sundima

oblique /o'bli:k/ - viltune, vildak

oblivious /o'bliviəs/ - unustuslik

to be oblivious of - mitte märkama

observant /əb'zə:v(ə)nt/ - tähelepanelik, valvas

obvious /'ɒbviəs/ - ilmne, silmanähtav, selge

occasional /ə'keɪz(ə)n(ə)l/ - juhuslik

occurrence /ə'kærəns/ - esinemine; levik

oceanographic /ou'ɪənə'græfɪk/ - okeanograafiline

oceanography /ou'ɪənə'grafi/ - okeanograafia

ochre /'oukə/ - ooker (kollane või pruun maalrivärv)

octane - oktaanarv

high octane gasoline - kõrge oktaanarvuga bensiin

ocular /'ɒkjulə/ - okulaar

odd - (arvu järel/ rohkem kui, mõni üle

oddly - veidralt, imelikult

offhand - jalamaid, ilma pikema jututa

offset /'ɒ(:)fset/ - (taime) võsund, kõrvalvõsu

offshore - (veidi) rannast eemal (merel)

offspring /'ɒ(:)fsprɪŋ/ - järglane, järeltulija; järg-
lased, järeltulijad

oilskins - õliriidest ülikond

old hand - vana vilunud tegelane

omit /ə'mɪt/ - välja jätma

omnivorous /m'nɪvərəs/ - kõigesööja

onset /'ɒnset/ - algus

ooze /u:z/ - lima, lõga; immitsus, nõrgus

orchiaceous /daɪətə'meɪ(ə)s/ oozes - ränihüb, räni-
orchid /'ɒ:kɪd/ - orhidee muld

orchidaceous /ɔ:ki'deɪʃəs/ - orhideeline, käpaline
order - selts; klass, seisus, liik; kord, järjekord, reas-
tus

in short order - jalamaid

orderly - sanitar

originate /ɔ'ridʒineɪt/ - algatama, ellu kutsuma, loomä

orivle /'ɔ:rioul/ - peoleo e. vihmakass; (Am.) kollalind

ornithologist /ɔ:ni'θɔldʒɪst/ - ornitoloog, linnutead-
lane

oryx /'ɔ(:)riks/ - pitssarv-antiloop

oscillatory movement /'ɔsileɪtəri 'mu:vmənt/ - vōnkeli-
kumine

osmosis /ɔz'mousis/ - (vedelikkude segunemine läbi urbse
vaheseina), osmoos

osmotic /ɔz'mɔtɪk/ - osmootne, osmoosile omane

ostrich /'ɔstri:tʃ/ - jaanalind

otter /ɔtə/ - saarmas

outcropping - esilekerkimine; esile- või nähtavale kerki-
nud maakiht

outlast /aut'la:st/ - üle kestma, kestvaelt ületama

outline /'autlain/ - piir- e. äärjoon; visand

outnumber /aut'nʌmbə/ - arvult ületama

ovary /'ouvəri/ - sigimik; (anatoomias) munasari, ova-
rium

oven /ʌvn/ - ahi

overly /'ouvəli/ - üleliia, ülemäära

overtake - järele jõudma; (ootmatult) tabama

ovipositor /ouvi'pɔzɪtə/ - muneti, putuka munemiselund
ovocyte /'ouvəsait/ - ovotsüüt
ovum /'ouvəm/ (pl. ova) - muna (laiemas mõttes); munarakk
owing (to) /ouɪŋ/ - (millegi) tõttu; tagajärjel
ox - härg, (laiemas mõttes) veis
oxidation /'ɒksɪ'deɪʃ(ə)n/ - oksüdatsioon
oxygen /'ɒksɪdʒ(ə)n/ - hapnik
oyster /'ɔɪstə/ - auster
oyster thief - pruunvetika liik

P

packet /'pækɪt/ - (väike) pakk, saadetus
pad - polster, padjand
pagan /'peɪɡən/ - paganlik
painfully - valulikult, valusasti, valusalt.
'paint-root' - "värvijuur"
pair - paarima; paariviisi korraldama, paari panema,
 paaritama
palate /'pælɪt/ - (kõva) suulagi
paleolithic /pælɪəʊ'liθɪk/ - paleoliitiline
paleontologist /pælɪən'tɒlədʒɪst/ - paleontoloog
Paleozoic /pælɪəʊ'zəʊɪk/ = palaeozoic - paleozoiline,
 vana-aegkonda
 kuuluv
palm /pɑ:m/ - peopesa; palm
sea palm - pruunvetika liik

paper-weight - paberi või kirjapress

papyrus /pə'paɪərəs/ - papüürus (egiptuse papüüruslõikhein)

paradox /'pærədɒks/ - paradoks (näilik vasturääkivus või tavalisele arvamusele vasturääkiv arvamus)

