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The Zoological Society of London

Scientific Report

1979–1981

A summary of the scientific activities of the Society carried out by the Institute of Zoology at Regent's Park and Whipsnade Park.

Contents

INTRODUCTION

J. P. Hearn

"The Advancement of Zoology and Animal Physiology and the introduction of new and curious subjects of the animal kingdom" was defined as the purpose of the Zoological Society of London in its charter in 1829. One hundred and fifty years have not changed the validity of this objective. Today more animals than ever are endangered or threatened and the projections of future growth of human populations lend increasing urgency to the Society's aims.

With the human population numbering more than 6 billion within the next 20 years, exotic animals in captivity and in the wild will need careful management as a whole in order to prevent the extinction of many species. Success will depend on a sound scientific approach to understanding the limiting factors of animal disease, genetics, nutrition, reproduction and veterinary management. The success of these efforts is important for the inherent beauty and interest of wildlife as well as for the resource that wildlife represents for agriculture and medicine in the future.

The Zoological Society of London has always been a focus for research. With the establishment of the Wellcome Institute of Comparative Physiology in 1963 and the Nuffield Institute of Comparative Medicine in 1964, facilities for laboratory research on wild animals were provided that are unmatched anywhere else in the world. The formation of the Institute of Zoology, which has evolved to include the above noted laboratories, the Department of Veterinary Science and the Curators' research units, presents a team of research workers in Departments of Genetics and Haematology, Infectious Diseases, Nutrition, Radiology, Reproduction and Veterinary Science that can avail of the unique opportunities afforded by the Institute's position in Regent's Park and Whipsnade Zoos. The Society provides opportunities for research and materials for study that can be found nowhere else.

The opportunities afforded make it easy to find innumerable projects and the prospects for the future are unlimited. However, it is important to concentrate efforts on projects that advance basic zoology and are useful to animal conservation, agriculture and comparative medicine, making the best use of the available resources. The scope for research work is immeasurably enhanced by collaborative studies with other institutions; Research Council establishments, Universities, clinical research groups or with other Zoos. Each department has developed such links and will continue to do so. In addition, collaborative research links are fostered with some field projects, enabling an important feedback between conservation and breeding of animals both in captivity and in the wild.

An important area of activities is in teaching and research training. Close links with University departments, developed in particular over the past two years, allow the Institute's staff to present formal lecture courses and to provide opportunities for graduate and undergraduate students. In addition, many workers from the UK and abroad visit the Institute each year to learn research techniques or to participate in projects.

Dr L. G. Goodwin, FRS, Director of Science, retired at the end of July 1980. He joined the Society's staff in 1964 to direct the newly formed Nuffield Institute of Comparative Medicine and was subsequently appointed Director of Science in 1966. He played a leading part in

developing the Society's role in biological research and in reinforcing its original scientific purpose. The staff of the Society, and especially of the Institute, owe him a great deal for his leadership, vision and friendship.

Miss Patricia Wright, Administrative Assistant in the Nuffield Laboratories of Comparative Medicine for the past 16 years, died in October 1980 after a short illness. Her death deprived us of a capable helper and friend on whose advice and encouragement we all relied.

In February 1981 the research programme of the Society was reviewed by a Visiting Group appointed by the Advisory Board to the Research Councils (ABRC). The members of the Group were Dr Anne McLaren, FRS (Chairman), Sir Arnold Burgen, FRS, Dr Barry Cross, FRS, Professor Richard Gardner, FRS, Professor D. L. Hughes, CBE and Dr R. M. Laws, FRS. They were accompanied by Dr R. Riley, FRS, Dr J.A.F. Rook, FRSE, Mr. R. J. Harris, Mr K. N. Burns, Dr J. S. Perry and Dr M. Carpenter from ARC headquarters.

The Visiting Group reported very favourably, defining the Institute as a unique national resource. They made a number of recommendations that have since been implemented in consultation with the Institute of Zoology Committee and the Board of Studies. We are most grateful for the continued advice and help of members of the Visiting Group, and to the ABRC whose support is proving instrumental in realizing the potential for research presented by the Institute of Zoology.

Aims and Activities

OBJECTIVES

1. *Basic science.* To advance fundamental knowledge of zoology and animal physiology.

2. *Conservation.* To improve the diagnosis and treatment of disease and the breeding and management of animals in captivity and in the wild.

3. *Comparative medicine.* To apply the findings from research to medical and agricultural science.

4. *Education.* To pursue an active teaching and training programme at undergraduate, postgraduate and postdoctoral levels (in addition to the Society's comprehensive programmes for school children).

5. *Collaboration.* To act as a resource centre in working with up to 200 other institutions in joint projects or in the supply or research materials.

SUMMARY OF RESEARCH PROGRAMMES

In each department a balance is maintained between projects related to animal conservation or management and those related to physiology and comparative medicine. In a growing number of cases the distinction between these two areas disappears. Furthermore, in a rapidly increasing number of cases, joint projects are developing that involve several departments.

1. *Genetics and Haematology*

Head: Dr D. B. Whitehouse (from August 1981)

The Genetics Department is situated in the Nuffield Laboratories and the Haematology Unit in the Wellcome Laboratories. The work of the Department focusses on the genetics of small populations of animals, investigating chromosomal changes and genetic markers that may provide improved methods of management and breeding, particularly of endangered species. Current projects are:

(a) Biochemical markers and their inheritance in Przewalski and domesticated horses.
(b) Karyotype variation in primates.
(c) Indices of inbreeding in the Scimitar horned oryx, deer species, the Mouflon and the Collared peccary.
(d) The genetics of complement and the mechanisms of its inheritance.
(e) Cytogenetic and immunological methods of sexing monomorphic species.

The Haematology Unit, under Dr Christine M. Hawkey, provides a diagnostic haematology service to the Zoos. The vast amount of data accumulated over the past 10 years is now being placed on a computer to enable more rapid diagnosis. Current research projects are:

(a) The effects of stress or sedation on the blood count.
(b) Animal models for hypertrophic cardiomyopathy.

2. *Infectious diseases*

Head: Dr G. R. Smith

The Department is situated in the Nuffield Laboratories and studies the prevalence and spread of botulism as well as aspects of vaccine protection against strains of mycoplasmas. Major research projects are:

(a) The incidence of *Clostridium botulinum* in soil and mud and its relationships with avian mortality and public health.
(b) The development of vaccines against contagious bovine pleuropneumonia.
(c) Mycoplasmas and respiratory diseases.

The Immunoassay Unit, headed by Dr A. Voller, who is a staff member at the School of Hygiene and Tropical Medicine, is responsible for the development of several new assay methods, of which the enzyme linked immune absorbed assays (ELISA) are used worldwide. The research work of the Unit is in new assay technology and its application to the diagnosis of disease and the development of monoclonal antibodies. Major projects include:

(a) Improved assay technology to give rapid, simple and economic diagnostic tools for infectious disease.
(b) The development of monoclonal antibodies.
(c) Fluorescent assays.
(d) Vaccines against malaria in humans and primates, including the improvement of adjuvants.

3. *Nutrition*

Head: Professor M. A. Crawford

The Department is situated in the Nuffield Laboratories. Research work concentrates on the requirements for and the metabolism of essential fatty acids, particularly during pregnancy and in the formation of the brain during fetal and neonatal life. The studies are carried out in a range of animals and in man. Major research projects are:

(a) The lipid requirements for neonatal ungulates, marine mammals and man.
(b) The role of essential fatty acids in the development of the brain.
(c) The function of the placenta in storage and transfer of essential fatty acids.
(d) The relationship between essential fatty acids and prostaglandins.
(e) The association of fatty acids in cystic fibrosis and multiple sclerosis.
(f) Computer based analysis of diets.
(g) The formulation of synthetic and natural diets.

4. *Radiology*

Head: Professor G. H. du Boulay

The Department, situated in the Nuffield Laboratories, contributes a consultant radiology service to the Collections (and staff) as well as pursuing the following research projects:

(a) The significance of vasospastic fractions in cerebro-spinal fluid after spontaneous subarachnoid haemorrhage, head or spinal cord injury.
(b) The effects of high fat diet on cerebral arteries and its possible association with strokes.
(c) The accumulation of an X-ray museum of comparative skeletal anatomy and skeletal disease.
(d) Non-invasive methods for diagnosis of disease and monitoring reproductive events.

5. *Reproduction*

Head: Professor J. P. Hearn

The research of the Department concentrates on the reproductive physiology of exotic species, the New World primates and humans. There are four inter-related research units: Endocrinology and Behaviour Units are based in the Wellcome Laboratories; Gamete Biology and Developmental Biology are based in the Nuffield Laboratories. Major research projects are:

(a) Reproduction in exotic species.
The reproductive physiology of the Great apes (Gorilla, Orang-utan, Chimpanzee), Giant pandas, felids (Puma, Cheetah), African elephant, Black rhinoceros and Blackbuck;
the control of embryonic diapause in Bennett's wallaby.

(b) Reproduction in New World primates.
The reproductive physiology and captive breeding of Common marmosets, Owl monkeys and Cotton topped tamarins;
the endocrine control of ovulation, implantation and pregnancy;
the endocrinology of foetal and neonatal development;
monoamines and the control of pituitary function, aggressive and sexual behaviour;
sperm maturation and epididymal function;
membrane fusion, cryopreservation and artificial insemination;
endocrine, immune and morphological relationships during implantation;
the recovery, culture, freezing and transfer of ova, sperm and pre-implantation embryos.

6. *Veterinary science*

Head: Mr D. M. Jones.

The Department is situated in the Animal Hospital adjacent to the Wellcome Laboratories. The Department is responsible for the health of the animals in the Collections

and of the laboratory animals maintained in the Institute. Staff of the Department are involved, directly or indirectly, in most of the research projects carried out by the Institute's staff on animals in the Collections. In addition, major research projects are:

(a) The physiology of sedation and anaesthesia.
(b) The development of fibre-optic laparoscopy for diagnostic or research purposes.
(c) Artificial breeding of exotic species (in collaboration with the Department of Reproduction).
(d) Nutrition in the Scimitar horned oryx and the Reeves's muntjac.
(e) Comparative pathology and virology.
(f) Computerized diagnosis of animal disease and clinical care.
(g) Development and improvement of clinical treatment and management of exotic species.
(h) Supervision of wildlife conservation studies in Niger and in Southern Sudan.

7. *Curators' Research Units*

The Curators, of Mammals, Birds, Reptiles and the Aquarium and of Whipsnade (Dr B. C. R. Bertram, Mr P. J. Olney, Dr H. G. Vevers and Mr V. J. A. Manton, respectively) are responsible for developing the scientific basis of animal management. This includes husbandry, nutrition, natural and artificial breeding, and transport. They, and the Keeper staff who report to them, work closely with the research staff in facilitating projects on zoo animals. Apart from their own research work, they provide materials for projects, create opportunities for students, take part in national and international committees and in a considerable amount of editorial work. Dr Vevers, the Assistant Director of Science is responsible for the publications of the Society.

Professor A. J. E. Cave, Honorary Research Associate, carries out a number of projects on the anatomy of mammals. Current work includes studies on the Dolphin, Rhinoceros and higher primates.

8. *Workshop*

The workshop of the Nuffield Laboratories specializes in the development of equipment to assist research and animal management. Mr P. R. E. Wallace (Laboratory Superintendent, Nuffield Laboratories) and Mr W. G. Ray (Senior Technician) have designed and constructed many items of which the following are examples:

(a) Exercise wheel for rodents with digital counting display.
(b) Bird perches that contain an electronic weighing facility.
(c) Equipment for the *in vitro* culture of placenta.
(d) Lances for delivering anaesthetic to large animals.
(e) Remote controlled capture box for small mammals.
(f) Controlled environment egg incubators for birds.

TEACHING AND TRAINING

Seminars and Workshops

The Institute holds a weekly seminar, convened by Drs Moore and Hawkey, to which all members of staff are invited, related to research in conservation and biomedicine. The seminars are attended by a growing number of Keepers and by visitors from nearby

University or Research Council establishments and it is hoped that this initiative will develop into a forum for discussion of biological research in the London Area.

A weekly lunch-time workshop, convened by Drs Hodges and Whitehouse, is conducted on specific research projects. The workshop is open to all members of Institute staff, Keepers and a few, specifically invited, visitors or collaborating research workers.

Scientific Meetings and Symposia

Drs Vevers and Edwards organize a monthly scientific meeting, at which new research is presented and films are exhibited. The meetings are open to Fellows and Associates of the Society and always draw a large audience.

Drs Vevers and Edwards also organize and publish the series *Symposia of the Zoological Society of London.* These are major conferences held on average twice a year and dealing with particular zoological subjects.

Lecturing by Members of Institute Staff

A number of staff members hold University appointments and present regular lectures or courses for under- or postgraduates. In addition, a large number of invited lectures are given each year to under- or postgraduate students. The major involvements are:

Genetics and Haematology: Dr C. M. Hawkey is an Honorary Lecturer in Haematology, Royal Free Hospital (University of London) and a Lecturer at Paddington Technical College. *Infectious diseases:* Dr G. D. R. Smith is a course Lecturer at the Royal Veterinary College (University of London) and at the University of Surrey. Dr A. Voller is Reader in Immunology of Parasitic Diseases, London School of Hygiene and Tropical Medicine (University of London). *Nutrition:* Professor M. A. Crawford is Honorary Professor of Applied Biochemistry and Nutrition at the School of Agriculture, Nottingham University. *Radiology:* Professor G. H. du Boulay is Head of the Lysholm Radiological Department, National Hospital for Nervous Diseases, London. *Reproduction:* Professor J. P. Hearn is Visiting Professor in the Department of Zoology and Comparative Anatomy, University College (University of London). Dr A. F. Dixson is a course Lecturer in the Department of Zoology at University College and Birkbeck College (University of London) and in the Department of Psychology, Bedford College (University of London). He and Miss S. Kingsley were Visiting Lecturers and Tutors at the Summer School on "Primate Biology and Conservation", Jersey Wildlife Preservation Trust, 1981. Drs J. K. Hodges and H. D. M. Moore give lectures in the Department of Zoology, University College. Professor Hearn and Dr Moore are Lecturers in the WHO post-doctoral course on reproductive physiology held at the Royal Postgraduate Medical School (University of London). *Veterinary science:* Mr D. M. Jones is a course Lecturer at the Department of Medicine, Royal Veterinary College. Mr J. A. Knight is a Lecturer at Paddington Technical College. *Curators' Research Units:* Dr B. C. R. Bertram is a Lecturer at Paddington Technical College and a Guest Lecturer at the University of Stockholm.

Professor Hearn and Mr Jones are members of the Board of Studies in Zoology at the University of London.

Research Training

Opportunities exist for research training at both under- and postgraduate levels. In the

period under review (1979–81), the following undergraduates completed short periods of research towards their BSc degrees under the supervision of staff members of the Institute.

From University of Cambridge: Elizabeth Newbury. From University of London: C. Bishop, Helen Boorman, Christine Fraser, D. Harris, April Jones, Anne McBride, Jane O'Gorman, Gillian Pitts, Jacqueline Sutton. From University of Oxford: Ruth Mace, Elisabeth Bowes. From Oxford Polytechnic: Rose Chard, Farina Nagarwalla, Karen Oxenbury, D. Thornhill, Alison Warner. From Reading University: Jane Bowcock. From University of St Andrews: R. Panaman. From Open University: Catherine Scanlon.

PUBLICATIONS

Dr H. G. Vevers, Assistant Director of Science, Dr Marcia, A. Edwards and the staff of the Publications Department are responsible for the following scientific publications:

Journal of Zoology
Nomenclature Zoologicus
Symposia of the Zoological Society of London
Transactions of the Zoological Society of London
International Zoo Yearbook (Mr P. J. S. Olney, Ed.)
Zoological Record (in co-operation with BIOSIS UK LTD)

THE INSTITUTE OF ZOOLOGY COMMITTEE

The Institute of Zoology Committee, whose members are appointed by Council, meet three times a year and advise on all aspects of the scientific development of the Institute. The current members of the Committee are:

S. K. Eltringham, PhD
Professor B. K. Follet, PhD, DSc
Professor I. M. Glynn, PhD, MD, FRS
Sir William Henderson, DSc, FRCVS, FIBiol, FRS, FRSE Chairman
Professor G. E. Lamming, MS, PhD, FIBiol
Professor N. A. Mitchison, DPhil, FRS
J. S. Perry, PhD, DSc
Professor J. G. Phillips, PhD, DSc, FRS
C. A. Wright, PhD, DSc, FIBiol
Professor A. J. Zuckerman, MD, DSc
Professor J. P. Hearn, M.Sc, PhD, FI Biol (Secretary)

THE BOARD OF STUDIES

All PhD level staff are members of the Board of Studies, which meets monthly with the aim of improving communication and co-ordinating the research effort; availing of opportunities within the Zoos, developing inter-departmental collaboration and improving scientific standards.