paraphenalia /pærəfə'neɪljə/ - isikliku omandi juurde kuuluvad asjad, varustis

parasitic /pærə'sitik/ - parasiitlik, nugine

parasitize /'pærəsitaɪz/ - parasiteerima

parchment /'pɑ:tʃmənt/ - pärgament

parent - esivanem, millegi algallikas

parental /pə'rent(ə)l/ - vanemlik, vanemaline

parlor /'pa:l / - elutuba, vöörastetuba, saal

partially /'pa:ʃli/ - osaliselt

particle /'pa:tɪkl/ - osakene

particulate /pə'tɪkjuleɪt/ - partikulaarne

particulate inclusion - osadena esinev sisaldis

pass - läbikäik

paste /peɪst/ - kleepima; kleepimise teel katma

pasture /'pa:stʃə / - karja või rohumaa; karjasööt

patch /pætʃ / - lapp, laik

pathetic /pə'θetik/ - liigutav, kaastundmust äratav

pathogenic /pəθə'dʒenɪk/ - patogeenne

pathologist /pə'θɒlədʒɪst/ - patoloog

patrol /pə'traʊl/ - patrullima, valvesalgana liikuma

pattern /'pæt(ə)n/ - näidis, muster

paw /pɔ:/ - käpp

pea /pi:/ - hernes

sweet pea - lillhernes

peach /pi:tʃ/ - virsik e. persik

peak - (terav) tipp; mäetipp; diagrammikõvera kõrgeim tipp,
maksimaalarv

peat - turvas

pebble - (väike) veerkivi e. munakas

peculiar /pik'ju:liə/ - iseäralik, omapärane

pecularity /pikju:li'æriti/ - iseäralikkus

peduncle /pi'dʌŋkl/ - õieraag

pedunculate oak /pi'dʌŋkjulit/ - harilik tamm

pelican /'pelikən/ - peelikan e. puguhani

pendent - rippuv

pendulous /'pendjulas/ - rippuv

penetrate /'penitreit/ - läbi tungima, läbistama

penguin /'peŋɡwi:n/ - pingviin e. rasvahani

penicillin /peni'silin/ - penitsiliin

peninsula /pi'ninsjulas/ - poolsaar

perch /pɜ:tʃ/ - ahven

perennial /pə'renjəl/ - alaline, kestev; (taime kohta)
mitmeaastane, püsik

performance /pə'fɔ:məns/ - talitus, toiming

performance of the bullits - kuulide löögijõud

periphery /pə'rifəri/ - perifeeria

permanence /'pɜ:mənəns/ - jäävus, kestvus, püsivus

permanent /'pɜ:mənənt/ - jääv, kestev, püsiv

permeable /'pɜ:miəbl/ - läbitav, vedelikule läbitungitav

perpendicular /pə:pen'dikjula/ - pendikulaarne; püst-
sirge, vertikaalne
perpetually /pə(:)'petjuali/ - püsivalt, lakkamatult,
alaliselt
persecution /pə:si'kju: ʃ(ə)n/ - jälitamine, tagakiusami-
ne
persistent /pə'sist(ə)nt/ - püsiv
personify /pə'sɒnifai/ - isikustama, kehastama
persuasion /pə:'swei ʒ(ə)n/ - veenmine
Peruvian /pə:'ruviən/ - peruua
pest control - kahjurite tõrje
petal - kroonleht
phagocytosis /fæɡəsai'toʊsis/ - fagotsütoos
pharmacology /fə:mə'kɒlədʒi/ - farmakoloogia
phenomenon /fi'nɒmɪnən/ - (pl. -ena) - fenomen, nähtus
Philippine /'filipi(:)n, -paɪn/ - filipiini
photosynthesis /fəʊtə'sɪnθəsis/ - fotosüntees
phraseology /freizi'ɒlədʒi/ - fraseoloogia, sõnastus-
viis
physician /fi'zi ʃ(ə)n/ - arst
physiognomic /fizi'ɒnɒmɪk/ - füsiognoomiline
physiognomy /fizi'ɒnəmi, -'ɒɡnə-/ - üldine (väline)
ilme
physiological /fiziə'lɒdʒɪk(ə)l/ - füsioloogiline
physiologist /fizi'ɒlədʒɪst/ - füsioloog
phytoplankton - fütoplankton
picric acid - pikriinhape

pier /piɔ/ - muul, sadamasild

pigeon /'pidʒən/ - tuvi

pile - hunnik, virn, kuhi

piling - vaiad

pin - nõõpnõelaga või nagu nõõpnõelaga kinnitama

pinch - näpistus, pigistus, kitsikus, häda

in a pinch - hädaga, äärmisel juhul

pine-apple - ananas

pit - kaevand, auk

pitch - pigi

plague /pleig/ - katk

plain - tasandik, laus(k)maa

plank - plank, paks laud

plant - istutama

plant sociology - fütotsünoloogia

plantigrade /plæntigreid/ - tallul kõndija (loom),

plantigraad

plash - (hekipõõsa oksi) alla painutama

plastic - plastiline, kujundav

plastid - plastiid

pleomorphism /pli:ɔ'mo:fizm/ - mitmekujusus, pleomor-
fism

plumage /plu:midʒ/ - (linnu)sulestik

plunger /'plʌndʒə/ - pumba kann, kolb

pneumonia /nju:'mouniɔ/ - kopsupõletik

poacher /poutʃə/ - salakütt

pod - kaun, kõder

point - rõhutama, toonitama, osutama, viitama

point of view - vaatepunkt

poison - /pɒɪzn/ - mürk

pole - teivas, ritv

polish - poleerima, läikivaks tegema

pollard /'pɒləd/ - puid pügamise teel tihendama; põetud
puu

pollen /pɒlin/ - õietolm

pollute /pə'ljʊ:t/ - reostama

pollutant - reostaja, reostav lisand

polymorphic /pɒli'mɔ:fɪk/ - polümorfne, mitmekujuline

polysaccharide /pɒli'sækəraɪd/ - polüsahhariid

pompon /'pɒmpɒn/ - (kinga või mütsi) ehistutt, siin:
pruunvetika liik

pond - tiik

pondweed - vesikatk

pore /pɔ:/ - poor, urve

porpoise /'pɔ:pɔs / - pringel e. seakala

port - sadam

pose - asetama, esitama küsimust

possess /pə'zes/ - omama, haldama

posture /'pɒstʃə / - seisang, asend

pot - lille potti istutama

potent /'pɒt(ə)nt/ - võimas, tugev; mõjus, tõhus

potential /pə'ten(ə)l/ - potentsiaal

pounce /pauns/ - (kallale) sööstma, kallale kargama

pound - puruks tampima, taguma, kolkima

powder /'pauda/ - pulber

prairie /'prɛəri/ - preeria, (P. Ameerika) rohtlatasandik

precarious /pri'kɛəriəs/ - ebakindel, kõikuv

precious /'preʃəs/ - väärtuslik, (kalli)hinnaline

precipitation /presipi'teiʃ(ə)n/ - sademed

precipitous /pri'sipitəs/ - järsk, järsaklik, äkiline

precise /pri'sais/ - täpne

precocious /pri'kouʃəs/ - varaküps, enneaegselt arenenud

predation /pri'deiʃ(ə)n/ - kiskjalisus

predator /'predætə/ - röövloom

predatory /'predət(ə)ri/ - röövlik, röövellik

preference /'pref(ə)r(ə)ns/ - eelistus; eelistatus

in preference - kõige paremini, meelsamini

pregnant /'pregnənt/ - rase

preparation /prepə'reiʃ(ə)n/ - preparaat

presence /prezns/ - välimus

preservation /prizə:'veiʃ(ə)n/ - säilitamine, (alal)hoid

preservative /pri'zə:vativ/ - säilitus e. hoide- või
kaitsevahend

preserve /pri'zə:v/ - säilitama, hoidma; jahiloomade
kaitseala

presumably /pri'zju:məbli/ - eeldatavasti, oletatavasti,
arvatavasti

presume /pri'zju:m/ - eeldama, oletama, arvama

presumption /pri'zʌm(p)ʃ(ə)n/ - jultumus, ülbus, upsakus;
oletus

presuppose - eeldama

prevail /pri'veil/ - valitsema, ülekaalus olema

prey - (elusat saaki) püüdma; kiskja looma röövsaak, saak

beasts of prey - röövlloomad

birds of prey - röövlinnud

primarily /'praɪməri/ - esmaselt, esmajoones, peamiselt

primate /'praɪmɪt/ (pl. primates /praɪ'meɪti:z/) - esik-

loom, primaat

prior to - eelnevalt

prism - prisma

privilege /'prɪvɪlɪdʒ/ - eesõigus, privileeg

procreate /'prəʊkriːt/ - sigitama, sünnitama; siginema

production - aretatud loom

proficient /prə'fi(ə)nt/ - asjatundlik, tubli, vilunud

profit - kasu tooma või andma

progeny /'prɒdʒɪni/ - järglased, järelsugu

progressive /prə'gresɪv/ - järguti edasiliikuv või tõu-

sev

project /prə'dʒekt/ - projekteerima

projectile /prə'dʒektail, 'prɒdʒɪktail/ - viskekeha,

kuul

prolific /prə'lɪfɪk/ - kiiresti siginev, viljakas

prominent /'prɒmɪnənt/ - silmapaistev

pronounce /prə'naʊns/ - tugevasti esileastuv, rõhutatud

proof - tõend

propagate /'prɒpəgeɪt/ - paljundama, sigitama, levitama

propel /prə'pel/ - liikuma panema

proper - oma, enda

proportion /prə'pɔ:ʃ(ə)n/ - proportsioon, suhe, võrdeline osa

proportional /prə'pɔ:ʃ(ə)n(ə)l/ - võrdeline, proportsionaalne

propose /prə'pəʊz/ - ette panema, esitama; kavatsema

propound /prə'paʊnd/ - esitama, esile tooma

prosperity /prɒs'perɪti/ - vohamine, rikkalik kasv

protein /'prəʊti:n/ - proteiin, valk

protoplasma /prəʊtə'plæzəm/ - protoplasma

prototrophic /prəʊtə'trɒfɪk/ - prototroofne

protozoa /prəʊtə'zəʊə/ - pl. ainuraksed

protrude /prə'tru:d/ - esile või välja ulatuma

pry /praɪ/ - oma nina toppima (into)

psychological /saɪkə'lɒdʒɪk(ə)l/ - psühholoogiline

ptarmigan /'ta:mɪgən/ - rabapüü, raba e. sookana; lüskana

puddle - lomp, loik; segatud savikate

puff - puhang, pahvang, pahv, mahv

pulmonary /'pʌlmənəri/ - kopsu-

pump up - täis pumpama

punctuate /'pʌŋ(k)tʃueɪt/, -tʃu/ - vahemärgistama

puncture /'pʌŋktʃə/ - läbi pistma

punish /'pʌnɪʃ/ - karistama

purify /'pjʊərɪfaɪ/ - puhastama

purpose - eesmärk, siht

to all intents and purposes - niisama hästi kui, peaaegu

pursue /pə'sju:/ - jälitama, taga ajama

pursuit /pə'sju:t/ - jälitus, tagaajamine, püüdlus, taotlus

in pursuit of - (millegi, kellegi) otsimisel, jahil

pus /pʌs/ - mäda

putrefy /'pju:trɪfaɪ/ - mädanema, roiskuma

putrid /'pju:trɪd/ - roiskunud

pygmy /'pɪgmɪ/ - kääbus; (kä) teatava kääbusrahva liige

pylon /'pailən/ - püloon, torn, tornitaoline post

Q

quadruped /'kwɒdrʊpɪd/ - neljajalgne (loom), kvadrupeed

quagmire /'kwæɡmaɪə/, kwɒɡ-/ - mädasoo, soomülgas

quanta /'kwɒntə/ - quantum - kvantum, hulk, määr

quarry /'kwɒrɪ/ - (tagaetav) jahisaak

quarters /kwɒ:təz/ - korter

Quaternary /kwɒ'tɜ:nəri/ - kvaternaar, uusim ajastu või ladestu

queer /kwiə/ - imelik, veider

quickset /'kwɪkset/ - elavaist põõsaist (eriti viirpuust koosnev) hekk

quiescent /kwai'esnt/ - tegevuseta, liikumatu, vaikiv, rahulik

R

rabbit - küülik e. kodujänes

rack - raamistik, võrestik; varn
radiation /reidi'eɪ(ə)n/ - kiirgus, radiatsioon
radient /'reidiənt/ - kiirtena või raadiustena väljasaa-
 tev või väljuv
raid - läbiotsimine, haarang
rainbow /'reɪnbəʊ/ - vikerkaar
raise /reɪz/ - üles kasvatama
rally - (uuesti) koguma või kogunema
ram - rammima, sisse taguma
ramification /ræmifi'keɪ(ə)n/ - harunemine, hargnemine;
 haru
range /reɪndʒ/ - mäeahelik; ulatus; kasvuala
at close range - lähedas kauguses
rank - rida, rivi
rate - kiirus
ratio /'reɪ(ə)ʃiəʊ/ (pl. -os) - (matemaatiline) suhe, re-
 latsioon
ration /'reɪ(ə)ʃiəʊ/ -/- - päevane toiduportsjon,
 kondlaksmääratud päevamoon,
 ratsioon, (toidu)norm
ravage /'rævɪdʒ/ - laastama, rüüstama
raw meat - toores liha
ray - (uime) kiir
ray-fin - kiirruimeline (kala)
rear /rɪə/ - (üles) kasvatama; tagaosa, -kül, -plaan,
 pära
reason /'ri:zn/ - arutlema; järeldama, otsustama

reasonable /'ri:zənəbl/ - mõistlik, mõõdukas, vastuvõetav,
arukas

reassure /ri(ə)' } uə/ - kindlust või usaldust tagasi andma

recede /ri'si:d/ - taganema, taanduma

receptacle /ri'septəkl/ - õiealus või õisikualus, -telg,
kobaratelg

recipe /'resipi/ - retsept (ravimi, toidu jne. valmistus-
õpetus)

reclamation /rekla'mei } (ə)n/ - maa kultiveeritavaks tege-
mine

recommendation /rekəmen'dei } (ə)n/ - soovitamine, soovitus

record /ri'kɔ:d/ - üles märkima e. tähendama;

/ 'rekɔ:d/ - ülestähendus; register, ürik, dokument

on record - üles märgitud, üldiselt teada

recreation /rekri'eɪ } (ə)n/ - meelelahutus, karastus, ko-
sutus, lõbustus

rectal /'rekt(ə)l/ - pärasoole-, rektaalne, rektaal-

recur /ri'kɔ:/ - uuesti esinema, korduma

red-grouse (pl. grouse /graʊs/) - soo e. rabakana

redoubt /ri'daʊt/ - reduut, (eraldiselisev) kinnine kind-
lustus

reduce /ri'dju:s/ - kahandama, vähendama; muutma (milleks-
ki)

reed - pilliroog

reed beds - roostik

reef - riff e. rahu, veealune või natuke üle veepinna ula-
tuv kalju

refer (tc) /ri'fə:/ - (millelegi) tagasi viima, omistama;
viitama, osutama; (millegi) kohta
käima

reference /'ref(ə)r(ə)ns/ - viide, juhatus, vihje

refinement /ri'fainmənt/ - rafineeritus, peenus; siin:
täiustus, viimistletud töötlus

reflect on /ri'flekt/ - mõtisklema, (meelt) mõlgutama

reforestation - taasmetsastamine

natural reforestation - looduslik metsastumine, looduslik
metsa uuendumine

refuge /'refju:dʒ/ - pelgu- või varjupaik

regard - vaade; suhtumine

in or with regard to - (mingis) asjas, (millegi) pärast,
suhtes

regardless (of) /ri'ga:dli:/ - vaatamata (millelegi),

regeneration /ridʒənə'rei(ə)n/ - taastekkimine, re-
generatsioon

regurgitation, /rigə:dʒi'tei(ə)n/ - tagasihoovus, -voo-
lus; (allaneelatud
toidu uuesti välja-
ajamine).

reject /ri'dʒekt/ - kõrvale heitma

rejectamenta - jäänused

relate - ühendusse viima; suhtesse viima

relation /ri'lei(ə)n/ - vahekord, suhe; sugulus, sugu-
lane

in relation to - (millegi) suhtes

relatively /'relativli/ - suhteliselt
relic /'relik/ - säile, jäänus
relieve /ri'li:v/ - kergendama
rely on - usaldama, lootust rajama
remain - jääma; jäänus
remark - märkama, tähendama
remedy /'remidi/ - ravima; heaks tegema
remodel /ri'mɒd(ə)l/ - ümber kujundama
remorseless /ri'mɔ:slis/ - halastamatu, hoolimatu, julm
replica /'replikə/ - täpne koopia, dublett
replica-plating - (bakterite) ülekandmine ühelt söötmelt
teisele
replicate /'replikeit/ - teist enesesarnast sünteesima,
tekitama; replitseerima, kahen-
dama
reproduce /riprə'dju:s/ - paljundama; paljunema
reproductive /riprə'daktiv/ - paljunemise-
reptile /'reptail/ - reptiil, roomaja
request /ri'kwest/ - paluma, nõudma
requirement /ri'kwaɪəmənt/ - nõue, vajadus
resemblance /ri'zembləns/ - sarnasus
residue /'rezidju:/ - jääk, järelejääv
resin /'rezin/ - vaik
resist /ri'zist/ - vastu seisma või panema
resistant /ri'zistant/ - resistentne, vastupidav; kindel
(haiguse, parasiitide suhtes)
resort to - abi või nõu otsides pöörduma; (millestki)
väljapääsu otsima