RESEARCH PROGRESS REPORT 1979–81

J. P. Hearn

The Institute of Zoology includes the Nuffield Laboratories of Comparative Medicine, the Wellcome Laboratories of Comparative Physiology, the Animal Hospital and the Curators' Research Units. In addition to the approximately 100 members of staff and students in the Institute at any one time, a growing number of Keepers are involved in research projects and the studies on animals in the Society's Collections depend on close collaboration between the scientific staff, Overseers and Keepers.

This research progress report continues from the Scientific Report 1977–79 and covers the period from September 1979 to October 1981.

Genetics and Haematology

GENETICS

As originally planned when it was established in mid-1979, the work of the Genetics Department has developed in two main areas. The first is the comparative genetics of groups of related species in order to study evolutionary processes at the levels of the chromosome and the single gene. This work may be described as "Evolutionary genetics". The second is in response to specific problems identified in zoo animals and may be termed "Case genetics". In addition, research depends on the development of new techniques and the refinement of existing methods. Work of this kind is reported under the heading "Methods". The results reported below were obtained by Dr Rachel Fisher, Dr J. Matthews and Dr D. Whitehouse, and Miss Wendy Putt.

EVOLUTIONARY GENETICS

The work of the Department requires methods that are applicable to a variety of species, often unstudied, and that also permit the investigation of a large number of different gene products. A major aim is to detect and follow the processes of chromosomal re-arrangement by comparing both the gross and the fine structure of the genetic material. Therefore the karyotypes of various closely related species are examined so that homologous regions of chromosomes can be identified and to complement this the chromosomes are mapped for biochemical markers produced by the genes they carry. The gross mapping will be done using somatic cell hybridization techniques. The fine mapping will be done from data derived from family segregation.

A further aim is to study the evolution of single, or sets of genes. The approach to this is to determine the incidence of polymorphism at any given locus, to look for evidence of gene duplication and to study species differences in the physiological properties of the gene product.

Useful results can only be gained by concentrating the effort on a restricted number of animal groups. From consideration of availability of samples and the degree of importance to conservation, the equidae and the primates have been chosen as the subjects for intensive work. The Department has a grant to support the equid study.

Equidae

One hundred and twenty-eight individuals were examined for 57 biochemical markers of which 18 showed inherited variation. Fifty-four animals were karyotyped and five chromosome markers identified (four C-band polymorphisms and one acrocentric chromosome). All the chromosome preparations examined confirmed to the Przewalski karyotype ($2n = 66$) and no hybrid karyotypes, potentially derived from a cross between a Przewalski stallion and a domestic mare ($2n = 65$), were observed. Family studies indicated that the markers were inherited as stable features. Linkage studies showed negative results for most pairs of markers indicating that they do not lie close together. However, the two Prealbumin loci appear to be closely linked to each other and one of the blood groups and the two C7 loci are probably closely linked. This study was begun as a joint project and includes work done on karyotyping by Dr Joy Delhanty of University College (London) and work done on blood grouping by Mr M. Scott at the Equine Research Station, Newmarket.

A project was initiated to produce somatic cell hybrids using lymphoid cells grown from horses as parent lines. The resulting hybrid clones will enable the assignment of enzyme loci to specific equid chromosomes.

Small populations of other equidae were examined karyotypically and biochemically. A detailed study of Common zebra biochemical markers and chromosomes is under way to discover if there is a molecular or cytological basis for differentiating the common geographical races.

Primates

Great apes

Participation in the Ape Advisory Panel scheme, which is devoted to research leading to improvements in Great ape breeding performance, has continued. Karyotypes were prepared by Dr J. Parrington at UCL and the Genetics Department, and the blood grouping by Dr P. Tippett and Dr Daniels at the MRC Human Blood Group Unit. A sample collection kit and instruction sheets were designed and despatched to 23 participating Zoos and Collections. So far, four Zoos have returned specimens for genetic analysis.

Squirrel monkeys

This group shows considerable karyotype variation according to geographical origin. The karyotypes of animals from the Whipsnade colony and from some laboratory animals in the Institute were examined. Biochemical marker polymorphism were found to be surprisingly low in the Whipsnade animals although each animal can now be identified by its genetic

markers. A larger survey using experimental animals also showed a low level of polymorphism. The findings suggest a relatively high degree of inbreeding. If this is the case, the genetic make-up of any two separate groups may be very different and in experimental physiological studies these differences could have significant effects.

Lemurs

The biochemical markers and karyotypes of the Zoo's Ruffed lemur colony were examined. The colony is represented by a single family. No linkage has been found between any segregating markers.

Baboons

At the request of Dr Barnes (CRC), the biochemical markers of a group of baboons were examined. These animals are being used in experiments to induce immunological tolerance to donor cells received *in utero* and if successful, the bone marrow of the recipients should exhibit mosaicism. Evidence was sought by examining the biochemical markers of recipient circulating red cells for evidence of variants known to exist in the donors but not in the pretreated recipients.

A number of useful markers were identified but because the first series of experiments was initiated before the genetic information was available, with the exception of a single case, the fate of the donor cells could not be monitored. However, further experiments which can be controlled using the biochemical markers are now underway.

Common marmosets

A study of the biochemical markers of the marmosets in the experimental colony at the Institute of Zoology was begun. Initial findings suggest that the level of polymorphism may be low. Two variable markers (C6 and C7) were shown to be of value in controlling embryo transfer experiments carried out by the Department of Reproduction.

Owl monkeys

Mr D. N. Anderson of the Wellcome Foundation requested an examination of the chromosomes of a group of Owl monkeys believed to be members of the Colombian race. The Owl monkeys show extreme chromosomal variation with diploid counts ranging from 46 to 56. The Colombian race itself varies ($2n$ = 54, 53 or 52) due to a fusion polymorphism. Karyotypes were prepared and the belief confirmed.

Artiodactyla

Scimitar-horned oryx

Seven of these animals were studied cytogenetically and in one an aneuploid karyotype resulting from the centric fusion of two acrocentric chromosomes was found. Samples from related animals will be analysed to discover whether this condition has arisen *de novo* or whether the chromosome re-arrangement was inherited. This variant might affect fertility and, if so, would be of relevance to plans for reintroduction of this species to the wild. Testicular biopsies will be examined for normal meiosis.

Deer

The evolutionary relationships of deer were studied by Mr M. Looker (visiting student) as part of his BSc course, by analysing 14 biochemical markers in 101 samples from 14 different species. Low levels of polymorphism were found but sufficient interspecific differences existed to be able to construct dendrograms. The conclusions were in broad agreement with those of other taxonomists.

Mouflon and Collared peccaries

Biochemical markers were examined in these species. Samples from every individual in the London and Whipsnade Collections were examined and some karyotypes were prepared from the Mouflon. Both groups showed low degrees of polymorphism, almost certainly due to inbreeding. The Mouflon were found to have a variant haemoglobin of the sickling type but this is thought unlikely to be the cause of any clinical abnormality.

Genetics of complement

In man, a great deal is known about the genetics of the complement system (*C'*). These studies were carried out to determine whether a comparable situation exists in other animal groups particularly with respect to the linkage arrangements of *C'* producing genes for the purpose of understanding aspects of the evolution of the *C'* system.

Structural polymorphisms that were found in non-human complement components are listed in Table I below.

TABLE I

Structural polymorphisms in complement from non-human mammals

Species	Component	No. of loci	No. of alleles	Inheritance shown
Przewalski horse	C7	2	3,3	Yes
Ruffed lemur	C7	1	2	Yes
Squirrel monkey	C7	1?	3+	No
Baboon	C6	1	4	No
(Olive/yellow)	C7	1	4	No
	FacB	1	2	No
Marmoset	C6	1	6	Yes
	C7	1	3	Yes

The horses and possibly the Squirrel monkeys contrast with humans in that there appears to be more than one C7 locus controlling the production of C7 in these species.

An attempt to establish linkage between C6 and C7 in the marmoset is under way. The current data very strongly suggest linkage but are not statistically significant. Matings have been scheduled that should confirm linkage.

A study of human C6 is being carried out in collaboration with Dr P. J. Cook of the MRC Human Biochemical Genetics Unit in an attempt to produce a chromosomal assignment for the C6 and C7 loci.

The fact that an avian C7 reagent can be prepared from Macaw acute phase serum suggested that birds possess an alternative pathway, but it is not readily detectable. For instance, when using a normal test system, swan alternative pathway seems to require an extrinsic non-avian serum factor before it can induce lysis of erythrocytes.

CASE GENETICS

The projects reported in this section were undertaken because of specific problems identified in zoo animals.

1. *Przewalski horses*

A number of syndromes have been described in these animals including a progressive but non-fatal ataxia and a sudden rapidly fatal collapse, not unlike grass-sickness, which may occur in the pre-adult period. Both these conditions are probaby genetically determined although the inheritance patterns are not clear. In collaboration with Mr D. Ashton (Department of Veterinary Science), Mr K. Whitwell (Equine Research Station), Dr M. Frankenhuis (Rotterdam Zoo) and Dr and Mrs Bouman (Society for the Preservation of the Przewalski Horse), attempts are being made to define the syndromes and make early diagnoses so that detailed post mortem studies can be carried out. Samples were sent to Great Ormond Street and the Institute of Neurology to see if they resemble any samples from known human inborn errors. The findings so far have been negative. A table of normal haematology and biochemical values from data collected over the past 10 years was drawn up. There appear to be considerable changes in most parameters with development. Some chronically "abnormal" animals were detected whose clinical states are usually reported as normal. One of these animals has since died and the others are being followed with particular attention.

2. *Collared peccaries*

It has been known for a long time that the Collared peccaries kept at Whipsnade are prone to attacks of arthritis, particularly following stress, yet this does not appear to be a problem in other Collections. By chance an X-ray of one animal was seen by Dr A. Young, then in the Department of Rheumatology in the Middlesex Hospital. He felt that the appearances of the joints were sufficiently like rheumatoid arthritis for it to be worth investigating these animals as a possible model for the human disease. The investigation was undertaken by the Genetics Department because of the inherited pre-disposition to this disease that is known to occur in man. During the summer of 1980, a 5th year veterinary student, Mr P. Markwell, was employed to carry out a clinical investigation of the whole Whipsnade herd. All the animals were X-rayed and bled. All animals over three years showed evidence of osteo rather than rheumatoid arthritis. They had raised ESRs and a normochromic anaemia. Plasma biochemistry was apparently normal. Bacteriological investigations showed *Yersinia enterocolitica* to be present in the faeces of some affected animals. In the past, direct culture of sinovial fluid and antibody titres for an exhaustive list of organisms known to cause arthritis in domestic pigs have not indicated any causative organism. A similar batch of tests are being done in the present investigation. Malnutrition is also being investigated, in collaboration with the Department of Nutrition, as a possible predisposing cause.

PLATE I. Ruffed lemur with naked offspring. Inherited nakedness in the ruffed lemur is thought to be homologous to human BIDS syndrome. Photo: M. Lyster.

3. *Ruffed lemurs*

The nude animals born in this family are thought to be suffering from a condition homologous to the human BIDS syndrome (Brittle hair; Intellectual impairment; Decreased fertility; Short stature). This is associated with reduced fertility of unknown cause. When the remaining nude animal (a male) reaches sexual maturity its reproductive status will be investigated (see Plate I).

4. *Bird sexing*

Sex determination in monomorphic bird species was carried out using the lymphocyte culture technique to obtain chromosome preparations, and the C-band staining method to identify the sex chromosomes. Sexing was successful in cranes, Chilean flamingos and three species of owls. A list of birds required for breeding purposes but of unknown sex was obtained from the Curator of Birds and the work of assigning gender to these cases is now under way.

5. *Inbreeding*

A programme was started to investigate the records of some of the animal groups in

the Collections in order to estimate the degree of inbreeding, to consider the general health of the group and its current breeding potential. The neonatal mortality and recurrent disease syndromes are of particular interest. The Regent's Park Mouflon were chosen as a pilot study group. A search of the records showed that no new blood had been introduced at least since 1930. Furthermore, for several years Soay sheep were kept with the Mouflon and hybrids were born. It is not clear whether all hybrids were removed. Neonatal and early infant mortality has apparently increased over the years and is now in the region of 50% and above. The animals were all caught, weighed, blood sampled and tagged in the early spring of 1980. Biochemical markers were examined in an attempt to identify each individual so that family relationships may be elucidated in the future. A table of "normal" haematology and biochemical values for adults was constructed. More recently, in collaboration with Dr Bertram, Professor Crawford and Mr Jones the study has been extended to include a prospective biochemical analysis.

A special diet designed by the Department of Nutrition is now being tested in an attempt to correct apparent nutritional deficiency.

METHODS

1. *Low contrast image enhancer*

An optical device based on the Schlieren principle was developed in order to see more clearly, and record photographically, the results of the complement studies. Experiments show the apparatus is capable of greatly increasing the contrast between a layer of red cells and the zone of lysis therein. A grant was obtained from the Royal Society Paul Instrument Fund to finance the building of the final version.

2. *ELISA technique applied to the detection of proteins separated by electrophoretic methods*

The identification and characterization of specific proteins after electrophoresis is normally achieved either histochemically (in the case of many enzymes) or immunologically. The latter method depends on the specific binding of antibodies to antigenic regions of the protein molecules. Although this process is highly specific, it normally requires that relatively large amounts of antigenic protein are present. In collaboration with Dr A. Voller, a method that will allow very small amounts of antigen to be detected following electrophoresis is being devised. Success in this endeavour should increase the range of gene products available for study.

3. *Isoelectric focusing*

The separation of proteins by isoelectric focusing in acrylamide gels continues to be improved. It is now possible to identify four polymorphic loci in Przewalski horses using one gel. The resulting separation has revealed three alleles at the post albumin locus and five alleles at the prealbumin locus where previously in both cases only two alleles had been described.

4. *Binding assays for the H–Y antigen*

The H–Y antigen is present on most cells of the heterogametic sex (XY males, ZW females), as such it has great potential as a tool for assigning the gender to members of

sexually monomorphic species. In collaboration with Dr Moore and Dr Voller at the Institute of Zoology and Dr Elizabeth Simpson of the Clinical Research Centre, Harrow an ELISA is being developed that might rapidly and inexpensively detect the presence of the H–Y antigen.

HAEMATOLOGY UNIT

The Haematology Unit moved from the Nuffield to the Wellcome Laboratories in 1980 with the aim of increasing collaborative studies with the Department of Veterinary Science. Further automation of equipment allowed the analysis of a larger number of blood samples. Emphasis was given to the establishment of reference values for a wide range of species in the Collections at Regent's Park and Whipsnade.

Routine haematology

Estimations of fibrinogen were introduced as a part of the routine screen and found to be useful as an indicator of infection and inflammation. High fibrinogen levels were associated with thrombosis in flamingos, suggesting that the affected birds might benefit from treatment with Ancrod, a defibrinating extract of snake venom. Dr Christine Hawkey and Miss A. Blofield, on sabbatical leave from Goldsmith's College, studied the effects of Ancrod on avian blood coagulation, finding similar effects in ducks, swans, flamingos and in man.

Studies on changes in the blood count of animals during sedation continued. Splenectomy or pretreatment with combined alpha and beta adrenergic blocking drugs abolished the fall in red cell count, packed cell volume and haemoglobin levels that were previously shown to occur in sheep sedated with xylazine or ketamine.

Haematological studies in the field

In order to apply laboratory studies to field conditions, a mobile haematology laboratory was developed and tested by Dr Hawkey during a visit to the Jonglei Ecological Project in the Sudan in March and April 1981. The studies were carried out principally on native cattle in the area since time and local facilities did not allow any extensive studies on wildlife.

The survey aimed to test the feasibility of carrying out blood counts and plasma protein measurements under field conditions and to assess the usefulness of these tests for monitoring the condition of the native cattle in the area. It proved possible to measure packed cell volumes, white cell and platelet counts and haemoglobin, total protein and albumin levels on the spot. In addition, blood films were fixed and brought back to London for subsequent examination. Four groups of cattle were examined comprising Nuer, Shilluk and Dinka cows and calves from the cattle camps around Woi, Malakal and Nyany respectively and, for comparison, Dinka cows from the MAFAO Dairy Farm at Juba which received dietary supplements and regular veterinary care. Results from the latter group were within the normal ranges for British dairy cattle but many animals from the cattle camps were anaemic and had abnormally low total protein and albumin levels, probably reflecting malnutrition or concurrent disease. No significant blood parasites were found but all groups showed eosinophilia, underlining the probable importance of parasitic infestation as a cause of ill health. Unexplained lymphocytosis occurred in many of the Shilluk cattle at Malakal.

Animal models for hypertrophic cardiomyopathy

Mr P. C. Pearce, in collaboration with Dr C. Symons of the Royal Free Hospital and Dr E. G. J. Olsen of the National Heart Hospital, investigated the role of thyroid hormones and catecholamines in the development of cardiomyopathies and examined ways of preventing the pathological changes seen.

Triiodothyroacetic acid (triac) and, at a much higher dose level, thyroxine, when injected into rats throughout pregnancy, produced cardiac muscle damage in the newborn offspring. The abnormalities, which are similar to certain features of hypertrophic cardiomyopathy in man, consist of hypertrophy and, at the ultrastructural level, disarray of the myofibrils. These findings, together with the known association between hyperthyroidism and cardiac hypertrophy, suggested that myocardial damage may be caused by some action of thyroid hormones during foetal development.

Using the neonatal rat as a model, a pharmacological approach was employed to investigate the mechanism of action of triac. Three drugs, with related but differing activities, were tested for their ability to influence the triac induced changes. These were dl propranolol, which has beta adrenergic blocking and membrane stabilizing activity; d propranolol, which has membrane stabilizing but minimal beta blocking activity; and oxprenolol, which acts similarly to dl propranolol but has the additional property of partial agonist activity. All three drugs prevented triac-induced myofibrillar disarray but had little or no effect on the hypertrophy. The results suggest that triac has its own direct action, not involving stimulation of beta receptors.

In a recent experiment verapamil, a calcium antagonist, was administered with triac. Preliminary results showed that a low dose of verapamil can reduce the amount of disarray and also the level of hypertrophy, although a high dose may have its own damaging side effects.

Infectious diseases

The Infectious Diseases Department contains Dr G. R. Smith's laboratory, where work has continued on studies of botulism and mycoplasmas, and the Immunology Unit, under the direction of Dr A. Voller.

Botulism

In studies reported earlier (1977–79 Scientific Report in *J. Zool., Lond.* **190**: 473–590), the prevalence of *Clostridium botulinum* (types B, C, D and E) were shown to be high in the mud of British lakes and waterways. Dr Smith, Mrs Angela Young and Mrs Janet Oliphant found, however, that the prevalence of *C. botulinum* in British soil is much lower than in lake mud. Of 174 samples only 10 (5·7%) were positive and no type other than B was found. The Market Paddocks in Gorgie, Edinburgh and the Society's premises at Regent's Park and Whipsnade differed from the site of the former Caledonian Cattle Market, London, in that their soil contained little or no *C. botulinum*.

Of 17 mud samples from Mauritius, five contained *C. botulinum* type C; of eight from Botswana, one contained type C; and of 18 from Nigeria, five contained type C and eight type D. Thus the absence of reports of botulism in waterfowl in the tropics is not due to failure of the causative organism (type C) to multiply in tropical aquatic environments.

Recent mortality in waterfowl on the Mersey estuary has caused concern. In addition to chemical intoxication, botulism may have played some part. If so, type C spores—which are by no means ubiquitous in this country—should still be present in the mud. A survey is in progress, in collaboration with the North West Water Authority.

Exceptionally high concentrations of toxin were found occasionally in the serum of waterfowl with botulism; a point that is relevant to the development of diagnostic methods.

Examination of so-called ***Mycoplasma mycoides*** *subsp.* ***mycoides*** *strains from goats and sheep by mouse-infection techniques*

Dr Smith and Mrs Oliphant showed that large-colony (LC) strains differed from small-colony (SC) strains, including genuine *M. mycoides* subsp, *mycoides* (MM), by (1) failing to produce mycoplasmaemia in mice; and (2) producing partial but not complete immunity against MM.

The partial immunity given by LC-strain vaccines against MM could not be significantly increased by hyperimmunization. This suggests that, although some protective antigens are shared between the LC and SC types, at least one of importance is present only in the latter.

Vaccines prepared from LC strains gave strong partial protection against *M. mycoides* subsp. *capri* (MC); those from SC strains gave weak partial protection. The LC strains are therefore related more closely than the SC strains to MC.

Although LC strains—unlike SC strains—do not produce mycoplasmaemia readily, they will do so if large doses are injected together with mucin. Evidence is accumulating that LC-strain vaccines protect only partially against heterologous LC-strain challenge. The protective antigens of all SC strains, on the other hand, are homogeneous.

Growth curves, fermentation reactions (27 substrates) and antibiotic sensitivity (11 agents) were examined. The zoo-strain "Brack"—unusual among LC strains in its ability to produce mycoplasmaemia—had a viable count strikingly higher than that of any other LC strain; the viable count of MC was lower than that of any LC strain. Sorbitol and streptomycin showed promise of being of discriminative value in separating the strains.

IMMUNOASSAY UNIT

During the past two years the microplate enzyme-immunoassay (ELISA) method, pioneered by Dr A. Voller and Dr D. E. Bidwell in this Unit, has come into general use in diagnostic laboratories throughout the world. It is now used for a variety of purposes such as measurement of hormones, the detection of antibodies and antigens, the assay of tumour indicators and to quantitate drug levels. Over 500 publications based on the microplate ELISA method have appeared in the scientific literature in the last two years. These have covered such diverse fields as medical and veterinary diagnosis, agriculture and food science.

Basic studies

The current objectives of the Unit are to provide ever better immunological methods for the measurement of biological materials. In the short term this depends on optimizing the performance of ELISA tests. In these tests the major variable is the solid phase support material used to carry antibody or antigen. Numerous plastic materials were investigated for this purpose and polyvinyl chloride microplates were found to be best for coating with antibody while polystyrene was best for antigen coating.

The need for higher sensitivity assays led to an investigation of luminescence immunoassays. In this system a luminescent signal is generated by the biological or chemical degradation of a substrate. Considerable technical problems have yet to be overcome before the potential of these ultra-high sensitivity tests is achieved.

The other main requirement of immunoassays is high specificity. The recent development of monoclonal antibodies, produced *in vitro* by hybridomas, has provided material that is exquisitely specific. Work is in progress to compare results of assays using such monoclonal antibody with conventional antibody.

Applied studies

Non-infectious diseases

(a) In conjunction with Dr L. Burek (Wayne State University, Detroit, USA) a microplate ELISA was developed to assay antibody to thyroglobulin. This performed well and could be used to monitor auto-immune thyroid disorders.

(b) Studies are in progress with Dr N. Wald (Radcliffe Infirmary, Oxford) to monitor the performance of an ELISA method for alpha-foetal protein (AFP). This could result in an assay of general use for indicating neural tube defects. Already a collaborative study with Dr A. Zumla (Zambia) has shown that the ELISA is efficient in detection of elevated AFP in primary hepatomas.

Infectious diseases

(a) *Malaria*

Malarial antibody levels were studied by ELISA in human populations in Iran (with Dr G. H. Edrissian) and in the Gambia (with Dr A. Greenwood). In addition, ELISA was used to study the malaria mediated suppression of immune responses to various vaccines.

Efforts were made to detect infectious agents directly by ELISA. Using an inhibition ELISA method it has been possible to detect one malaria parasite per 10^4 erythrocytes.

(b) *Hepatitis*

Collaborative studies have been set up with Dr Hollenbeck and Dr Kaplan (New Jersey, USA) to develop ELISA for the detection of Hepatitis B surface antigen (HBsAg) and antibody to Hepatitis B (anti-HBs). Using microplate ELISA based on monoclonal affinity purified antibody it was possible to devise tests with about the same sensitivity as radioimmunoassay.

(c) *Toxocariasis*

ELISA and radioimmunoassay methods were developed for the diagnosis of Toxicariasis (with Dr de Savigny, Ontario, Canada), yielding a method that is better than any techniques used at present in Europe.

(d) *Chagas disease*

A collaborative study with Dr I Nilsson (Goteborg, Sweden) enabled a comparison to be made between thin layer immunoassay and ELISA. Both methods performed well in the detection of antibody to *Trypanosoma cruzi* in Brazilian populations.

Animal models

Research in the development of a malaria vaccine for man was hampered by the absence of a good, available primate model for *in vivo* tests. The *Aotus–Plasmodium falciparum* model was developed earlier in the laboratory but Owl monkeys are not generally available in the numbers required. During 1981 (in collaboration with Dr G. Mitchell, Guy's Hospital) attempts were made to adapt human *P. falciparum* to the Squirrel monkey. After initial failures, the malaria adapted to splenectomized Squirrel monkeys and now gives high parasitaemias. However, further passaging is being carried out in the hope of achieving an adequate infection of intact Squirrel monkeys.

Other activities

In April 1980 the Unit organized a four-day meeting on "Immunoassays for the 80s". Over 40 speakers of international renown took part and 250 delegates from numerous countries attended. The proceedings of the meeting were published (Voller, Bartlett & Bidwell, 1981).

The Unit continued to receive large numbers of visitors for short term training in immunoassay methods. This has resulted in many fruitful bilateral projects being established with collaborators throughout the world.

Nutrition

Professor M. A. Crawford and his staff have continued to build a research programme investigating the biochemistry of the essential fatty acids (EFAs) and their function in growth, development and the maintenance of health. In addition the relationships between EFAs and the prostaglandins are being examined. These studies address fundamental scientific questions as well as providing practical improvements for the management of animals in the Collections and for the management of specific human disorders.

Basic studies on EFA deficiency

Radioactive tracer studies in rats showed that the greater the chain length and degree of desaturation the higher the proportion of the acid incorporated into cell membrane phosphoglycerides, and the greater the biological activity in suppressing the biochemical indications of essential fatty acid deficiency.

EFA deficiency of between four to eight weeks in rabbits led to a loss of the long chain n-3 fatty acids but dihomo-*a*-linolenic and arachidonic acids were conserved in membrane lipids. Previous studies, which showed that prostaglandin synthesis was depressed in this model of essential fatty acid deficiency, were followed up and confirmed for PGE_2, PGE_1 and PGE_{1a} in brain, liver, spleen, eye and smooth muscle. However, prostacyclin synthesis was not depressed at this stage of the deficiency. The physiological stretching and relaxing of the aorta may bring the lipase and membrane phosphoglycerides into close contact, providing sufficient free fatty acid precursors for prostacyclin synthesis.

EFA deficiency studies in the guinea pig showed that fat free diets resulted in an increase in the level of arachidonic acid in tissue phosphoglycerides similar to that seen in the rabbit. In both species the first response to fat free diets is a loss of the long chain n-3 fatty acids, e.g. of docosahexaenote (22 : 6, n-3). An increase in arachidonic acid could be explained as a

compensatory mechanism to maintain the degree of unsaturation required in cell membranes.

The contrast between the guinea pig or the rabbit and the rat might be explained by differences in their food adaptations. Rabbits and guinea pigs eat green foods rich in n-3 acids whereas the food chain of the rat contains little n-3 but provides mechanisms conserving the essential fatty acid family least abundant in their food chain (cf. the requirements for Vitamin C by the guinea pig but not the rat). The contrast in response suggests that the current definition of fat deficiency which concerns only the n-6 family may need reviewing.

Nutrition in zoo animals

Mouflon

Mr W. Hare, Mr G. Williams and Miss Beverley Hine examined neonatal nutrition in a group of Mouflon in which perinatal mortality was high and the birth weight low. Plasma and red blood cell fatty acid analysis showed high concentrations of eicosatrienoic acid (20 : 3w9) which in mammals is indicative of an EFA deficiency. This was accompanied by low levels of arachidonic acid and 22 carbon fatty acids. The results suggested a possible malabsorption syndrome caused by a genetic defect, or that the animals were supplied with insufficient EFA and Vitamin E in their diets. Vitamin E is an essential antioxidant required by mammals and is necessary for the protection of long chain polyunsaturated fatty acids against peroxidation. Four animals were separated from the herd and treated with Vitamin E and Selenium. More whole grain was included in the diet to provide an improved EFA and Vitamin E source. Vitamin E was also added to the diet in the acetate form. Sequential blood fatty acid analyses showed an improvement in the fatty acid status. Vitamin E levels have subsequently risen and are now comparable to levels expected in domestic sheep. The appearance of the animals has also improved. It is anticipated that the experiment will continue through the next breeding season in order to monitor the weight and progress of the lambs.

Scimitar-horned oryx

Mr Williams, Mr Hare, Miss Melanie Duc and Miss Pamela Stevens investigated the nutritional status of this species because of an increase in their perinatal mortality. Plasma and red blood cell (RBC) choline phosphoglyceride lipids were analysed as an index of nutritional status. The RBC fraction displayed abnormal amounts (30–40%) of lignoceric (24 : 0) and nervonic acids (24 : 1) which would be five to ten times the value expected. This abnormality was related to findings of red blood cell differences that have been described as "Jigsaw" by Dr Christine Hawkey. Analysis of the milk of Scimitar-horned oryx showed that the animals maintained on synthetic diets contained 495 cal per litre of fatty acids, whereas the milk from a grass-fed animal from Marwell Zoo contained 1129 cal per litre. If the sample from Marwell represents a true composition of oryx milk, then it is likely that the milk of animals on synthetic diets may be deficient in energy content.

Two suckling oryx, whose plasma and red cell fatty acids suggested under-nutrition, were treated with a commercial preparation of Intralipid. In one calf there was a satisfactory response both biochemically and nutritionally, but the second calf did not respond well. Further studies and improvements in the diets of mothers and young will clarify the necessary nutritional requirements of neonatal oryx.

Dolphins

Mr Williams visited the South West Fisheries Center at San Diego, California, to obtain baseline data on dolphin lipids. Analyses suggested that the fatty acid content of muscle and liver of dolphins in captivity may be abnormal. The lipids of marine species are rich in w3 essential fatty acids and contain relatively little w6 essential fatty acids. This principle was used in developing diets for zoo dolphins based on North Sea herring and mackerel. However, in contrast to expectations, analysis of the organs of wild dolphins showed high levels of w6 fatty acids (e.g. kidney, 30–40%; muscle, 15–24%). Collaboration will continue with the South West Fisheries Center to identify the source of the w6 fatty acids in the marine food chain and their availability to dolphins.

Aspects of human nutrition

In studying aspects of nutritional biochemistry in humans, this Department concentrates on relating biochemistry to physiology in a way that is not being done elsewhere, while employing the laboratory resources and the comparative approach inherent in the Institute of Zoology. The major projects concern nutrition during pregnancy, placental transport, and the diagnosis of EFA deficiencies.

Nutrition during pregnancy

In a study carried out in the East End of London by Mrs Wendy Doyle, Mr P. Drury, Mr Hare, Professor Crawford and Miss Stevens, together with Dr B. Laurance from the Queen Elizabeth Hospital for Children, the most interesting finding to date is that the placenta accumulates a substantial pool of the long chain derivatives of the essential fatty acids in the form used by the developing brain (especially arachidonic acid). No other tissue in the body contains such high concentrations of these acids.

The source of placental lipid is the blood plasma phosphoglycerides which contain 8·9% arachidonic acid, but the placenta contains 20–30% arachidonic acid. While this high concentration could be achieved by a highly effective metabolic system, such a system is not known in other tissues and cannot be demonstrated in the placenta. Therefore this accumulation is presumably obtained by placental "selection" and must be maternal in origin. The most likely source is the red blood which contains a phosphoglyceride rich in arachidonic acid. A study of the composition of maternal blood at mid-term compared with term showed the red blood cell content of essential fatty acids to be lower at term and suggested that the combination of maternal food and metabolism is not keeping pace with placental and foetal demands for arachidonic acid.

In addition to its academic interest, this facet of placental physiology is important for two reasons:

(a) The fall in maternal arachidonic acid could reflect an inadequate maternal food intake which would not be detected by conventional dietary studies.

(b) Arachidonic acid is required as a component of cell membranes and also as the precursor for those prostaglandins which can induce labour. The fall in the concentration of arachidonic acid in the mother and its rise in the foetus may be a physiological mechanism related to parturition.

In the past year, studies were carried out on the weekly weighed food intakes, in each trimester, in 76 pregnant women from a low socio-economic group. Their mean energy

intake was 1689 ± 87 kcal per day, compared with the recommended daily allowance of 2500 kcal. The mean birth weight of the sample was 3026 g and 50% of the mothers had babies below 3001 g. Comparing the low birth weight group (< 2500 g) with the rest of the sample, there was no significant difference in protein intake, both groups having a mean protein intake above the recommended level. Energy, fat and pyridoxine intakes were, however, significantly lower in the low birth weight group. In addition, examination of plasma and red cell phosphoglycerides showed that EFAs were significantly lower in both maternal and cord blood in samples taken from the low birth weight group. The results of this study suggest that the diet is insufficient to maintain both mother and baby in optimum health and that as a result of the overall energy deficit a considerable amount of the available fat will be used for energy.