resource /ri'sɔ:s/ - ainelised või jõutagavarad
respect - suhtuma
with respect to - (millegi) suhtes
respiratory /res'paɪrət(ə)ri, 'respireitəri/ - hingamisteed
respiratory passages - hingamisteed
respond /ris'pɒnd/ - vastama
response - vastus, reaktsioon
responsibility /rɪspɒnsɪ'bɪlɪti/ - vastutus
restrict /ris'trikt/ - kitsendada, piirama
to be restricted to - seotud olema
result (from) - tulenema, järelduma
result in - (millegagi) lõppema, tulemusena andma
resume /ri'zju:m/ - uuesti alustama, jätkama
retain /ri'tein/ - säilitama, alal hoidma; säilima
retrieval /ri'tri:v(ə)l/ - uuestileidmine, tagasisaamine
retrieve /ri'tri:v/ - päästma
Rev. = reverend /'rev(ə)r(ə)nd/ - kõrgeauline (vaimuliku nime ees)
reverse /ri'vɜ:s/ - ümber pöörama, tagurpidi pöörama; ümberpöördud, vastupidine
reversion /ri'vɜ: (ə)n/ - tagasipööre endisesse olukorda
reward /ri'wɔ:d/ - tasu; tasuma
rheumatism /'ru:mətizm/ - reumatism
rhinoceros /raɪ'nɒs(ə)rəs/ - ninasarvik
ridge - vaotaoiline kõrgendik
rigging - (laeva) taglas, taaklus, taklaaz

rigidly - /'ridʒidli/ - karmilt, valjult, rangelt
rigorous /rig(ə)rɪs/ - range, karm, vali
rite - usutavand, -komme
roach /routʃ/ - tarakan; prussakas
roam /roum/ - uitama
roan /roun/ - kimmel, (er.) kimmelpunane või -kõrb
robe - rüü, pikk lahtine rõivas
rockery - kiviktaimla
rod - kepike, vääts
rodent /'roud(ə)nt/ - näriline, närija(loom)
roll - veerema, veeretama
roller /roulɜ:/ - siniraag e. sinine vares, "saksamaa vares"
rook /ruk/ - külvi- e. künnivares
rope - köis
rorqual /'rɔ:kwɔ:l/ - vaguvaal, seljauimega vaal
rotation of crops - külvikord
rough /raf/ - ligi- või umbkaudne; kare, jäme
roundworm /'raundwɜ:m/ - ümaruss
route /ru:t/ - liikumistee
en route - teel
row /rou/ - rida
rowan /'ro(u)ən, 'raʊən/ - pihlakas
royal /'rɔi(ə)l/ - kuninglik
rude - toores, töötlemata, algeline
rugged /'rʌɡɪd/ - konarlik, sakiline; siin: ebaühtlase, vormitu siluetiga
run - jook, käik

run wild - metsikult üles kasvama

in the long run - pikapeal, lõpuks, lõppeks

S

sac - kott, villi või põiekujuiline moodustis

sacrum /'seikrəm/ - ristluu

safety /'seifti/ - ohutus, julgeolek; kindlus
with varying degrees of safety - mitme-
suguses ulatuses

sake /seik/; for the sake of - (millegi) pärast, jaoks

salicylate /'sælisileit/ - salitsülaad

saliva /s(ə)'laivə/ - sülge

sanctuary /'sæŋ(k)tjuəri/ - pelgu- e. varjupaik

sap - mahl

sapiens /seipienz/

homo sapiens - inimene (loodusteaduslikus klassifikat-
sioonis)

saturate /'sætjureit, 'sæt(ə) - küllastuma

sauerkraut /'sauʊkraut/ - hapukapsas

scale - ulatus, mõõtmed, suurused; suhted; soomus, naha
kestendus; kest, koorik; astmik, skaala

scalp - peanahk (ühes juustega)

scan - üksikasjaliselt vaatlama, täpselt uurima

scanning - üksikasjaline vaatlemine, täpne uurimine

scant - napp, kasin

scar /ska:/ - arm, jälge

scatter - laiali puistama, laiali ajama, sinna-tänna paigu-
tama

scenery /'si:nəri/ - kulissid, maastikupilt
Schizomyces /skizomai'si:ti:z/ - (Lad. k.)
school = shoal - (kala)parv
scope /'skoup/ - tegutsemisvabadus, voli
score /skɔ:/ - kakskümmend; tubli hulk
Scotch /skɒtʃ/ - šoti
scrape - kraapima, kratsima
scratch - kratsima, kraapima
screen - ekraan; kaitsevõrk (putukate vastu); sõel, sõe-
luma
scrub /skrʌb/ - võsa, võserik, võsastik, võsamets
scrutinize /'skru:tinaiz/ - täpselt vaatlema
scull - lühikeste aerudega või päraaeruga sõudma
scurry /skʌri/ - sibama, silama, liduma
seaboard /'si:bɔ:d/ - mererannik
seagull /'si:gʌl/ - kajakas
seal - hüljes
sea lion - merelõvi
sealskin - hülgenahk
sea palm - vetikas
sea-plane - vesilennuk
search /sɜ:tʃ/ - otsing
in search of - otsingul, jahil
sea-urchin /'si:ɜ:tʃ in/ - merisiilik
seaweed - merevetikas, -adru; (üldisemalt igasugune mere-
taim)
secondary wall - sekundaarne kest

secrete /si'kri:t/ - varjama, (ära)peitma, eritama, nõ-
 ristama
sediment /'sedimənt/ - sete, sadestis
seedling - seemik, seemnest kasvatatud noor taim
seep - nõrguma, immitsema
seer /si:ə/ - nägija, prohvet
seer-sucker kelp - pruunvetika liik
segment /'segmənt/ - lõik, tükk; lüli, segment
selection /si'lekʃn/ - valik
natural selection - looduslik valik
selective /si'lektiv/ - (välja)valiv, valikut teostav
semi - pool
sensory /'sensəri/ - aistingu-, aistmis-, tundemeele-
sequence /'si:kwəns/ - järgnevus, järg, järjestik;
 järjekord
sergeant /sa:dʒ(ə)nt/ - seersant
serve /'sə:v/ - otstarvet täitma
set - kogum; rühm
set forth - esile tooma; teele asuma
set free - vabastama
set off - esile tõstma; käima panema
settle - põhja vajuma
severe /'si'viə/ - karm, vali, range; äge, tugev, tõsine
sewage /'sju:ɪdʒ/ - roiskvesi
sexual /'seksju(ə)l, kʃu-/ - seksuaalne, suguline
shadow - vari, viirastus; armetu jäänus
shaft - kaevus, šaht
shale - sau-, kiltkivi

shallow /'ʃælu/ - madal; (vee)madalus, madalik, madal
koht

share /ʃɛə/ - jagama

shark /ʃa:k/ - hai(kala)

shatter - laostama, hävitama

shed, shed, shed - (lehti) langetama, maha heitma

sheer - selge, puhas; puhtalt, lausa

sheeting - kate

shell - (muna, pähkli- jne.)koor, koorik, kest, (koorik-
looma)karp

shepherd /'epʃd/ - lambur

Scottish shepherd - šoti lambakoer

shield /ʃi:ld/ - kaitsevari

shift - nihutus, nihe; nihutama, nihkuma, vahetama, muutuma

shifting sand - lahtine, settimata liiv

shimmer - kumama, helkima, valendama

shingly /'ʃɪŋli/ - (mereranniku kohta) kivine

shiver - vöbisema, värisema

shoelace /'ʃu:leɪs/ - kingapael

devil's shoelace - vetikas (pruunvetika liik)