Placental transport and the metabolism of prostaglandin precursors

Dr D. C. Kuhn and Miss Stevens investigated the transport and metabolism of essential fatty acids by the perfused human placenta. A perfusion chamber, designed to contain an isolated lobe of the fresh human placenta, was developed in the Nuffield Workshops by Mr P. R. E. Wallace and Mr W. G. Ray. Validation of this perfusion system included the pH stability of buffers, the measurement of oxygen and carbon dioxide, the production of chorionic gonadotrophin and the transport of 14C-leucine and 3H-dextran. Results show that the placental lobe functions in a physiological manner over the 2·5 h experimental period.

Experiments involving the addition of 3H-arachidonic acid to the maternal circulation showed that the placenta is extremely active in distributing albumin-bound fatty acids into different lipid compartments. The placenta rapidly transfers labelled fatty acid from the maternal circulation and whereas the fatty acid appears largely in the triglyceride fraction in the maternal circulation, in the foetal circulation the label is associated predominantly with the phospholipid fraction. The placental tissue itself contains labelled fatty acid in equal amounts in both triglyceride and phospholipid.

Studies of placental prostaglandin (PG) production showed that the placenta synthesizes little PG from added fatty acid precursors. However, under the experimental conditions described above, synthesis that does occur follows the lipoxygenase pathway rather than the cyclo-oxygenase pathway leading to the production of the traditional PGs, prostacyclin and thromboxanes.

The diagnosis of EFA deficiencies

In a study requested by NHS hospitals, Mr Williams and Mr Hare, in collaboration with Dr M. Farthing (St Bartholomew's Hospital), Dr J. Shaw and Mrs Judith Harding (University College Hospital), investigated two clear cases of EFA deficiency in humans.

1. An adult fed an elemental diet (Vivonex) over a period of three to four years, which contained 1·3% of its energy as linoleic acid, had a raised triene/tetraene ratio in blood, liver, muscle and gut, demonstrating that in this case 1·3% linoleic acid was inadequate to meet the metabolic demands. After surgery and a return to normal foods the biochemical signs reversed slowly.

2. A child with an ileostomy, following necrosis of the colon, was fed on an allergy-free diet, the main ingredients of which were caloreen and prosparol. The child failed to thrive

and analysis of the blood fatty acids provided evidence of essential fatty acid deficiency. Treatment with essential fatty acid rich sources (Naudicelle and Cod Liver Oil) was initiated. The child subsequently gained weight and gradually returned to normal.

In related studies, samples of blood from two children with cystic fibrosis showed that the content of essential fatty acids of the plasma and red cell fractions was low. Such a finding is characteristic in these children. That the deficiency was long term was demonstrated by the incorporation into red cell phospholipids of an unusual fatty acid synthesized only in deficiency. Dietary advice was offered and further samples from these patients will be monitored. A major study of the role of essential fatty acids in the aetiology of cystic fibrosis is being undertaken. In addition, a diet enriched with primrose oil supplement containing essential fatty acids is being provided to 50 children suffering from cystic fibrosis in an attempt to develop a more adequate diet for such children.

Radiology

The principal research projects of Professor G. H. du Boulay's Department concern the study of vascular spasm related to spontaneous subarachnoid haemorrhage, head and spinal cord injury; the response of cerebral arteries to high fat diets; and studies of comparative anatomy.

Vascular spasm

Professor du Boulay, Dr D. Boullin, Dr B. Kendall, Mrs Victoria Aitken and Miss Jennifer Beckett, in collaboration with the MRC Clinical Pharmacology Unit at Oxford and The National Hospital, Queen Square, London, studied samples of cerebrospinal fluid (CSF) from human patients in several centres in Europe and Australia. Results established that vasospastic fractions in the CSF are responsible for angiographic spasm and clinical deterioration. The active fractions were partially characterized by column chromatography, as well as by angiography and organ bath studies carried out in rats and baboons; and shown to include haemoglobin and other high-molecular weight portions. The activity of known substances likely to be involved was quantified in these models. Evidence of the effects of angiotension I and II, met-haemoglobin and oxyhaemoglobin, and more recently leukotrienes, were obtained.

The response of cerebral arteries to high fat diets

Professor du Boulay, Dr Boullin, Mrs Aitken and Miss Beckett, in collaboration with the Nutrition Department of the Institute of Zoology and with Roche Ltd, studied five baboons and showed disordered CO_2 reactivity related to a prolonged high fat diet, with some indication of a return towards normality when the diet was supplemented by dihomogamma linoleic acid. Further study and a control experiment suggested that some part of the technique of angiography was reducing thromboxane production in the baboons' blood (Plate II). Halothane anaesthesia was suspected to be the cause of this, and it was thought possible that this might be masking the degree of change in prostaglandin production. A further experiment with a different anaesthesic regime (Thiopentone and N_20) has shown no interference with thromboxane production. If confirmed, the results pose fundamental questions about mechanisms of CO_2 reactivity and suggest a previously unstudied way in which high fat diets may influence the occurrence of strokes.

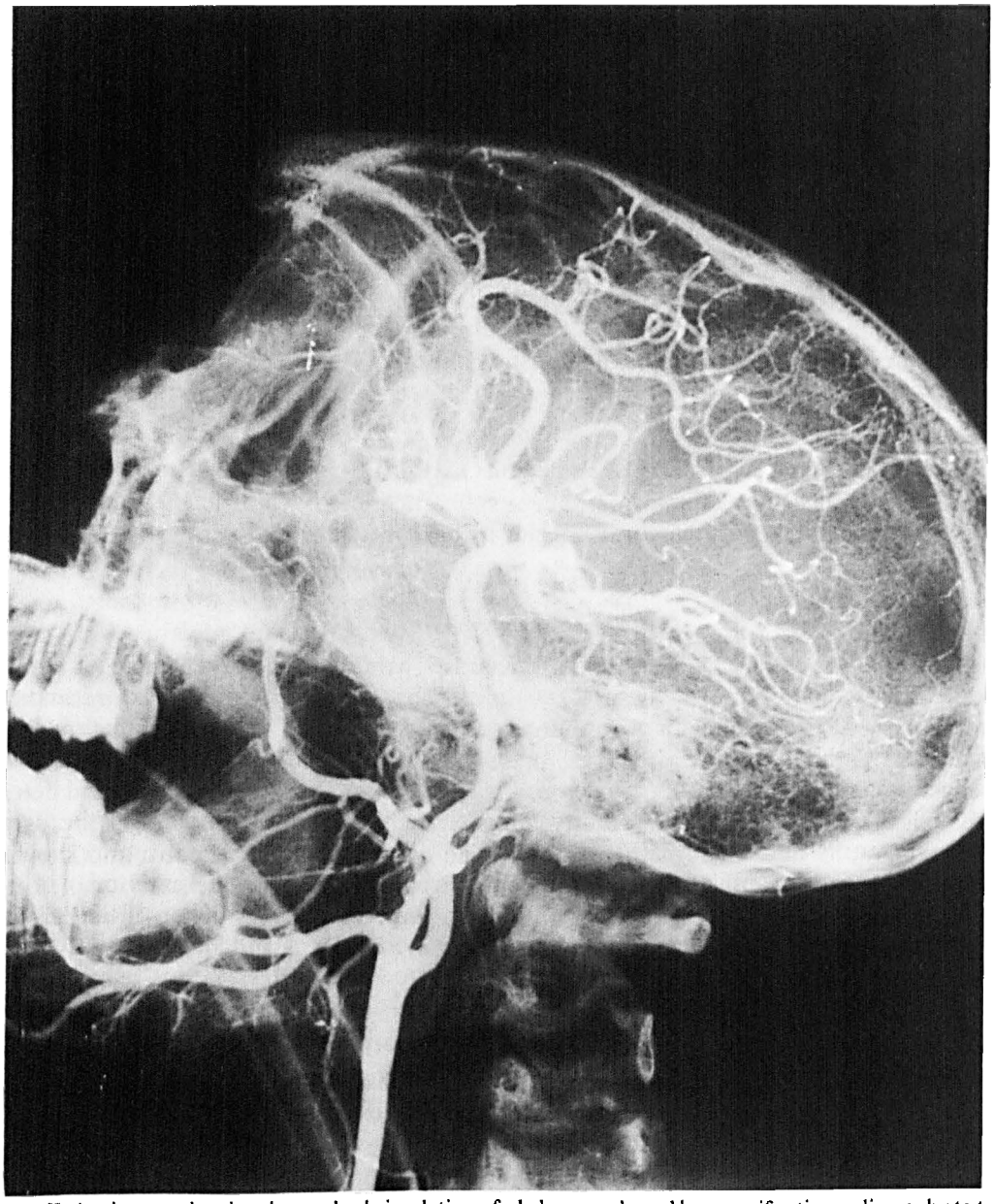

PLATE II. Angiogram showing the cerebral circulation of a baboon, enlarged by magnification radiography to twice life size.

Comparative anatomy of the cranial arteries of birds

Professor du Boulay, Mrs Aitken and Miss Beckett continued to build up a comprehensive collection using techniques of radiographic injection. A considerable body of material has already been accumulated and the work proceeds whenever birds die in the Society's Collections and are available for preparation.

The Wellcome Animal X-ray Museum

This continues to grow as new species are added to the radiological collection. It is at the moment principally a museum of comparative skeletal anatomy and skeletal disease, but because of the interests of the X-ray workers of the last 15 years also contains many detailed studies of cerebral blood vessels and other injection work.

Reproduction

The research programme of the Department developed in four related areas. Studies in endocrinology and in behaviour, under Dr J. K. Hodges and Dr A. F. Dixson, respectively, are based in the Wellcome Laboratories. Studies in gamete biology and in developmental biology, under Dr H. D. M. Moore and Professor J. P. Hearn, respectively, are based in the Nuffield Laboratories. The main themes of the programmes are the reproductive physiology of zoo animals; the developmental and reproductive physiology of primates with, wherever possible, a comparative approach including studies on the human; and applied studies aimed at improving natural and artificial breeding in endangered species.

During the period under review, the methods for measurement of reproductive hormones in urine and plasma were expanded and improved. Absolute confidence in the hormone assays is essential, so the methods must be fully validated for each species being studied. The breeding colonies of laboratory animals were consolidated and the Department is now self sufficient in its breeding of primates for research work. In addition, breeding nuclei and advice on the management of primates of special interest to biomedical research were provided for several other laboratories. A number of new research projects were initiated.

Increasingly, a team approach has proved valuable both for projects within the Department and in initiating new projects with other departments of the Institute and with other laboratories. Close collaboration continued in many projects with the Department of Veterinary Science.

Reproduction in zoo animals

Great apes

A service for pregnancy diagnosis in Great apes and other primate species from the Society's Collection and from various other Zoological Collections in the United Kingdom and Europe continued. Methods utilized for the diagnosis of pregnancy included a commercially available immunoprecipitation test for urinary gonadotrophins and radio-immunoassays for urinary oestrogens and pregnanediol-3α-glucuronide.

The high incidence of testicular atrophy in captive gorillas reported earlier (Scientific Report 1977–79) was confirmed by Dr Dixson in studies of samples from several collections.

However, similar studies on captive Orang-utans and Chimpanzees showed no such atrophy. A study of sexual development in Bornean orang-utans showed that spermatozoa could be obtained at six to seven years of age in three animals although at this age they were 50–60% the weight of fully matured males and lacked the cheek flanges and laryngeal sac seen in adults. Two of the young animals were subsequently paired with females and showed frequent sexual activity. The study is currently being extended to young Gorillas and a satisfactory procedure for short term sedation of these animals was developed by Dr Dixson and Mr J. A. Knight using a mixture of Ketamine and Xylazine.

Miss Susan Kingsley completed her research on the reproductive behaviour and physiology of Orang-utans and submitted the results successfully for a PhD degree. The patterns of urinary oestrone, oestradiol-17β, oestriol, pregnanediol-3α-glucuronide and chorionic gonadotrophin were studied through 11 complete menstrual cycles and eight full term pregnancies, showing profiles very similar to those seen in women. In collaboration with Dr Rosemary C. Bonney, urinary androgens and oestrogens were also measured in juvenile and adult male Orang-utans.

White faced saki

Preliminary data obtained by Mr R. B. Willis, Overseer of Mammals, and Dr Dixson show an ovarian cycle of 16 days and interbirth intervals of 304, 305 and 326 days in this rare primate, two pairs of which are maintained in the Society's Collection. A reduced interbirth interval of 179 days followed the death of a newborn infant. Work is continuing on the growth and sexual development in captive born male Saki.

African elephant

Circulating levels of oestrone, oestradiol-17β and oestriol were measured by Dr Hodges and Mrs Cilla Henderson in serum samples collected from a total of 28 pregnant and non-pregnant African elephants culled in the wild. The results confirmed that levels of unconjugated oestrogens remain extremely low throughout pregnancy but also showed that over 90% of circulating oestradiol was present in the conjugated form, principally as the sulfate. Despite considerable individual variation, concentrations of total (unconjugated plus conjugated) oestradiol after three months of gestation were consistently higher in pregnant than in non-pregnant animals, indicating the potential of oestradiol sulfate as a possible method of pregnancy diagnosis in this species. Circulating progesterone and other progestagens were measured in collaboration with Dr A. S. McNeilly of the MRC Reproductive Biology Unit in Edinburgh. The practicality of urinary oestrogen determinations for pregnancy diagnosis in the elephant is currently being re-examined in a collaborative study with Mr Tom Begg of Howletts and Port Lympne Estates Ltd, Hythe, Kent.

Black rhinoceros

Urinary oestrogen excretion was measured in a female Black rhinoceros from samples collected during July-September 1980. Preliminary data obtained by Mrs Henderson showed a rise in total oestrogen excretion around the time of behavioural oestrus and identified oestrone as a major urinary metabolite. The possibility of using urinary oestrogen analysis as a method of detecting pregnancy in this species is being explored.

Giant panda

A number of studies were carried out on both the male and female Giant panda. All members of the Departments of Reproduction and Veterinary Science and of the Sobell Pavilions were involved in studying the hormonal levels of oestrogens and androgens, the behaviour of the animals and the development of techniques of artificial insemination. During 1980 studies on the female "Ching Ching", and on "Ling Ling", the female in the National Zoo, Washington, showed that the former did not come into oestrus but the latter did so. Using samples of urine collected during oestrus in the female from Washington, Dr Hodges developed a hormone assay based on oestrone that could predict oestrus by two to three days. "Ching Ching" was seriously ill with peritonitis in 1980 and her clinical care and recovery are summarized in the report from the Department of Veterinary Science.

In early 1981 the male panda "Chia Chia" went to Washington as the chances of successful mating were judged to be best if he were introduced to the female there, who is 10 years old and has showed behavioural oestrus for at least three years. As a precaution in case "Ching Ching" came into oestrus, samples of semen were collected and stored by Dr Moore. Previous observations had established that testis size increased substantially during 1980, indicating the onset of sexual maturity. Semen from "Chia Chia" contained a high concentration of spermatozoa, of which 80% was progressively motile. Some samples were examined by electron microscopy but most were processed for long term storage in liquid nitrogen. Frozen-thawed semen displayed 50–60% motile spermatozoa.

In late April 1981 hormonal measurements (Fig. 1) and behavioural observations confirmed that "Ching Ching" was coming into oestrus. Artificial insemination was carried out. Daily urine samples and occasional plasma samples collected over the subsequent five months all showed elevated levels of progestagens rising in a similar manner to that seen in

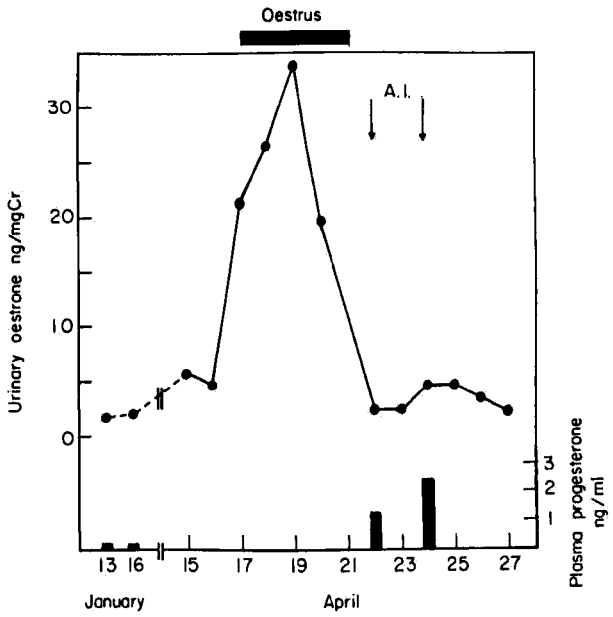

FIG. 1. Urinary oestrone levels during oestrus in the Giant panda. The rise in levels of oestrone coincides with the onset of behavioural oestrus (horizontal black bar). Circulating progesterone concentrations measured in two samples collected at artificial insemination (A.I.-arrows) indicated that ovulation had occurred.

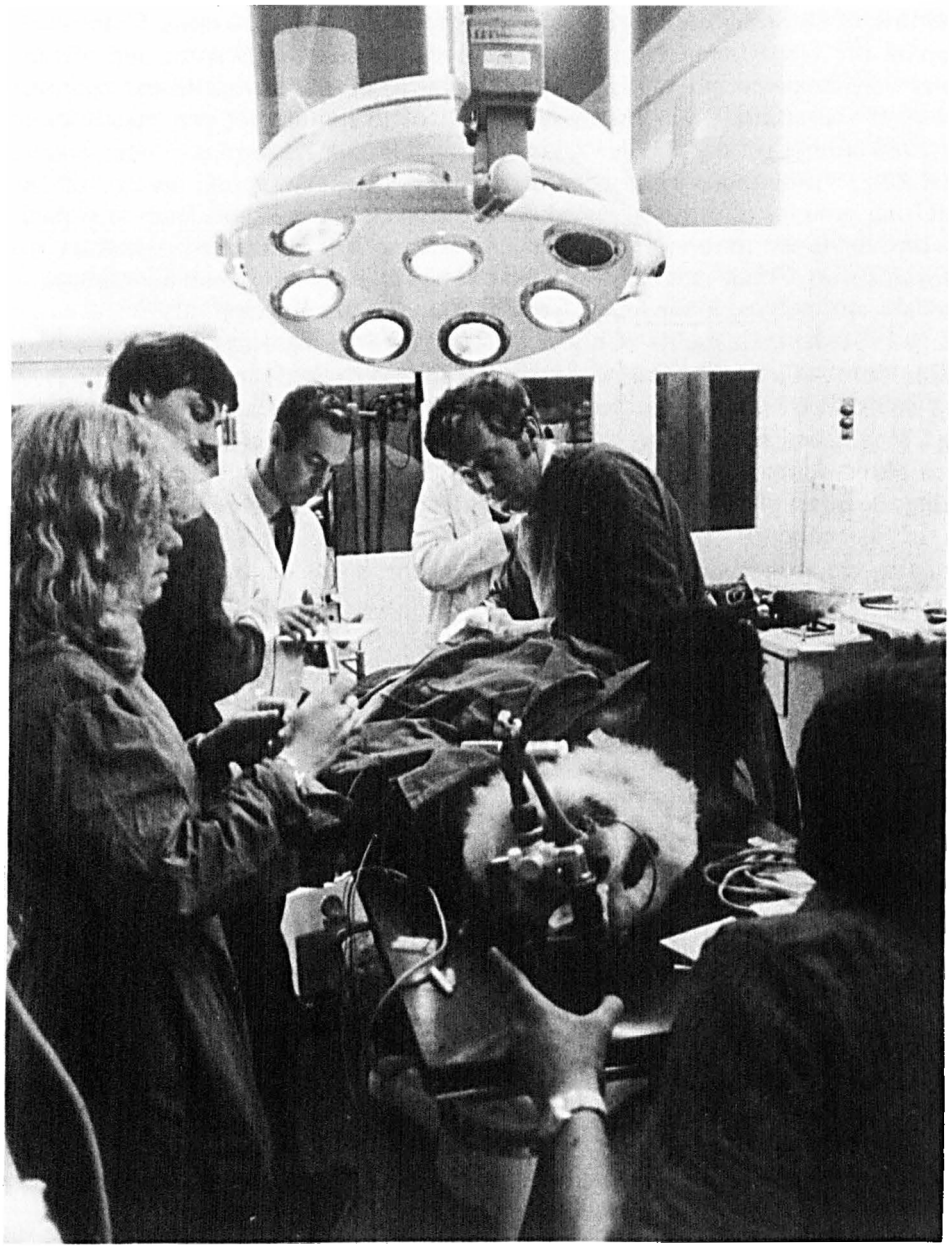

PLATE III. Laparotomy carried out on female Giant panda "Ching Ching" in October 1981. Photo: M. Lyster.

pregnancy in other species. However, when the longest recorded gestation of 168 days for a panda in China was passed and the levels of progesterone were still increasing exponentially, a simple exploratory laparotomy was carried out by Mr D. Jones and Professor Hearn (Plate III) to confirm a pregnancy or to diagnose any pathological causes. The uterus was found to

be five times the normal size but did not appear to contain a foetus. There was considerable evidence of ovarian and uterine hormone production which was brought under control by local administration of prostaglandin. Without a dissection of the uterus, which would have risked her future fertility, no pregnancy or resorption could be proved and none are therefore being claimed. Throughout the period "Ching Ching" remained in excellent health and we hope for a successful natural mating with "Chia Chia" next spring when "Ching Ching" should again come into oestrus.

In the course of these studies a wealth of data on the reproductive physiology, behaviour and clinical care of Giant pandas was obtained which was circulated to other Zoos and to Chinese colleagues whose help and advice is warmly appreciated.

Puma and Cheetah

In June 1980, the first large wild cat (a puma) to be produced by artificially induced ovulation and artificial insemination was born in the Institute of Zoology (Plate IV). This is perhaps the most tangible result of a successful period of research on reproduction of wild felids carried out by the Department of Reproduction (Drs Moore, Bonney and Hodges) and Department of Veterinary Science (Messrs Jones and Knight). Work has continued to

PLATE IV. Puma cub "Bonny" born as a result of artificial ovulation and artificial insemination of her mother, "Betsy". Photo: M. Lyster.

characterize the normal oestrous cycle and the exact time of ovulation using radioimmunoassay and laparoscopic methods. In the puma, oestrous occurred approximately every 20 days with ovulation 30–40 h after HCG injection. Plasma progesterone levels rise rapidly following ovulation and either fall after 50 days during pseudopregnancy or immediately prior to parturition. More emphasis is now being placed on the cheetah which shows oestrus every 23 days and has a relatively poor breeding record in captivity.

Blackbuck

Preliminary studies of male and female Blackbuck were initiated by Drs Hodges, W. V. Holt and Moore, in collaboration with the Department of Veterinary Science with the intention of using this ungulate species in comparative studies of semen preservation and embryo transfer. A technique was developed for the collection of spermatozoa by electroejaculation, and a system was developed to collect urine from females for hormonal analysis.

A technique for the isolation of sperm membranes was also developed by Dr Holt and applied to Blackbuck sperm as well as to spermatozoa from the domestic ram. The lipid composition of such membrane fractions is being determined in collaboration with the Department of Nutrition (Mr G. Williams) in order to examine the relationships between sperm surface properties and successful freezing.

Bennett's wallaby

A small breeding colony of wallabies was established in the Institute early in 1980. Professor Hearn and Miss Sara Gems initiated a project on the reproductive physiology of the wallaby, studying the control of seasonal breeding and of embryonic diapause; the mechanism by which an 80-cell blastocyst may be held in reserve for 11 months in the uterus. Peripheral plasma samples were collected during the cycle, pregnancy, lactation and seasonal quiescence. Samples were also collected from the utero-ovarian vein during pregnancy and quiescence. With validation of the necessary assays by Dr Hodges, analysis of these samples is now proceeding. Collaborative studies with Mr Knight of the Department of Veterinary Science improved the surgical techniques used and Mr D. Fleming is examining the breeding seasonality of the large numbers of wallabies at Whipsnade. Miss Helen Boorman, an Honours student from the Zoology Department of University College, London carried out her honours research on an aspect of this project, under the supervision of Dr Hodges. A number of blastocysts were recovered by Professor Hearn and Miss Gems and although attempts to culture them *in vitro* have had limited success, several were fixed for electron microscope studies by Dr Moore.

Laboratory primate research

Primate colonies

As predicted in the Scientific Report 1977–79, the numbers and species of primates held by the Department were consolidated to form self sustaining breeding colonies of three species, the Owl monkey, the Cotton-topped tamarin and the Common marmoset. All three are important "new" laboratory primates for biomedical research and the Institute is becoming recognized internationally as the centre of expertise on the reproductive

physiology and breeding of New World primates. The above species are placed as top priority for laboratory breeding for biomedical research by the World Health Organization and by the Primate Breeding Committee of the Primate Society of Great Britain. They are also numerically the species most in demand for biomedical research in the UK. It should be noted, however, that the Cotton-topped tamarin is severely endangered in the wild, where less than 1000 are thought to exist; no more will be available from the wild and successful captive breeding helps to reduce the demand from wild stocks.

Research during the year continued into the reproductive physiology, behaviour and endocrinology of these species and several new projects were initiated in applying them as models for aspects of human development and reproduction. The numbers of animals held on 1 November 1981 are shown in Table II.

TABLE II
Breeding colonies of New World primates

Species	Total number held	Number of breeding pairs	Number born at Institute
Owl monkey	79	12	39
Cotton-topped tamarin	60	15	42
Common marmoset	280	55	186
Totals	419	82	267

The advantages of these New World species over the Old World monkeys more conventionally studied in biomedical research are in their small size, high fecundity in captivity, relatively short ovarian cycles and lengths of gestation; and in particular their rapid attainment of sexual maturity (18–20 months). These factors allow them to be maintained in family groups, handled, trained and managed relatively easily and inexpensively, becoming self-sustaining in a fraction of the time and cost of larger laboratory primates. The successful breeding and excellent health of the animals in these colonies is due to the meticulous and dedicated care provided by Mrs Barbara Murrill, Mr T. D. Noble and the staff of technicians who manage them; and to the help of the Department of Veterinary Science.

Of particular note is the flourishing state of the colony of Cotton-topped tamarins. The reproductive physiology of these animals, previously thought to be extremely difficult to breed, was studied by Mrs Heather Brand, who found an ovarian cycle of $22 \pm 1{\cdot}7$ days and a gestation of about 166 days. Improvements in management and breeding, based on the findings of the scientific studies, enabled breeding nuclei of animals to be provided to several Zoos and Institutes where their breeding is continuing.

Successful breeding in the colony of Owl monkeys allowed small numbers of animals for breeding to be provided to the Wellcome Research Laboratories, Beckenham, and to Dr A. Voller (Immunology Unit) for studies related to the development of vaccines against malaria. The Owl monkey is unique among animals in its acceptance of strains of human malaria. The colony of Owl monkeys is now one of the largest successfully breeding laboratory colonies of these animals in the world.

The colony of Common marmosets is thriving and provides the opportunities for a wide range of studies in developmental and reproductive physiology. These projects are designed

to clarify the control mechanisms of mammalian reproduction and the results are useful in basic and applied studies aimed at improving the welfare of humans and of animals in captivity and in the wild.

While the marmoset forms a common theme to these investigations, the research is carried out concurrently in a number of other mammalian species reported above under *Reproduction in zoo animals* and in the human. A summary of the studies carried out during the past two years is given below under the headings of *Endocrinology, Brain and behaviour, Gamete biology* and *Developmental biology.*

Endocrinology

The work of the hormone assay laboratory was reorganized by Dr Hodges, Dr Sally-Ann Eastman, Mrs Brand and Mrs Deborah Bevan; with emphasis being placed on the development of a system of hormone measurements for multi-species application. The assay protocols were adapted to conform to those of the World Health Organization Matched Reagent Program and the laboratory is now participating in the WHO external quality control scheme. Using materials from various sources, radioimmunoassays for nine steroid hormones were established and are now in routine use. Where possible, assays were developed for urinary as well as plasma determinations since, for many of the animals in the Society's Collections, urine analysis represents the only feasible approach to endocrine studies and enables studies to be carried out without any stress to the animal concerned.

In order to validate each assay for use with various animal species, two systems for the chromatographic separation of steroids were introduced; partition chromatography on celite microcolumns and reverse phase high pressure liquid chromatography. Used individually or in combination these systems provide a powerful method for testing the validity of an assay and also enable a range of measurements to be performed on samples of small volume (under 0·1 ml) allowing research even on very small animals.

An *in vitro* bioassay for luteinizing hormone/chorionic gonadotrophin was established by Mr G. Watson and is now being run by Mr A. Hill. The assay is particularly useful for comparative studies, since by measuring biological activity, it is potentially applicable to most mammalian species. A heterologous radioimmunoassay for prolactin was also established by Miss Lynne George using reagents kindly supplied by Dr A. S. McNeilly (MRC Reproductive Biology Unit, Edinburgh). The assay is being used successfully in the marmoset monkey and is currently being validated for use with other species.

Endocrinology of early pregnancy

The major theme of this research is the study of the developmental physiology of the marmoset monkey with emphasis on the hormonal control of ovulation, implantation and the development of feto-placental function. The project was designed to cover aspects of pregnancy relevant to problems of human fertility and to the practical considerations attached to the captive breeding of endangered species.

Methods were developed for the precise timing of pregnancy by hormonal monitoring of the day of ovulation and the onset of the luteal phase of the cycle. Surgical methods were developed for the routine collection of utero-ovarian vein plasma and for the recovery of corpora lutea. Several inter-related studies are in progress.

Peripheral and utero-ovarian vein plasma samples were collected throughout the first 60 days of pregnancy in 30 female marmosets. Oestrone, oestradiol, progresterone and 17*a* OH progesterone were measured in each sample.

In order to study urinary oestrogen excretion during early pregnancy, urine samples were collected by Drs Hodges and Eastman during fertile and non-fertile cycles and the relative levels of various component oestrogens were measured. Oestrone, oestradiol and oestriol were measured individually and compared with the value for total oestrogen immuno-reactivity determined by the use of a non-specific oestrogen antibody. The presence of additional oestrogens was assessed by means of continuous elution high pressure liquid chromatography (HPLC) and a uterine cytosol receptor assay.

This study is being performed in collaboration with Dr R. W. Kelly, MRC Reproductive Biology Unit, Edinburgh; Drs L. Myatt and J. White, Institute of Obstetrics and Gynaecology, Hammersmith Hospital, London (rat uterine cytosol receptor assay); and Dr B. L. Lasley, Research Department, San Diego Zoo. It is hoped to extend the studies to the human and other primates in the near future.

Dr Hodges carried out a study, in collaboration with Professor W. P. Collins and Mr Makawiti of the Department of Obstetrics and Gynaecology, King's College Hospital, London, on the proportions of free and conjugated steroids in urine and plasma throughout pregnancy in the marmoset. Similar studies on the baboon and Vervet monkey are currently in progress in collaboration with Dr J. Else of the Institute of Primate Research, Nairobi. Dr Eastman, in collaboration with Dr N. Jenkins of the Department of Physiology and Biochemistry, University of Reading, is studying binding globulins in marmoset serum. Results show these globulins to be identical to those found in the human.

Brain and behaviour

Dr Susan P. M Schofield and Dr Dixson continued their studies on the reproductive physiology and behaviour of Owl monkeys and the hormonal control of reproductive and aggressive behaviour, concentrating on the role of the monoamine hormones in regulating pituitary function.

Reproduction in Owl monkeys

Clearly defined peaks of oestradiol-17β occurred at intervals of 15·5 days in this species and the follicular and luteal phases of the ovarian cycle were 6 and 10 days, respectively. Hormonal changes during the ovarian cycle did not correlate with changes in vaginal cytology or behavioural interactions. Sexual interactions occurred frequently throughout the ovarian cycle with no apparent changes in proceptivity, receptivity or sexual attractiveness of the female.

Mrs Jacqueline Hunter concluded her study of olfactory communication, aggression and sexual behaviour in the Owl monkey and was awarded her PhD degree. Anosmia had minimal effects upon masculine sexual behaviour when males were paired with familiar female partners. This contrasted with the decreases in intermale aggression in anosmic males, as detailed previously. Owl monkeys employed two distinctive patterns of scent marking behaviour to distribute either urine or secretions of the subcaudal gland. These two displays differed in their ontogeny and their functions in adulthood. Urine marking occurred at high frequencies in juveniles and adults of both sexes, whereas marking with the subcaudal

gland was primarily an adult display. If scent marks from conspecific strangers were placed in the home cages of Owl monkey family groups, then it was the adult males that showed the most pronounced responses, sniffing such substances more frequently than their female partners and exhibiting higher frequencies of marking behaviour. Secretions of the subcaudal gland elicited a stronger response than urine alone. Histological studies of the cutaneous glands were completed.

Quantitative studies of parental behaviour in Owl monkeys were detailed in the Scientific Report 1977–79. During 1980 possible endocrine changes in male Owl monkeys which were carrying and caring for offspring were examined. Blood samples were collected and assayed for testosterone and prolactin. A slight increase in both hormones was found in males carrying young, but the difference from single males was not statistically significant.