shoot /ʃu:t/ - võrse, ühe aasta kasv; oks, vars; pung,
võsu

short-lived - lühiealine

shot - tilgake (mingit rohtu)

shred - narmas, rübal, riba; raasuke

shrike /'ʃraɪk/ - suur pajuharakas e. tihasekull

shrink, shrank, shrunk - kokku tõmbuma; suuruselt kahanema

shrinkage /ʃriŋkidʒ/ - kokkutõmbumine; (suuruselt ka-
hanemine)
shroud /ʃraud/ - varjama, peitma, katma
sbrub - põõsas
shrubbery - põõsastik
shrubby - põõsataoline
sight - märkama, silmama
similarity /simi'ləriti/ - sarnasus, samalaadsus
singular /'siŋgjulə/ - erakordne, eriline
site - asukoht
skein /skein/ - pasmas; mõõduna = 120 jardi
skeleton /'skelitn/ - skelett, luustik; toes
sketch /sketʃ/ - skits, visand
skittish - peru; ülemeelik
slab - lamik; viilukas
slanting /'sla:ntiŋ/ - längus-olev, viltune
slaughter /'slɔ:tə/ - (loomi)tapma, maha nottima
sled - kelk, regi
sleet - lobjakas, lörts
slender /'slendə/ - sihvakas
slice /slais/ - viilukas, lõik
slight - väike ning nõrk, tähtsusetu, tühine
slightly - veidi, natukene
slime - (vedel)muda; lõga, lima
sling, slung - sideme(rihma) otsas rippuda laskma, rippu
viskama; tõstevahend
slip - libisema; libistama; lipsama

slope - kallakus, kalle; nõlv, nõlvak
sluggish /slʌɡɪʃ/ - pikaldane, pikatoimeline
smear /smiə/ - määrima, määrdunuks tegema; äigepreparaat
smokestack - (auriku, veduri jne.) suitsukorsten
smooth /smuːð/ - siluma, siledaks tegema
snail /sneɪl/ - tigu
snap - napsama, ahmama
 snap up - (teiste eest) ära napsama
snare /sneɪə/ - püünis
snout /snaʊt/ - (looma) ninamik, koon
soak /souk/ - leotama; ligunema; imbuma, (vedelikku) en-
 dasse imema
social - ühiskondlik
soda-lime - natroonlubi
soil - pinnas, muld
 calcareous soil /kæl'kɛəriəs/ - lubjane pinnas või
 muld
sojourn /'sɒdʒən/, sɑdʒ - Am. sɒdʒ -/ - ajutine vii-
 bimine või asumine
solitary /'sɒlɪtəri/ - üksik, üksildane
soluble /'sɒljubl/ - lahustatav, lahustuv
solution /sə'ljʊː(ə)n/ - lahus
 in solution - lahusesena
sound - terve, veatu; mõistlik; usaldatav
sour /sauə/ - hapu; hapuks minema
souring of milk - piima hapnemine
southerly /'saʊðəli/ - lõunapoolne

souvenir /'su:v(ə)niə/ - mälestis, mälestusese
space - ruum; avarus
open spaces - avamaastik
spaceman - kosmonaut
spade - labidas
span - lühike ruumi- või ajavahemik
life span - (lühike) eluiga
wing span - väljasirutatud tiibade laius
spare /spɜː / - säästma, kokku hoidma
sparingly branched - vähese harunemisega
spawn /spɔːn/ - kudema; (kala-, konna- jne.) kudu
spear /spiə / - oda
species /'spiːʃ i(:)z, - ʃiiz/ (pl. species) - (taime-,
loomaliik
specify /'spesifai/ - eriti mainima või kirjeldama, lähemalt iseloomustama; täpsemalt määratlema, spetsifitseerima
specimen /'spesimin/ - musternäidis; (taime, looma jne.) eksemplar
specle /spekl/ - täpp, tähn
spectacular /spek'tækjula/ - suurejooneline, toreduslik; tähelepanuväärne
spell - lühike vältus, kestus, hoog; tähendama
spermaceti /spɜːmə'si:ti, -seti/ - spermatseet e. tseetaatseum e. vaalavõidis (kašeloti pealuus sisalduvast õlist saadav aine)

spermatozoan /spə:məto'zouən/ (pl. zoa) - seemnerakk,
-niit, spermatozoid

sperm oil - traan

spherical /'sferikəl/ - sfääriline

spinal /'spain(ə)l/ - selgroo-, selja-,aju-

spine - astel, okas, oga

spiny /'spaini/ - okkaline

spiral /'spaiə(r)əl/ - spiraalne, keeritsaline

splint - puuliist, -pilbas

split, split, split - lõhkuma, lõhestama; lõhustuma, lõhe-
nema; lõhki ajama; lõhkuma

spokesman - eesträäkija, -kõneleja, esindaja

sponge /spɒndʒ/ - käsn

spook /spu:k/ - hirmutades ajama

spore /spɔ:/ - eos, spoor

'sporting plants' - hüppeliselt kõrvalekalduvad taimed

spot - üles leidma, avastama

spray - oks (ühes lehtede ja õitega); piserama

spring - allikas, läte

spring up, sprang up, sprung up - esile tõusma, tärkama

spruce /spru:s/ - kuusk

spruce beer - kuusevõrseist tehtav ravimjook

spume /spju:m/ - vaht, kobrutis

spurn /spɜ:n/ - jalaga eemale tõukama, põlglikult tagasi
lükka, põlastama

spy /spai/ - silmama, avastama, nägema

squalor /'skwɔ:lə/ - mustus, räpasus

squat /skwɔt/ - kükitama
squid - kalmaar (väike seepiataoline peajalgne)
giant squid - kaheksajalgne polüüp
staff /sta:f/ - (relvana) teivas
stagnant /'stægnənt/ - (vee kohta) seiskuv
stain /'steɪn/ - värv; värvima
stalk /stɔ:k/ - vars, kõrs
stamen /'steɪmən/ - tolmukas
stamp - stamp, pitsat, tempel, pitser, jälg
stand - alus, tugi; siin: tüüp - assotsiatsioon
stand one's ground - mitte järele andma
standard /'stændəd/ - standart, norm; näidis
starch /sta:tʃ/ - tärklis
starling - kuldnokk; (Am.) Ameerika muustrastas
startle - jahmatama, ehmatama
starter - käivitaja, starter
starvation /sta:'veɪ(ə)n/ - nälgimine, nälgasuremine
stationary /'steɪ(ə)nəri/ - paigalpüsiv, liikumatu,
muutumatu
steadfast /'stedfəst/ - kindel, püsiv, muutumatu
steamer /'sti:mə/ - aurik
steamer duck - aurikpart
steep - järsk, jääras
stellate /'steleɪt/ - tähekujuline
stellate down - tähekujulised ebemed, udemed
stem - (taime) vars, (puu)tüvi; põlvnema, pärinema
stench - hais, lehk

steppe /stepi/ - stepp

sterile /'sterail/ - sigimatu, viljatu

stew /stju:/ - hautatud liha, moorpraad, moorliha

stick bag - pruunvetika liik

stilt - harkjalgkurvits

stimulus /'stimjulʌs/ (pl. -li /lai/) - ergutis, ärritus,
stiimul

stink, stank, stunk - haisema, lehkama

stipe /staip/ - vars; siin: tallus

stipule /'stipju:l/ - abileht

stock - sugukond

stoma (pl. stomata /'stoumætə/) - õhulõhe

store - tagavaraks koguma; säilitama; varu, tagavara

stork - toonekurg

stout /staut/ - vapper, sõakas, tugev, tüse

stow /stou/ - tihedasti pakkima (eriti laevalaadungit)