The occurrence of an apparent partial atrophy of the testis in the Owl monkey was reported previously. The condition did not occur in several other New World species in captivity and was not associated with infertility in male Owl monkeys. A suggestion (by workers at the New England Primate Research Center) that the condition results from an irreversible Vitamin E deficiency in captivity was evaluated and is probably baseless. The condition is, however, different to that found in some captive gorillas and noted earlier in this report.

Neuroendocrinology and reproductive behaviour in marmosets

Monoamines play a fundamental role in the regulation of pituitary function and of behaviour. A knowledge of the anatomical distribution of these neurotransmitters provides an essential basis for studies of their functions in the brain. In 1980 Drs Schofield and Dixson completed histofluorescence mapping studies of monoamine neurons in the CNS of the Common marmoset. Substantial populations of dopamine (DA), serotonin (5-HT) and noradrenaline (NA) cell bodies were found throughout the brainstem (Fig. 2). DA cell bodies were found in the upper mesencephalon, within and around the substantia nigra, and gave rise to ascending axons which innervated the striatum and limbic nuclei of the relatively small populations in the medulla and caudal pons and larger groups within the rostral pons and mesencephalon. The latter populations were the major sources of serotonergic efferents in the diencephalon and telencepahlon. NA neurons were also distributed throughout the brainstem and formed two systems. A relatively scattered population was found within the tegmentum of the pons and medulla which gave rise to a terminal plexus in the diencephalon. A second, very large, compact group of cell bodies within the lontine locus coeruleus provided the major noradrenergic innervation of the neocortex. NA terminal varicosities within the diencephalon were predominantly fine and sparse in nature, whereas DA innervation of the striatum and limbic areas of the forebrain was extremely dense. 5-HT nerve terminals could not be visualized in the diencephalon with this technique.

Neuroanatomical mapping studies were also carried out in the Owl monkey and showed a similar distribution of the monoamine neurons. However, cellular features such as dendrites and axons could be seen in much greater detail than in the Common marmoset, indicating possible differences in amine concentration and/or morphology between these two primate species.

Subsequent to completion of mapping studies, behavioural work was carried out to define the most appropriate conditions and scoring system for recording sexual interactions in marmosets. Pharmacological studies were initiated using dopamine agonists which

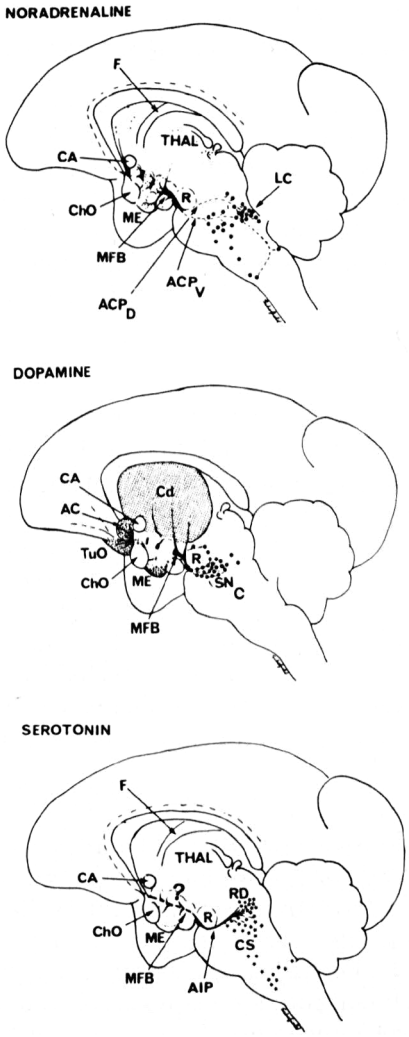

FIG. 2. Semi-diagrammatic representation of sagittal view through marmoset brain showing the distribution of cell bodies, ascending axons and terminal fields for noradrenaline, dopamine and serotonin systems, respectively. *Abbreviations*: AC, nucleus accumbens; ACP_D, ascending "dorsal" catecholamine pathway; ACP_V, ascending "ventral" catecholamine pathway; AIP, ascending indoleamine pathway; CA, anterior commissure; Cd, nucleus caudatus; ChO, optic chiasm; CS, nucleus centralis superior; F, fornix; LC, nucleus locus coeruleus; ME, median eminence; MFB, medial forebrain bundle; R, nucleus ruber; RD, nucleus raphe dorsalis; THAL, thalamus; TuO, tuberculum olfactorium.

depressed and antagonist drugs which elevated prolactin levels, the latter decreasing the sexual performance of males. Handling and blood sampling from trained males resulted in no elevation of prolactin indicating that the procedures caused no stress. Research is now focussing on the nucleus accumbens which has a high concentration of dopamine terminals and may be involved in the control of prolactin secretion. Dr Dixson and Dr K. M. Kendrick, who joined the Department in September 1981, in collaboration with Dr B. J. Everitt of the Department of Anatomy, Cambridge University, are currently studying the

effects of neuroactive peptides and endogenous monoamines on the nucleus accumbens and the resulting control of prolactin secretion in both marmosets and Owl monkeys.

Hormones, catecholamines and post-partum depression

The plasma levels of a number of steroid and gonadotrophin hormones were examined in 48 women, some of whom were suffering from post-partum depression. The studies, in collaboration with Dr C. Wilson and others at the Department of Obstetrics and Gynaecology, St George's Hospital, showed no differences in most hormones between the two groups, but some changes in the levels of noradrenaline and adrenalin were found.

The evolution of "sexual skin"

Dr Dixson completed a long-term comparative study on the evolution of sexual skin in female primates. The conclusions suggest that sexual skin has arisen independently in three lines of catarrhine primates, in forms ancestral to the Cercopithecinae, in the common ancestors of the subgenera *Procolobus* and *Piliocolobus* and in the ancestors of the Chimpanzee. Secondary reduction of the sexual skin has also taken place in some groups such as the macaques and guenons. Sexual skin may have arisen as early as the Miocene in some of the Old World monkeys, as part of a complex of adaptations for increased visual communication in terrestrial or semi-terrestrial conditions. The arboreal New World monkeys make much more use of olfactory mechanisms for communication and have not developed a true sexual skin. The arguments which support such conclusions are complex and a detailed monograph on the subject has been submitted for publication.

Gamete biology

Research on gamete biology concentrated on the processes involved in the development of spermatozoa within the testis and epididymis and the events leading to fertilization. Dr Moore, Dr Holt and Mr T. Hartman moved from the Wellcome to the Nuffield Laboratories in August 1980 to make greater use of the electron microscope and the embryo culture facilities. In November 1980, Dr Asha Prakash from the University of Delhi joined the group to investigate the hormonal control of the epididymis and in July 1981 Dr Christina Wang from the University of Hong Kong joined for a three-month study of Leydig cell culture and *in vitro* fertilization.

Spermatogenesis

The ultrastructure of spermatogenesis was studied by Dr Holt in a number of mammalian species. Particular attention was paid to sperm development in the Common marmoset, as this species is currently being evaluated as a primate model for research related to human reproduction.

Light microscopic studies were performed to distinguish the various cell associations which comprise the spermatogenic cycle and eight distinct stages were recognized; this compares with six in the human. The relatively small and simple acrosome of the marmoset presented some difficulty in using steps of acrosomal development to distinguish the various spermatogenic stages, and therefore a method based on the nuclear morphology of successive germ cell generations was developed. The successive spermatogonial generations in the

marmoset could not be recognized purely by their morphology and therefore a study of spermatogonial renewal, using tritiated-thymidine and autoradiography, is currently in progress.

Electron microscope studies on spermatogenic cells in the marmoset were also pursued; the ultrastructural events which accompany spermatocyte development, from the preleptotene to the secondary spermatocyte, mainly involve expansion of the nucleus and development of the endoplasmic reticulum and Golgi apparatus. In view of the interest in the role of the sperm plasma membrane in sperm maturation and fertilization, special attention is being paid to the morphological aspects of plasma membrane synthesis, which is known to occur extensively in pachytene spermatocytes.

Spermiogenesis in the marmoset follows the general pattern seen in other primates, including man, but, in common with the human, a relatively high incidence of spermatid abnormalities is apparent. These morphological studies indicate that the marmoset is probably a suitable animal model for human orientated research, especially in studies where interest is given to effects manifested at the cellular level. Comparative studies of spermiogenesis are also being undertaken with the intention of increasing our understanding of this complex process, especially the factors which determine acrosomal shape.

To complement previous studies, comparative spermiogenesis in the Common marmoset and the Minnie Downs River mouse are now being studied. The marmoset spermatozoon, which possesses a small simple acrosome, contrasts markedly with the Minnie Downs River mouse spermatozoon. This is large and possesses three hook-like, anterior projects, only one of which apparently contains acrosomal material.

Sperm maturation

A key area of research was to ascertain the nature of the epididymal secretion required for sperm to develop their fertilizing ability. Dr Moore and Mr Hartman established that in the rabbit and hamster androgen-dependent glycoproteins are secreted in the proximal epididymis and bind to specific regions of the spermatozoon as shown by immunofluorescence and agglutination tests. These factors were isolated and characterized, and monospecific antisera have been produced against them. Significantly, antibodies (or IgG fragments) against a specific fraction inhibited fertilization *in vitro* and *in vivo* indicating the importance of the glycoproteins in this process. Monoclonal antibodies were produced against sperm surface antigens and in collaboration with Drs Voller and Bidwell, ELISA methods were developed. The next task is to investigate epididymal secretions in primates. Preliminary observations indicated that protein fractions with low isoelectric points similar to the glycoproteins isolated in the rabbit are present in both the marmoset and man.

Since the ultrastructural observations indicated that the epididymis in monkeys and man has several unique features, special emphasis was placed on the study of sperm maturation in primates. The fertilizing ability of the spermatozoon from different regions of the epididymis in the marmoset monkey was determined using an *in vitro* penetration test with zonaless hamster eggs. In collaboration with Mr J. P. Pryor from the Institute of Urology, this assay system is now being extended to measure the fertilizing capacity of human epididymal spermatozoa. Such information is vital to determine the region of the epididymis in man responsible for sperm maturation.

An investigation of steroidogenesis in the epididymis was carried out by Dr Asha Prakash. The results showed that the activity of steroid dehydrogenases in the epididymal epithelium

was correlated with sperm maturation. It is hoped to visualize androgen receptors on the epididymal epithelium using autoradiography.

Fertilization

Investigations on the mechanisms of fertilization centered on the processes of cell fusion. Dr Moore and Mr Hartman used the zonaless hamster egg to look at sperm egg interactions. The benefit of this technique is that oocytes are readily available and can be used as a preliminary indication of sperm capacitation in a number of species (i.e. human, marmoset). It is hoped to develop the method as a test for sperm fertility after freezing. Dr Holt continued with experiments on fusion between spermatozoa and avian erythrocytes in order to clarify the mechanisms of membrane fusion involved in fertilization.

Developmental biology

For ethical reasons and because of the scarcity of material, very few experimental studies have been possible on early embryonic development from ovulation to implantation in the human and in other primates. The marmoset, which usually produces twins and breeds throughout the year, is perhaps one of the most suitable laboratory primates for such studies, presenting an opportunity to examine these events on an experimental, controlled basis. The purpose of these studies, carried out by Professor Hearn, Miss Gems and Mr C. R. Harlow, is to examine the following:

1. The endocrine, immune and morphological relationships between mother and embryo during implantation.
2. Growth and development of the embryo from fertilization to implantation.
3. Recovery, *in vitro* fertilization, culture, freezing and transfer of pre-implantation embryos.

Apart from their relevance to human and other primate breeding, these projects allow the development of techniques of artificial breeding for application to other, more endangered animals.

Aspects of the work are being developed in collaboration with Drs Hodges and Moore and in close collaboration with Dr D. Whittingham and Mrs Lynette Wilson of the MRC Mammalian Development Unit. Further studies on transferrins on trophoblast were initiated with Professor W. Page Faulk at the Blond-McIndoe Centre; and on gonadotrophin receptors with Professor M. G. Elder of the Institute of Obstetrics and Gynaecology.

Surgical methods were developed for the routine recovery of oocytes, unfertilized eggs and embryos at timed stages to implantation. A culture laboratory was established. Over 70 early embryos were obtained and their growth and development compared *in vivo* and *in vitro*. Twenty embryos were frozen in order to build up a bank of embryos for controlled experimental work. Preliminary results show that thawed embryos resume growth after being frozen for periods of up to one year. Mouse embryos are routinely used as control procedures in all these studies in order to ensure that the culture and experimental conditions are normal on each occasion. Peripheral and utero-ovarian vein plasma was collected in all cases for steroid and gonadotrophin analysis and the culture fluid was stored for analysis of early pregnancy proteins. A few corpora lutea were collected for analysis of gonadotrophin receptors.

Studies of *in vitro* fertilization proceeded with development of a simple electroejaculation treatment giving high yields of marmoset semen; Dr Moore and Mr Harlow examined the capacitation of marmoset sperm. To date, limited success in *in vitro* fertilization and embryo transfer has been achieved but further improvements are needed. The results show that implantation commences between days 9–11 in the marmoset and growth and development rates are more varied than seen in rodents. Several embryos continued to grow in culture up to 10 days beyond the normal time of implantation, enabling electron microscope studies of early embryonic development during this critical stage (Plate V). When samples of *in vivo* implantation have been obtained to validate the stages seen *in vitro*, studies on the morphology and physiology of the embryo during extended development *in vitro* will become possible. Monoclonal antibodies against developmental antigens, new lines of specific cell types and autoradiographic localization of cell secretion will be examined.

A preliminary study of foeto-placental development throughout pregnancy was completed and 15 measurements of foetal growth collected. A study of the role of chorionic gonadotrophins was also completed, showing that active or passive immunization against the hormone prevented implantation or would terminate early pregnancy after implantation had occurred.

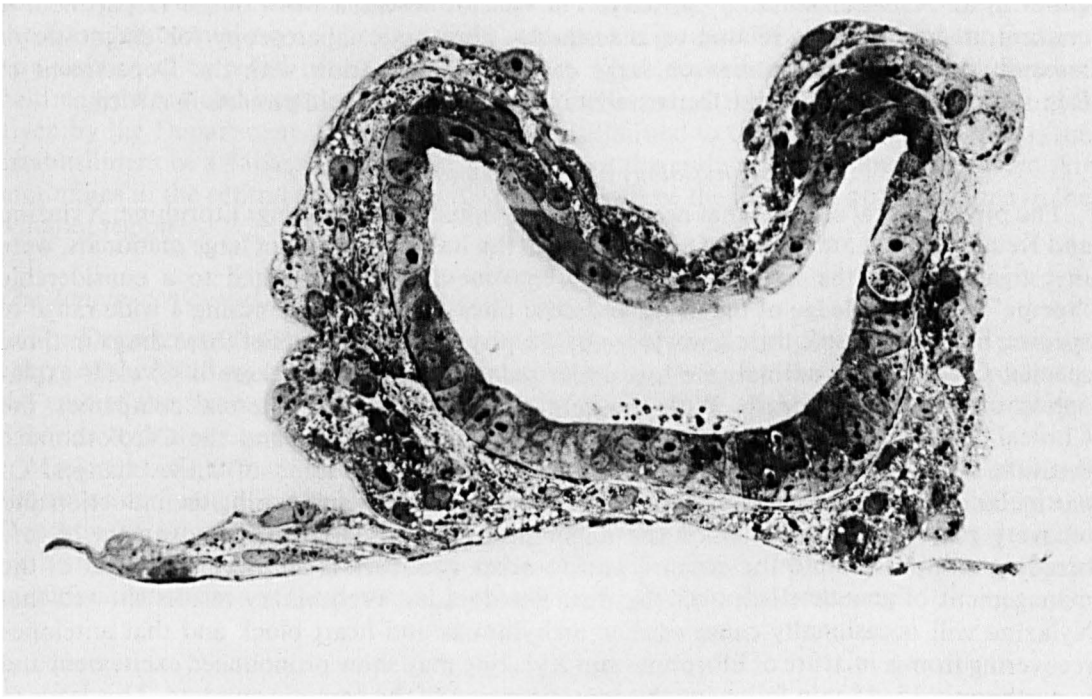

PLATE V. Marmoset embryo after extended development in culture.

The effects of transfer of MPA and NET through milk to neonatal marmosets

Long acting contraceptive steroids administered to lactating women may be transferred to the newborn infant through the breast milk. A project to study the effects of medroxyprogesterone acetate (MPA) and norethisterone (NET) on neonatal marmosets was initiated

by Professor Hearn and Dr Hodges. As a first step labelled MPA and NET were fed orally to 25–30-day-old male and female marmosets and the distribution throughout body tissues examined. Accumulation in certain neural and gonadal tissues was observed.

Veterinary science

The Veterinary Department (Mr D. M. Jones, Mr J. A. Knight, Mr D. G. Ashton and their staff) carries three major responsibilities:

1. The health of the animals in the Collections and of the laboratory animals maintained in the Institute.
2. Research projects related to anaesthesia, reproduction and nutrition, including collaborative research with other departments of the Institute and outside organizations.
3. The supply of specimens from living, or dead animals that receive post mortem examination through the Pathology Laboratory, to over 200 investigators or educational establishments in Britain and abroad.

In acting as a principal link between scientific staff and the animal Collections, most of the research on animals other than laboratory maintained species involves the veterinary staff either in an active or advisory capacity. The specific research work of the Department is concentrated in projects related to anaesthesia, fibre optic laparoscopy for diagnostic or research purposes, and studies on large cats (in collaboration with the Department of Reproduction). In addition the Department is involved in two field projects in Africa.

The physiology of sedation and anaesthesia

The physiological changes that occur under the influence of the drugs Etorphine, Xylazine and Ketamine, that are now used extensively for the immobilization of large mammals, were investigated. Over the last 20 years the Department has contributed to a considerable "recipe" type knowledge of the drugs and dose rates required for handling a wide range of species, but there is still little knowledge of the physiological effects of these drugs in those species. On occasions animals are lost under sedation and usually there is no clear explanation of the cause of death. With the help of a number of commercial companies, the Clinical Measurement Department of the Westminster Hospital and the Cardiothoracic Institute, sufficient equipment was available to investigate some of these changes. Of particular interest is the effect of these drugs on nervous ruminants during the induction and recovery phases of sedation when the major problems arise. The safe movement of rare breeding animals around the country and to other countries is an essential aspect of the management of genetic stock over the next few decades. Preliminary results showed that Xylazine will occasionally cause cardiac arrhythmias and heart block and that antelopes recovering from a mixture of Etorphine and Xylazine may show pronounced excitement and hyperthermia 15–45 min following the administration of the narcotic antidote. This leads to an alarming increase in blood pressure which may culminate in sudden collapse.

Routine pathology

Through the detailed examination of all the carcasses of animals from the Collections and the Institute, a considerable volume of information of managerial, biological and medical interest has accumulated. Cases of particular significance are regularly recorded in formal

publications as also are extensive reviews and summaries of the data obtained on particular species, organ systems or causes of diseases. Current reviews in preparation include the pathology of the Giraffe with particular reference to lesions of skeletal and cardiac muscles, an analysis of the post mortem examinations of pheasants and related species and a survey of the helminth parasites of reptiles.

The pathology records are amongst the most comprehensive of any zoological collection in the world and the recent gift of a computer will enable data to be more readily available for the Department's diagnostic purposes or for the many enquiries received from others.

Field projects

The Department is involved in the supervision of two field projects in North Africa.

The Air and Tenere, Niger

The Department, in co-operation with the International Union for the Conservation of Nature, the World Wildlife Fund, the Fauna and Flora Preservation Society and Marwell Zoological Society, have set up a project to survey and gazette two areas of Sahelian steppe and sub-desert as part of a programme to look at the ecology of Saharan antelope, especially the Scimitar-horned oryx. The initial surveys were organized by the Department and are now continued by a full-time ecologist based in Niger. Laboratory support in the form of field equipment and examination of materials collected in the areas under survey is also given by the Department. Proposals have been submitted to the Niger Government for the establishment of a Saharan National Park taking in the eastern edge of the magnificent Air mountains in the central desert. If established, this will be the first such protected area in the Saharan region.

The Jonglei ecological research programme, Southern Sudan

The Department is organizing the veterinary aspect of a wide ranging study of the possible effects of the building of the Jonglei canal on the Sudd swamps of the Nile and the plains to the east of the swamp. The study includes an examination of the botany, range ecology, fisheries, hydrology, geology, wildlife resources and animal production of the area.

Mr Jones is Chairman of the Steering Committee for these studies, the first stage of which should be completed in 1983. A livestock officer and a veterinary officer, supervised by the Department, are already in the field and although much of their work so far has involved the evaluation of domestic livestock production, they will shortly be extending the study to include a comparison of the potential productivity from large wild herbivores.

Clinical work

A full account of the clinical work and related research of the Department is presented in the Veterinary Clinical Report commencing on p. 52.

THE ANIMAL COLLECTIONS

C. G. C. Rawlins

Introduction

The Curators are responsible for the management of the Society's collections of animals at Regents's Park and Whipsnade. This involves maintaining on a scientific basis the size and quality of the Collections; providing an exhibition which is scientifically correct, educationally valuable and aesthetically attractive; seeing to the proper care and accommodation of the animals and monitoring and changing the management of individual species or groups of animals to ensure the best results.

The Curators carry out these tasks through the Keepers and in co-operation with other staff, in particular those of the veterinary and research departments. While their prime responsibility leaves little time for specific research projects, nearly all the Curators' work is, by its nature, a form of research, since it deals with aspects of the biology and management of many uncommon species of animals. The behaviour, diets, breeding systems and health problems of such species have to be explored, accepted knowledge tested under captive conditions and necessary adjustments made to the management regime.

As was noted in the last Report, co-operation with other zoos in the exchange of animals, particularly those of endangered species, is an essential part of modern zoo management. This process has probably developed further in Britain than elsewhere and, in its development, the Zoological Society of London has played the leading role.

In the period 1979–81 further progress toward communal management of stocks was made in British zoos. The distribution of Great apes in these zoos is now subject to the recommendations of a special advisory group, while Pygmy hippos, Red pandas, all three species of zebra, Humboldt's and Black-footed penguins, have been added to the list of species which are being jointly managed by those Zoological Societies and Trusts in whose collections most of the animals of these species are kept.

This close control of the disposal of British zoo stock is, however, carried out under the rules of the International Wild Animal Studbook system, the co-ordinator of which is Mr P. J. Olney, Curator of Birds and Editor of the International Zoo Yearbook. The Zoological Society of London has led the world in establishing and strengthening this system which is essential for the proper captive management of endangered species.

Curators' Research Units

MAMMALS

Dr B. C. R. Bertram was appointed Curator of Mammals in January 1980, following the appointment of Dr M. R. Brambell as Director of Chester Zoo.

Animal breeding

The breeding success achieved with many of the species of mammals kept in the Collections depends on good husbandry based on experience and on the information gained

from earlier research. As a result our recent outstanding breeding record with species as diverse as giraffe, marmosets and tamarins, Greater kudu, Sugar gliders, Fruit bats, Saki monkeys, Orang-utans, Gibbons and Margays is taken almost for granted. With some species, breeding success has been less sustained, and births have therefore been particularly noteworthy. The female Gorilla "Lomie", who maltreated her two previous offspring when she was on her own, is rearing her third in exemplary fashion at Howletts' Zoo Park, where the company of other Gorillas keeps her interested and protective. Pudu, Gaur, Aardvark, Yellow mongoose, Grey foxes, Dama gazelle and Short-clawed otter are all species which have been bred recently, and these births have provided useful information for future management.

Animal movements

An important part of managing the mammal collection is the moving of animals to and from other collections, to supply mates, to provide different mates, to remove surplus, and to set up better social groups. The most notable example was the sending of the male Giant panda "Chia Chia" to Washington in an attempt to mate him with the National Zoo's female; the attempt was unsuccessful because the two animals fought when first introduced when the female was in oestrus. With this move, as with that of an adult female Indian elephant sent to Rotterdam, co-operation with the Veterinary Department provided information of long term use in the management of these animals.

Stricter quarantine requirements and better co-operation between zoos have resulted in the great majority of movements taking place within the UK. A large number of moves aimed at improving breeding here or elsewhere have taken place, involving Greater kudu, Californian sealion, Polar bear, Chimpanzee, Giraffe, Okapi, Scimitar-horned oryx, Kinkajou, Beaver, Gibbon, Blackbuck, Sooty mangabey, Mandrill, squirrel, Diana and De Brazza monkeys, Ring-tailed lemur, Jaguar, and Leopard among others.

Record keeping

The successful maintenance of the Collection in the future depends on information gathered now. The routine records of births and deaths assimilated from the daily reports of the Keeper staff have continued to contribute an enormous quantity of data for studies on topics such as age of first reproduction, sex ratio and longevity. Recent data on sex ratios are being analysed at present. All our primates are entered on the computer of the International Species Inventory System.

Keeping full records depends on being able to recognize all individuals, either by natural features or by tags or marks. This poses considerable problems with species kept in large social groups. Suitable methods differ between species. A programme, helped by Miss Lucy Vigne, a visiting research assistant, is still in progress to establish methods appropriate for all the mammals we keep.

Institute of Zoology studies

The mammal department staff provided the animals and much of the technical assistance required for the numerous studies by members of the Institute of Zoology on mammals in the

Collections. Such studies are described in more detail elsewhere in this report. They included behaviour and hormone studies on Giant pandas; urinary hormonal studies on Black rhinos; feeding studies on both Black and White rhinos and on a range of small mammals; hormonal studies on puberty in male Orang-utans, Gorillas and Saki monkeys; studies on the genetics and mechanism of hairlessness in Ruffed lemurs; research into arthritis in Collared peccaries; artificial reproduction in Tigers, Cheetahs and Pumas, and artificial control of reproduction in Lions and Brown bears; genetical and nutritional studies of the Mouflon herd; nutritional studies on Scimitar-horned oryx; suckling behaviour in Blackbuck; and studies of the responses by the public to some of the mammals and labels displayed.

Projects outside the Zoo

A considerable amount of information and advice was communicated to outside bodies or individuals. This consisted particularly of answering queries and questionnaires on animal management and breeding.

Dr Bertram's student, Mr H. P. Whitehead, completed his PhD on the behaviour and ecology of the Humpback whale. A field and laboratory project on the Naked mole rat by Mr R. A. Brett has been initiated.

Morphological investigations

Professor A. J. E. Cave, Honorary Research Associate, continued his morphological investigations with a study of the disposition of lymphoid tissue in the oropharynx of the Bottle-nosed dolphin. A laryngopharyngeal tonsil, not previously described, was shown to exist in this cetacean. Studies of the rhinoceros heart showed a direct inter-nodal pathway of Purkinje tissue as a canonical feature of this organ. A first-time account of the Sumatran rhinoceros heart has been published. The innervation of the rhinoceros aortic and pulmonary trunks was investigated macroscopically and a chemoreceptor organ was discovered in relation to these vessels. Studies were also carried out on certain morphological features (selenapophyses) of the cervical vertebrae of the higher primates which are not accorded formal recognition in descriptive osteology.

BIRDS

Volume 2 of the proposed seven volumes of *'The Birds of the Western Palearctic'* was published in 1980. The Curator of Birds acts as an honorary editor being responsible for editing and writing the sections on food and feeding behaviour. Volume 2 contained accounts for 105 species and volume 3, which is nearing completion, will contain accounts for 123 species.

The main development in the Bird Department has been the expansion in use of the incubation and rearing unit, with two sections now being actively involved. An incubator designed primarily for eggs of Birds of Prey was purchased, a similar incubator was built by the workshop staff of the Nuffield Laboratories and two human-baby incubators were purchased. Useful baseline data on the humidity and temperature requirements of eggs for a number of species were collected. Artificial rearing has increased and successes have included species not reared in this way before (Plate VI).

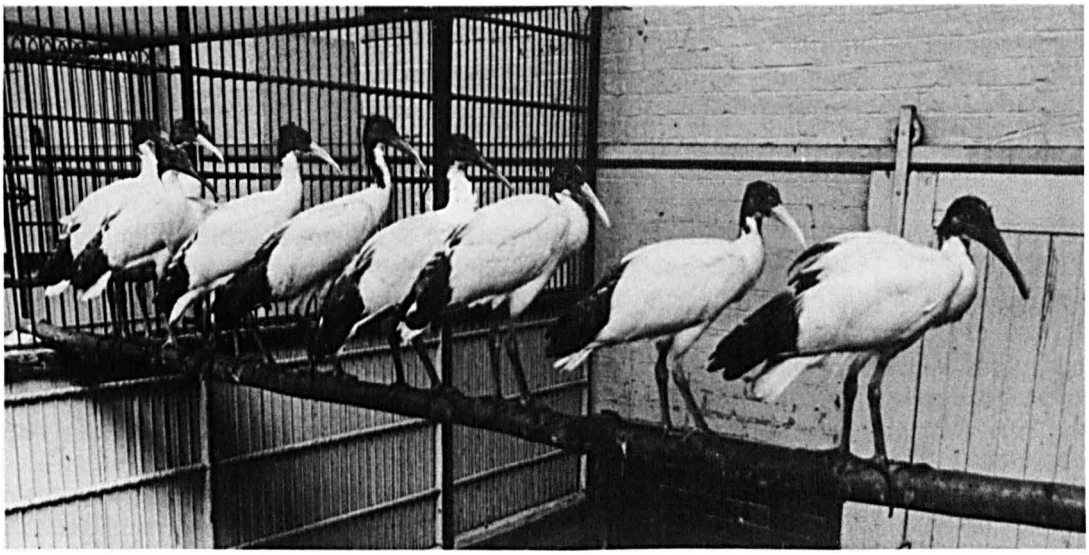

PLATE VI. Sacred Ibis hatched in incubators and hand reared at Regent's Park. Photo: M. Lyster.

Useful data were collected on the breeding biology of a number of species and will form the basis of future papers. These will include the rearing by parents of Abdim's storks, Jerdon's imperial pigeon, Tarictic hornbills, and the artificial rearing of Ruffs and Sacred ibis.

Eggs were sent to Dr Board, University of Bath for his work on the pore structure of shells. Fertile eggs were sent to Dr Dawes, Royal Veterinary College, for his work on the physiology of the developing embryo, and to Professor Wolpert, Middlesex Hospital Medical School, for work on pigment pattern formation in embryos. Dr Sadie Coates (USA) recorded the vocalisations of different species of owls.

Dr H. G. Vevers and Dr G. Y. Kennedy completed their work on the eggshell pigments of ratites and are preparing an account for publication.

Dr Vevers has carried out preliminary work on the coloured secretion of the preen gland of birds. The colour is almost certainly due to the presence of carotenoid pigment but the evidence is not yet conclusive. Dr Vevers hopes to continue this work and also to extend his earlier investigations on feather pigments, although his time has been largely taken up with editorial duties and the organization of the Society's Scientific Meetings and Symposia.

REPTILES

The Reptile House staff under Mr D. Ball, Overseer of Reptiles, are experimenting with various materials to provide an hygienic substitute for the usual substrate of sand, peat, etc. The interiors of a number of cages are being renovated using natural rock and plants. Full-spectrum Vitalite lamps, concealed beneath rock ledges and suspended a short distance above the cage floor, provide basking areas for certain lizards.

A prototype climatic cabinet for reptiles is in process of construction. This is fully air-conditioned and the temperature, humidity and photoperiod will be controlled to provide the daily and seasonal variations to be found in different climatic zones.

Reptile eggs are now being incubated in standard hospital incubators, and the hatching rates have greatly improved.

The accommodation of reptiles not on exhibition was improved, using modified laboratory animal cages and racks.

WHIPSNADE

The Curator, Mr V. J. A. Manton, was responsible for organising the celebrations in 1981 of Whipsnade's Fiftieth Anniversary. Research into past achievements revealed some fascinating facts. It is probably quite well known that of the 1045 specimens of mammals kept in 70 species, over 84% on exhibition were bred in the Park and likewise of the 883 specimens of birds kept in 108 species, over 42% were hatched in the Park. However it was very encouraging to calculate that over a period of 50 years, 357 animals were imported into the Park from the wild but 18,561 were bred—a ratio of 52 animals bred for each one imported.

Although no individual is still in the collection from 1931, there were recorded a number of cases where animals lived longer than average. The two Common hippopotami are still alive, having been in the collection for over 31 years. A Przewalski horse mare, on deposit to another United Kingdom collection, is the oldest animal in the Studbook at 29½ years of age. A female giraffe died, during pregnancy, at over 21 years of age and the female Indian rhinoceros, deposited in a Continental collection, still lives 29 years 2 months after arrival from the Kasiranga reserve in India. The present breeding Red crowned crane was hatched in the Park over 19 years ago and still flourishes and a barren Californian sea lion lived in the Collection for 17 years.

The birth of a second Chimpanzee to the Whipsnade Group, this time a female and, like the first, also being mother reared, confirms the success of this group. It also emphasizes the importance of close collaboration between collections in the United Kingdom quarantine zone since the sire this time was the breeding male from Twycross Zoo thus successfully introducing unrelated blood into the Whipsnade group. Also on the collaborative front a multiple rhinoceros move was achieved. Paignton Zoo had an exhibit of a lone male Black rhinoceros—a species whose breeding record in captive collections is not outstandingly good. Since a lone female was present in Bristol, it seemed a good idea to arrange their "pairing". Unfortunately, Paignton did not want to lose a "Rhino exhibit" and Bristol no longer wanted to keep any. However, Chester had room for both animals so a pair of Whipsnade born White rhinoceroses were offered to Paignton and at the same time as these were delivered, the lone male was collected and transported to Chester. In a further effort to achieve further pairs of this species in alternative collections the Whipsnade born female was sent to Marwell to join the Regent's Park born male already there.