straddle - (jalgu) harki ajama; harkjalu seisma

strain - kurnama, läbi kurna laskma; sugukond; põlvnemine,
päritolu

strait /streit/ - väin, merekitsus

strand - (kõie) kee, keere; randuma, randa kinni jooksmata

stranding - randumine, randa kinni jooksmine

strangulation /stræŋgju'lei/ (ə)n/ - kägistamine, kägis-
tus

stray /strei/ - ära eksima

streak /stri:k/ - triibuliseks tegema, viirutama

stream /stri:m/ - vool; jõgi; oja

streamer - lehviv pael; siin: talluse harud
streptococcus /strepto'kɔkəs/ (pl. streptococci /strep-
to'kɔksai/ - streptokokk
streptomycin /streptou'maisin/ - streptomütsiin
stress - rõhk, pinge
stretch - ulatus
strictly - täpselt, rangelt, valjult nõudlikult
strident /'straɪdnt/ - kime, läbilõikavalt terav
strike, struck, struck /straɪk, strʌk/ - hämmastama,
rabama
striking - silmatorkav, rabav
strikingly - tabavalt, rabavalt, silmapaistvalt
string - nõör, pael
strip - riba
strive, strove, striven - püüdma, puudlema
strobe = stroboscope - stroboskoop (teatav riist pideva
liikumise illusiooni tekitamiseks)
stroke - hoop, löök
struggle for existence - olelusvõitlus
stubble /stʌbl/ - kõrretüükad, kõrrestik
stubby - jässakas, tömp
stuff - toppima, täis toppima; aine, aines, materjal
stump - känd, konts, tüügas
stupendous /stju:'pendəs/ - hämmastav, tohutu
sturdy /'stɜ:di/ - tugev, tubli
style /stail/ - emakakael
sub /sʌb-/ - all-, alam-, ala-, lähis-

- subdue /səb'dju:/ - alistama, alla heitma; maha või alla suruma
- subject /'səbdʒɪkt/ - subjekt, isik; (riigi)alam, alluv (kellelegi, millelegi to); kergesti vastuvõtlik (millelegi to)
- submerge /səb'mɜ:dʒ/ - üle ujutama
- submersion /səb'mɜ:ʃ(ə)n/ - üleujutus
- submit /səb'mɪt/ - (dokumenti) esitama, esile tooma
- subordinate /sə'bɔ:d(i)nɪt/ - alluv, kõrval-
- subsistence /səb'sɪst(ə)ns/ - olelus, püsimine; elatis, elatusvahend
- subsurface /'səbsɜ:fɪs/ - pinnaalune kiht
- succession /sək'seɪʃ(ə)n/ - järg, järgnevus, järjekord; rida; järglus
- in succession - järjest
- successive /sək'sesɪv/ - (pidevalt) järgnev
- succulent /'səkjʊlənt/ - mahlakas, sukulentne
- suckle - imetama
- sufficient /s(ə)'fɪʃ(ə)nt/ - küllaldane, piisav
- suffocate /'sʌfəkeɪt/ - lämbuma
- suffocation /sʌfə'keɪʃ(ə)n/ - lämmatamine, lämbumine
- sugar-cane - suhkruroog
- suggest /sə'dʒest/ - vihjama, tähendama
- sulphur /'sʌlfə/ - väävel
- summary /'sʌməri/ - (lühike) kokkuvõte
- superficial /sju(:)pə'fiʃ(ə)l/ - pinnaline, pinn- pealiskaudne

- superstition /sju(:)pəs'ti (ə)n/ - ebausk
- supplant /sə'pla:nt/ - välja või kõrvale tõrjuma
- supple /sʌpl/ - nõtke, paindub
- supply /sə'plai/ - varu, tagavara
- supralittoral /'sju:prə'litər(ə)l/ - supralitoraalne,
ülevalpool vee piiri
- surfy /'sə:fi/ - murdlaineline
- surplus /'sə:pləs/ - liigäär, ülejääk
- survey /'sə:vei/ - vaatlus, ülevaatus
- survival /sə(:)'vaiv(ə)l/ - ellu või püsijäämine
- susceptibility /səsepti'biliti/ - vastuvõtlikkus
- susceptible /sə'septibl/ - vastuvõtlik, tundlik
- suspect /səs'pekt/ - kahtlustama
- suspend /səs'pend/ - heljutama, heljuvana või rippuvana
hoidma
- sustain /səs'tein/ - vastu pidama, välja kannatama,
taluma
- sustenance /'səstinəns/ - ülalpidamine, toitmine; toitvus;
toit
- swarm /swɔ:m/ - parvlema, parves tunglema; kihama, kubi-
sema
- sway /swei/ - õõtsuma, kõikuma; õõtsutama, kõigutama
- sweep - kaar; looge; vuhinal liikuma, kaares ulatuma
- sweet - magus
- sweet pea - lillhernes
- swelter - kuumusest lämbuma
- swing, swung, swung - kiikuma, võnkuma, pöörlema, keer-
lema; pöörlevalt liikuma panema

switch off - välja lülitama
synthesize - /'sinθəsaiz/
syringe /'sirindʒ/ - prits, süstal ehk injektsioonprits
syrup /'sirəp/ - siirup

T

tail /teil/ - saba
take - võtma
 take for - (kellekski, millekski) pidama
 take action - samme astuma
 take note of - tähele panema
tame - taltsutama
tan - parkima, parkuma
tangible /'tændʒibl/ - kombatav, käegakatsutav, tõeline
tank - suur veemahuti
tap - torget tegema; tikkama
 tap for resin - vaigutama
tape recorder - magnetofon
tapering /'teipəriŋ/ - peeneotsaline
tapeworm - pael- e. laiuss
target /'ta:git/ - märklaud
taste - maitsuma, (millegi) järele maitsuma
tease /ti:z/ - õrritama
teem with - kihama, kubitsema (millestki)
telescope - (pikksilmana) kokku suruma või välja venitama,
 kokku käima
temper - mõõdukamaks muutma

temperate /'temp(ə)rit/ - mõõdukas, parajuslik

temporary /'temp(ə)rəri/ - ajutine

tempt - kiusama, kiusatusse viima, ahvatlema

I am tempted - mul on kiusatus, tahtmine

tend - suunduma, kalduma, kalduvust omama

tendency /'tendənsi/ - tendents, suundlus, kallak

tentacle /'tentəkl/ - kombits e. tentaakel, (looma)

katsesarv

term - termin

in terms of - (millegi) seisukohalt

terminal /'tə:mi:nl/ - piiriline

terminate /'tə:mineit/ - lõpetama

terminus x(pl. -ni /-nai/) - lähte või lõpp-punkt

tern /tə:n/ - tiir e. merepääsuke

terrain /tə'rein/ - maastik või maa-ala

test - proovima, kontrollima

tetracoccus /tetrə'kɔkəs/ (pl. tetracocci /tetr 'k ks i/
- tetrakokk

tetrad /'tetrəd/ - tetracoccus

thence /θens/ - sealt

thermocouple /'θə:məkʌpl/ - termopaar

thermometer /θə'mmi:tə/ - termomeeter

thigh /θa i/ - reis (-eie)

thistle /θisl/ - karuohakas

thorn /θɔ:n/ - okas, astel okaspõõsas (er.) okasviir-
puu

threat /θret/ - ähvardus, ähvardav hädasoht

thrill - tundevärin; erutushoog .

thrive, throve, thriven - hästi edenema, hästi kasvama

throat /'θrou/ - kōri, kurk (-rgu); neel, lōōr

throw - vise; heide

wind throw - tuuleheited

tidal /'taid(ə)l/ - tõusu või mõõna, tõusuvee

tide - (merevee) tōus ja mōōn

tidy /taidi/ - korralik, puhas, kena

tierra caliente - (Hisp. k.) kuum maa

till - maad harima

tiller - maaharija

timber - ehituspuit, -puu, tarbepuu

tine - pii, hammas, haru

tint - värvivarjund

tip - otsast katma; otsaga või teravikuga varustama

tolerance /'tɒlər(ə)ns/ - talumis- või vastupanujõud
(näit. mürgile)

tolerant /'tɒlər(ə)nt/ - salliv, leplik, tolerantne,
taluv

tolerate /'tɒləreɪt/ - sallima, lubama; taluma, välja
kannatama

toll /toul/ - (möldri) matt

topic - jutu- vői kōneaine, kōnealune asi

topis, topi - topi(s)antiloop

torpor /'tɔ:pə/ - tardumus, oimetus

torpid phase - tardumusfaas

tortuous /'tɔ:tjuəs/ - looklev, keermeline, kõver

torture /'tɔ:tʃə / - piinama

tortured and ravaged landscape - loodusjõudude poolt
laastatud ja rüüsta-
tud maastik

toss - pillutama, viskama, pilduma, loopima

total /'təʊtəl/ - kogu- e. totaalsumma

touch /tʌtʃ / - kriipsuke, (väike) kõrvaljooneke, varjund
või lisand

towering /'taʊəriŋ / - tornina kõrgeleulatuv

toxic /'tɒksik/ - mürgine, toksiline

toxicology /tɒksi'kɒlədʒi/ - toksikoloogia, õpetus
mürkidest

trace - jälitama; jälg, märk; väike lisand(us)

trace of oxygen - hapnikulisand

trail - teerada läbi metsiku maa-ala

train - treenima, välja õpetama

tranquillize /'træŋkwilaiz/ - rahustama, vaigistama

transformation /trænsfɔ'mei(ə)n/, tra:n/ - muundus,
ümberkujundus

transient /'trænzɪənt, -siənt, -ʃ(i)ənt/ - lühemat
aega peatuv

(hotellikülastaja kohta)

transpiration /trænspi'rei(ə)n/ - välja või läbiaura-
mine, aurumine

transportation /træns'pɔ:t(ə)n, tra:n/ - suudasu-
misele saatmine; (Am.)
transporteerimine, veondus

transship - ümber laadima
transverse /træns'vɜ:s/ - transversaalne, põiki või ris-
 ti kulgev
trap - lõksu püüdma
tread /tred/ - astuma, sõtkuma, tallama
tribe - suguharu
tribesman /'traibzmən/ - suguharuliige
tributary /'tribjut(ə)ri/ - lisa- või harujõgi
trickle - nirisema, nõrguma
trifle - tühiasi, pisi
trifling /'traifliŋ/ - tühine, tähtsusetu
trigger /'trigə/ - valla päästma, alustama
trophy /'troufi, trɒfi/ - trofee
tropics - troopika, troopikamaad
trough /trɔ:(ə)f/ - küna, mold; renn
truck - platvormvagunil vedama
truckload - autokoorem
"true" - siin: püsiv
trunk - (puu)tüvi
tub - tööber, vann
tube - toru, tuub
tuberculosis /tju(:)bɜ:kju'lousis/ - tuberkuloos, tiisi-
 kus
tubular /'tju:bjulə/ - tornjas
tug - puksiir e. vedurlaev
tumbler /'tʌmblə/ - kukerpallitaja, akrobaat
tuna /tu:n, tju:n/ - (Am.) (Kalifornia) tuunikala

turbulent /'tə:bjulənt/ - mässuline

turn - pööre, käänak

in turn - omakorda

turn over - üle andma

twig - oksake, raag

twist - väänama, käänama; väänlema

twofold - kahekordne

U

ultimately /'Altimitli/ - lõpuks, viimaks

ultraviolet rays /'Altrə'vaiəlit reiz/ - ultraviolett-
kiired

umpire /'ʌmpaɪə/ - vahukohtunik

unceasing /ʌn'si:siŋ/ - lakkamatu, järelajätmatu

unclench - (rusikat) avama

undergo - läbi tegema või elama või kannatama

under nature - looduslikus olekus

undertake - ette võtma

undesirable /'ʌndi'zaiərəbl/ - soovimatu, mittevajalik

undulating /'ʌndjuleitiŋ/ - unduleeriv, lainlev

undulation /ʌndju'lei (ə)n/ - lainetus, lainlemine

unflinching - kohkumatu, mitte millegi ees tagasipõrkav

unfold /'ʌn'fould/ - laiali laotuma, avanema

unharmed /ʌn'ha:md/ - vigastamata

unicellular /ju:ni'seljula/ - ainurakne

uniform /'ju:nifɔ:m/ - samakujuline, ühetaoline, ühtlane

unintentionally /ʌnin'ten (ə)n(ə)li/ - ettekavatsematult,
tahtmatult, kogemata

unique /ju'ni:k/ - ainulaadne, haruldane
uniqueness /ju:'ni:knis/ - ainulaadsus, haruldus
unit /'ju:nit/ - ühik
unlike /ʌn'laik/ - ebasarnane; mitte nagu
unobtrusively /ʌnəb'tru:sivli/ - pealetikkumatult
unperceived /ʌnpə(:)'si:vð/ - märkamatu
unseasonable - eba e. mitteajakohane
unseasonable frost - varane (sügisel) või hiline (keva-
 del) külm
unwarrantable /ʌn'wɔrəntəbl/ - õigustamatu, põhjendamatu
unwieldy /ʌn'wi:ldi/ - kohmakas, raskepärane
uproot - üles juurima
upset - ümber paiskama, segi paiskama
upwell - üles uhkama, hoovama
urchin /'ɜ:tʃ in/ - siil
sea-urchin - meresiielik
urge /ɜ:dʒ/ - tungivalt toonitama või rõhutama
urgent - tungiv, pakiline
utmost - kaugeim, äärmisim
utter - äärmine, täielik

V

vacuolar /'vækjuələ/ - vakuooli-
vacuole /'vækjuul/ - vakuool
valid /'vælid/ - kehtiv, maksev; (põhjenduse kohta) pai-
 kapidav
variability /vɛəriə'biliti/ - variaablus, muutlikkus

definite variability - määratletud muutlikkus

indefinite variability - määratlematu muutlikkus

variable /'vɛəriəbl/ - muutlik, vahelduv

variably - vahetevahel, ebareeglipäraselt, juhuslikult,
muutlikul viisil

variation /vɛəri'eɪ(ə)n/ - teisendus, muutus

variegated /'vɛərigeɪtɪd/ - kirju, kirev

variegation /vɛəri'geɪ(ə)n/ - mitmevärvilisus

variety /və'raɪəti/ - varieteet e. teisend; (laiemas mõt-
tes ka) liik, sort

varnish /'va:nɪʃ/ - värnits, lakk

vary /'vɛəri/ - muutma, mitmekesistama; muutuma, mitme-
kesistuma, erinema, varieeruma

vehicle /vi:ɪkl/ - sõiduk

veil - loorima, varjama, katma

vein /veɪn/ - soon, tõmbsoon, veen

venereal /vi'niəriəl/ disease - suguhaigus

verify /'verɪfaɪ/ - tõestama; kinnitama

vertebrate /'vɜ:tɪbrɪt/ - selgrooline

vessel /'ves(ə)l/ - anum, nõu; laev

victim /'vɪktɪm/ - ohver

vie /vai/ - võistlema

view /vju:/ - vaade; vaateväli

in view of - (midagi) silmas pidades

vigour /'vɪgə/ - jõud, elujõud; jõulisus

vinegar /'vɪnɪgə/ - äädikas

vineyard /'vɪnjəd/ - viinamarjaaed

violence /'vaɪələns/ - ägedus, vägivald
violence of wave action - lainetuse mõju
violet /'vaɪələt/ - violetne, kannikesesinine
virgin forest - põlismets
virtually /'vɜːtʃuəli/ - tegelikult
virtue /vɜːtʃuː/ - voorus
virulence /'vɪrələns/ - virulentsus, hakatus- mürgisus
virus /'vaɪərəs/ - viirus, pisiku- e. nakatusmürk
visage /'vɪzɪdʒ/ - nägu, pale
visibility /vɪzi'bɪlɪti/ - nähtavus
visible /'vɪzəbl/ - nähtav
vision /'vɪʒ(ə)n/ - nägemine, nägemisvõime; nägemus,
 visioon
vitamin /'v(ə)ɪtəmin/ - vitamiin
vitiate /'viʃieɪt/ - rikkuma, kõlbmatuks tegema
volition /vo(u)'liʃ(ə)n/ - tahe, tahtevõime
volume /'vɒljʊːm/ - ruumala; kogus, hulk
volunteer /vɒlən'tiə/ - vabatahtlik
voyager /'vɔɪ(i)dʒə/ - (mere)reisija
vulture /'vʌltʃə/ - raisakotkas e. kull

W

wade - kahlama, läbi sumama
warbler /'wɔːblə/ - siristaja
reed warbler - tiigiroolind
warfare /'wɔːfɛə/ - sõjapidamine, sõdimine, sõda; hävi-
 tamine

wart hog - tüügassiga (Aafrikas elutsev loom)

wasp /wɒsp/ - herilane

waste - /weist/ - jätted; raiskamine

waterbuck - vesipukk

web - võrk; kude, koetis

weed - umbrohi

weeping branches - leinakujuga oksad

well - kaev

well-defined /'wel di'faɪnd/ - selgepiiriline, kindlaks
määratud

whale /weɪl/ - vaal

beaked whale - nokisvaal

blue whale - sinivaal

humpback whale - pikkloib-vaal

killer whale - mõõkvaal

piked whale - narval (ükssarv)

pilot whale - mustvaal

pygmy right whale - kääbus silevaal

right whale - silevaal

sei whale - põhjavaal

sperm whale - kašelott e. võidisvaal

whip-like - piitsakujuline, niitjas

whitethorn = hawthorn

whole - terve; hea tervise juures

widow - lesestuma

wildebeest /'waɪldbi:st, vɪldə-, -beɪst/ - L. Aafrika
pühvelhobu, gnuu (=gnu)

wildlife - loodus
wildtype - metsik tüüp, metsik tüvi
wilfully - tahtlikult, ettekavatsetult
windrow - tormiheide
wing petal - tiibjas külgmine kroonleht
wire - traadiga varustama või kinnitama
wisp - tutt, kimp, tuust
wither /'wiðə/ - närtsima, närbuma
withstand - (millelegi) vastu seisma või panema
witness - tunnistajaks olema
woodland - metsamaa, -maastik
workmanship - meisterlikkus
worm /wɔ:m/ - uss, vagel
worth /wɔ:θ/ - siin: väarikus
wrap /ræp/ - mähkima, sisse mässima
wreck /rek/ - riise, rusu; purustama, hävitama, laeva-
 või rongiõnnetust tekitama

X

xerophyte /'zi:rəfait/ - kserofüüt

Y

yeast /ji:st/ - pärm; pärmseen
yelp - klähvima, kilavalt haukuma
yield /ji:ld/ - (saaki või tulu) andma

Z

zeal - ind, innukus, agarus
zebra /'zi:brə/ - seebra
zone /zoun/ - tsoon, vööde, vöönd.

Proper Names

Alaska /ə'ləskə/

Amazon /'æməzɒn/ - Amazonas, Amatsoni jõgi

Andes /'ændi:z/ - Andid (L. Ameerika Kordiljeerid)

Andrew Knight /'ændru: nait/

Argentina /a:dʒ(ə)n'ti:n / - Argentiina

Arimathaea /ærimæ'θiə/

Asa Gray /'eisa grei/

Auckland Islands /'ʊ:klənd 'ailəndz/

Australia /ʌ(:)s'treiliə/ - Austraalia

Avalon /'ævələn/

Avery /'eivəri/

Balkan Range /'bʌ(:)lkən 'reindʒ / - Balkani mäeahelik

Bougainville /'bu:gənvil/

Brittany /'brit(ə)ni/

Bulgaria /bʌl'gɛəriə/ - Bulgaaria

Cape Horn /keip 'hɔ:n/ - Kap Hoorn

Chase /tʃeis/

Chile /'tʃili(:)/ - Tšiili

Colombia /kə'lʌmbiə, -'lʌm-/

Congo /'kɒŋgou/ - Kongo

Danube /'dænju:b/ - Doonau

Dnieper /'(d)ni:pə/ - Dnepr

Dniester /'(d)ni:stə/ - Dnestr

Ecuador /ekwə'dɔ:, 'ekwə dɔ:/

Farnham /'fa:nəm/

Florida /'flɔːrɪdə/

Galapagos /gə'lə'peɪɡəs/ -

Gulf Stream /'gʌlfstriːm/ - Golfi hoovus

Herefordshire /'herɪfədʃɪə/

Hooker /hʊkə/

Horace /'hɔːrəs, 'hɔːrɪs/ - (rooma luuletaja) Horatius

Hudson /'hʌdsn/

Humboldt Current /'hamboult kərənt/

Iceland /'aɪslənd/ - Island

Ireland /'aɪələnd/ - Iirimaa

Kildare /kɪl'dɛə/

Lawrence /'lɔːrəns/

Lebanon /'lebənən/ - Liibanon

Lima /li:mə, Am. ka laɪmə/

Magellan /mə'ɡelən/ - Magalhaes

New Jersey /'njuː 'dʒɜːsi/

New Zealand /'njuː 'ziːlənd/ - Uus-Meremaa

Pacific /pə'sɪfɪk/ - Vaikne ookean

Panama /pænə'maː, 'pænə'maː/ - Panama

Paraguay /'pærəɡwai, -wei, -'wai/

Patagonia /pætə'ɡoʊniə/ - Patagonia

Pennsylvania /pensɪl'veɪniə/

Peru /pə'ruː/ - Peruu

Pyrenees /pɪrə'niːz/ - Püreneed

Rhone /roun/ - Rhone

Rio Guadalquivir /'ri(:)ou ,gwaɪd(ə)l'kwɪvə/

Rumelia /ru(:)'meɪniə/

Salinas /sə'li:nəs/

Santiago /sænti'a:gou/

Seattle /si:'ætɪ/

Sierra /si'ərə, 'siərə/ - pikk sakiline mäestik, mäeahelik (eriti Hispaanias või hispaania keelt kõnelevas Ameerika osas)

Staffordshire /'stæfəd (i)ə/

Stanley /'stænlɪ/

Surrey /'səri/

Tanganyika /tæŋgæn'ji:kə/ - Tanganjika

Theresa /tə'ri:zə, -sə/

Tierra del Fuego /'tjerədel 'fweigou/ - Tulemaa

Ukraine /ju:'krain, -'krein/ - Ukraina

Vaughan /vɔ:n/

Virginia /vɜ:'dʒiniə/

Wisconsin /wis'kɒnsin/

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II

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