Collaboration with Marwell also allowed a new herd of Przewalski's horses to be established in Japan at Ueno Zoo, Tokyo, consisting of three Whipsnade bred foals and two Marwell bred ones. Again the two Zoos joined to set up another United Kingdom herd in Wiltshire this time of five Whipsnade bred animals and four from Marwell. Pregnancies have already been achieved there.

The fertile Whipsnade Spectacled bear male was loaned to Jersey Zoo following the loss of their breeding animal.

Co-operation with Blijdorp Zoo, Rotterdam allowed for eight Common zebra to be

gathered, quarantined for two months at Whipsnade, prior to shipment to Melbourne Zoo, Australia.

Continued breeding successes have been recorded in the flock of Humboldt's penguins enabling 12 Whipsnade hatched birds to be sent to Chester to help populate their newly constructed pool. Birds have now been hatched in eight of the 12 months in two batches—November to January and April to August—and several eggs have recently been laid by birds themselves hatched in the Park.

Although the Rosy flamingos have again successfully laid and hatched, disturbance to the Chilean flock—possibly caused by preparations for the Anniversary celebrations or the celebrations themselves—appeared to prevent development of early courtship behaviour into actual egg laying and none were laid.

Further pressure of successful breeding in other collections has enabled the bachelor herds of Common waterbuck and Scimitar-horned oryx to be converted into potential breeding herds by the addition of females, themselves captive bred.

The birth of the 21st calf to the White rhinoceros herd imported in 1970, ensured the continuation of this group and enabled more surplus stock to be sent overseas to start new groups (this time in Australia). Of these birds, four took place in September, eight in October, four in December, one in January, one in March, one in April and two in June, indicating a preference for seasonal breeding in the autumn and early winter.

The utilization for behavioural studies of the animals in the Park was initiated and radio transmitters were fitted to two Reeves' muntjac so that their movements round the Park could be studied. A study on the ecological requirements of the free-ranging population of Red-necked wallaby in the Park will commence shortly.

Most species of antelope living in herds only tolerate the presence of one adult male in the group. Since quarantine restrictions on all cloven hoofed stock entering the United Kingdom insist that one year is spent in an urban confinement, the loss of a breeding male in a rural zoo means a long delay before a replacement can be obtained. In addition, pressure on space usually prohibits the keeping of a second male on his own and it is therefore an advance in zoo management for the Society to have commenced the keeping of all male bachelor groups. These are displayed as an exhibit at Whipsnade and at present consist of Roan antelope, Blackbuck and Thomson's gazelle. It is only in a Collection with the space like Whipsnade that such a policy can be carried out and it means that any Collection in the United Kingdom requiring a new male may obtain one very simply, quickly and inexpensively, without the need for complicated quarantine procedures. Indeed, following on the Society's agreement with Marwell Zoological Society to jointly own the United Kingdom's population of Hartmann's Mountain zebra, a management group representing some of the major zoos is now co-operating on programmes to breed Black rhinoceros, Greater kudu, Pygmy hippopotamus, Californian sea-lion, Red panda, Common zebra and Grevy's zebra. This means that in the future, zoos will be less conscious of individual collections and place more emphasis on the suitable placement of breeding groups throughout the quarantine area. The opportunities for research will therefore be increased considerably, as realistic numbers of animals will be available.

VETERINARY CLINICAL REPORT

D. M. Jones

The principal work of the Department of Veterinary Science is to maintain the high standards of animal health in the two Collections at Whipsnade and Regent's Park. As a by-product of this work a considerable wealth of knowledge has accumulated in animal management techniques, notably anaesthesia, practical nutrition, baseline data on biochemistry and haematology, and on techniques for the treatment of clinical problems. Much of this work depends on the collaboration of other Departments of the Institute and of other medical and biological institutions, mainly in the London area. In addition, the Department contributes to the specific research projects of other members of the Institute, notably in reproductive science, and also provides the Institute with advice on the care of our large breeding colonies of small primates and by developing new surgical and other manipulative techniques applicable to the many aspects of the research programmes of the other Departments.

Regent's Park

CLINICAL WORK

During the two-year period 886 clinical cases from the Collection were examined. This total was made up of 615 mammals, 168 birds and 103 reptiles. Seven hundred and forty-two of these cases, including 24 referred from Whipsnade, were treated in the hospital. In addition, 175 animals were examined for the research laboratories, and 358 were referred for examination from veterinary practices mainly in the London area.

One hundred and seventy-three mammals and 155 birds spent a period of isolation or statutory quarantine before being released into the Collection.

Clinical cases of special note

Pneumonia in Primates

Chronic respiratory problems were encountered in some of the small primates in the Clore Pavilion and in the Institute's animal holding facilities. Two Ruffed lemurs in the Clore Pavilion died of an acute bronchopneumonia following which all the larger lemurs in the Collection were examined clinically and radiographically. Although clinical signs were not evident in most cases, almost all the animals had radiographic signs suggestive of a widespread bronchopneumonia. Electron microscopy of samples of the lungs from the dead animals revealed the presence of large numbers of Mycoplasmas.

A serious outbreak of human influenza affected most of the holding rooms for Common marmosets in the Nuffield and Wellcome buildings. Fortunately only a few young animals were lost and the situation was brought under control by isolating severely affected individuals in the hospital and giving them covering antibiotics against the possibility of a secondary bacterial infection. The animals showing minor clinical signs were left in their cages and with intensive nursing recovered uneventfully. Both these respiratory problems were thought to be partly due to poor ventilation in the Clore exhibits and marmoset holding

rooms and help was sought from the Animal Husbandry Department of the Royal Veterinary College for a quantitative assessment of the air flow in these areas. As a result of this the ventilation has now been improved as far as the designs of the buildings allow.

Klebsiella

Three species of *Klebsiella* are regularly isolated from small primates in the Collection and Institute. These are *K. oxytoca, K. aerogenes* and *K. pneumoniae.* Attempts were made over the last three years to eliminate these organisms without success. An overall assessment of the clinical and laboratory findings during the two-year period suggests that *Klebsiella pneumoniae* poses by far the greatest threat in small primates, but providing the management of these animals is sound, the losses are likely to be so low as to make the expense of isolation, regular laboratory screening for the organism and treatment of carriers an uneconomic proposition. If *Klebsiella pneumoniae* is found during the routine clinical screening of newly arrived animals, either in primates or rodents, an attempt is made to eliminate the organism from the digestive tract after *in vitro* antibiotic sensitivity tests have been carried out. At present deaths due to this organism are limited to a few small areas of the primate collection such as the Silvery marmosets in the Clore Pavilion and providing these animals are not under stress, such as may occur if the family groups become too large, the problem only occurs infrequently.

Osteodystrophy

Despite the considerable amount of work which has been carried out in the Institute and other centres on the aetiology and prevention of nutritional osteodystrophy, cases still occur, especially amongst those animals which do not easily accept powdered vitamin/mineral supplements. A minor alteration in the usual hand-rearing diet for young ciconiiform birds which resulted in a slightly lower calcium intake, caused a number of losses in Sacred ibis chicks due to malformation of the long bones of the legs. Although there are known to be many other factors involved in leg deformities in birds, most of the cases are related to a nutritional imbalance and it would seem that long-legged birds are particularly susceptible to these problems.

Deaths in neonatal oryx

A difficulty which was investigated in considerable depth during the last two years was the high neonatal losses experienced amongst the breeding group of Scimitar-horned oryx. These losses usually occur at between three and five weeks of age, although occasionally the animals die within a few days of birth. Diarrhoea and a reduced growth rate are usually the presenting signs and the problem was initially thought to be due to a pathogenic coliform. Serotyping of the coliforms carried out by the Central Public Health Laboratory at Colindale revealed nine different types and on this basis it was assumed that the enteritis and possible coliform septicaemia must be secondary to some other factor. The same problem, to a lesser degree, was also seen in recent years in the parent breeding herd of this species at Marwell Zoological Park, but it now seems to have been virtually eliminated there. It is thought that this improvement may be associated with the fact that the females have access to grazing for most of the year. This theory was further supported when a Regents' Park calf

which had shown all the usual signs and was brought to the hospital in a collapsed state, recovered after intensive care involving the daily intravenous feeding of high levels of nutrients, but in particular, the inclusion of a range of essential fatty acids. Further cases, however, have not responded as well to this treatment and although it is thought that a nutritional problem is almost certainly the cause of these cases, the exact aetiology has not been defined and the problem is still under intensive investigation. It is of some interest to note that the red blood cells of these animals are usually distorted at birth, but become normal after a few days. They then become distorted once more at about the time the calves begin to show clinical signs. Low circulating vitamin E levels may also be playing a part in this syndrome.

Dental prosthetics

Co-operative work with the Eastman Dental Hospital on the use of new prosthetic materials for the replacement of avian bills was an important feature of the period. A Great Indian hornbill from a private collection which was presented with only half its lower mandible and even less of the upper had an entirely new bill fitted, moulded from acrylic reinforced with carbon fibre and steel rods. Cosmetic dyes were used to produce a matching colour and the animal soon learned to use its rather heavier bill. A pathological fracture of the mandible of an African spurred tortoise which resulted from a necrotizing osteomyelitis was repaired using a specially moulded metal alloy plate fitted to the shape of the jaw. The prosthesis appeared to be successful although the animal died some months later from other causes.

Syngamiasis

One parasitic problem of note was a severe nematode infestation involving *Syngamus trachea* in Red-billed hornbills and Wattled starlings. The starlings had been presented by a commercial laboratory and probably became clinically affected because they had not encountered the parasite previously. Our experience on this occasion confirmed previous findings that the parasite appears to be fairly resistant to treatment with Levamisole but was much more sensitive to therapy with Fenbendazole (15 mg/kg), providing the drug was given individually by stomach tube on the first occasion and then the birds separated into small groups so that they could be given a fairly accurate level of the drug on their food.

Giant panda

By far the most important clinical case of the period surrounded the problems experienced by the female Giant panda "Ching Ching". Late in 1979 it became evident that the animal had a greatly enlarged abdomen. She was examined under sedation and a large quantity of ascitic fluid was removed from the abdominal cavity together with quantities of gas from the lower intestine. Anaemia and hypoproteinaemia were also evident from examination of blood samples taken from her. An exploratory laparotomy was carried out and biopsies taken from a number of organs, all of which pointed to a chronic peritonitis. The animal was supported by regular intravenous feeding for periods of up to 5 h at a time, given while she was under deep sedation. After the exploratory laparotomy, this treatment had to be given on a daily basis for 16 days which, with the bamboo that she was eating herself, succeeded in increasing her body weight from a little over 60 to 72 kg. It became evident that the intravenous feeding in the mornings led to an increased appetite as time went by after this period

of "artificial nutrition" she began to eat more readily. Sedation and anaesthesia of the animal has now been carried out on over 100 occasions for supportive therapy or the regular checking of blood samples and it has been found that a mixture of 5 mg/kg of Ketamine and 0·5 mg/kg of Xylazine was ideal for initial anaesthesia of this patient, giving a fairly rapid induction in from 4 to 6 min. This dose results in about 10 minutes of surgical anaesthesia and a further 15 min of deep sedation. Further intravenous doses of one third to one half of the original dose rates are given at approximately 15–20 min intervals to maintain light anaesthesia. Apart from very slight and clinically insignificant cardiac arrhythmias, particularly when the animal was beginning to recover from the drug, no significant side effects have been seen. Even after anaesthesia of 4–5 h duration, she usually recovered within 1½–2 h of being taken out of the operating theatre. A second laparotomy, at which further biopsies were taken, revealed that the peritonitis had subsided, and that the formation of ascitic fluid was minimal. Extensive microbiological surveys of all the tissues removed has failed to reveal a cause, although it was probably originally infective.

A gamma scan carried out at University College Hospital after irradiated white cells from the panda had been reinjected into her, suggested that the peritonitis had probably originated from a mild inflammation of the upper intestine. There has also been some evidence from a number of laboratories who have been assisting, that she may be allergic to some of the proteins in her food. "Ching Ching" has shown evidence of an allergy to penicillin on two occasions, during which severe erythema and depression occurred accompanied by considerable discomfort and the discharge of a bloody diarhoea. A compact telemetric temperature-sensitive capsule made by the Medical Electronics Unit at St. Bartholomew's Hospital, was implanted subcutaneously into one of her hind legs, and revealed marked variation in her normal diurnal body temperature from 36·5 to 41·5°C. The use of a rectal thermometer gave far less reliable results and the readings varied only half a degree form the average of 37°C. A considerable amount of medical data has been accumulated on this animal, which has been circulated to Chinese scientists and other centres holding Giant pandas. Above all, it is evident that this species is very tolerent of regular clinical intervention and is relatively easy to handle using the sedative combination that has been described.

Sedation and anaesthesia

Some of the most interesting findings occurred following the use of the combination of Ketamine and Xylazine on many occasions in the same animals. The extensive work which was carried out with the Department of Reproduction on the breeding biology of large cats, in particular the Puma and Cheetah, necessitated the sedation of a number of these animals on many hundreds of occasions. At the beginning of the study Ketamine alone was used on pumas and the usual dose rate of 10–12 mg/kg of body weight rose steadily to a point where five times this level was needed to produce the same effect. This stage was reached after individuals had been sedated approximately 100 times. The effect was not quite as marked with the combination of Ketamine and Xylazine which is now used routinely, but it is still evident that where such animals have to be sedated regularly, they are likely to become resistant to Ketamine. There is no evidence from the studies that resistance to Xylazine occurs and too much additional Xylazine may result in greatly prolonged recovery times.

The most interesting individual case of the period was the successful movement under sedation of an adult female Indian elephant from Regent's Park to Rotterdam Zoo in

Holland. This animal had a reputation of being difficult to handle. An initial dose of 0·15 mg/kg of Xylazine base on an estimated weight of 3000 kg was given to facilitate walking her from her pen into a transport crate, a movement which otherwise would have been impossible with this animal. She was given additional doses of one third of the original level at 2-h intervals throughout the journey to keep her sedated but still standing. Complete recovery occurred shortly after entering her new accommodation at Rotterdam. Work on methods to achieve a standing sedative effect in adult elephants both at Whipsnade and Regent's Park over the last few years suggest that Xylazine at the above dose rate provides a satisfactory effect in the Indian elephant, but that Azaperone at the same dose rate is more effective in the African elephant. Because there is a necessity to keep adult elephants standing safely for clinical examination, further work is needed from other collections with elephants to try to elucidate whether these are the best techniques of sedation.

Surveys and collaborative research

Surveys on a number of groups of animals were carried out with other staff of the Institute, often with the additional help of outside laboratories. These have included an in-depth assessment of the nutritional status of the sheep and goats on the Mappin Terraces, in particular the flock of Mouflon. All these flocks and herds are highly inbred and a genetic examination of the stock is under way, together with an assessment of their nutritional and disease status. In particular it is felt that these groups may be deficient in essential fatty acids and vitamim E. Neonatal losses and poor growth rates are still seen in all three groups and it is thought that a combination of factors is probably responsible.

In parallel with the extensive survey on the incidence of Malignant Catarrhal Fever virus antibody (MCF) which was conducted at Whipsnade, almost all the ruminants on the Cotton and Mappin Terraces were screened in an attempt to try to eradicate the virus from Regent's Park. The small group of Gaur now at Regent's Park are particularly vulnerable to this disease. Many captive groups of the species have been badly affected by it. The study is being undertaken in cooperation with Dr Neil Eddington of the Royal Veterinary College. The evidence in both collections, backed up by further studies on blood samples from Marwell, suggests that apart from the Wildebeest, both Scimitar-horned oryx and Gemsbok may be important non-clinically affected carriers. The only two animals to show a significant antibody level at Regent's Park are both Scimitar-horned oryx. The virus is already present in the herds at Whipsnade and Marwell but does not appear to have caused any problems. It is likely from the evidence of this survey, that apart from the large bovines, the harnessed antelopes such as the Sitatunga and Kudu are probably the species most at risk. It is known from work by other centres that Red and Sika deer are also vulnerable although it is by no means certain that this is exactly the same virus as that found in Wildebeest. Any further ruminants to be introduced at Regent's Park will be automatically screened for MCF antibody levels prior to being put on exhibition.

All the Collared peccaries in both Collections have been examined by a combined survey team involving several Departments in the Institute and the Middlesex Hospital Medical School together with Dr Ian Keymer of Norwich Veterinary Investigation Centre to look at the aetiology of the widespread osteoarthritis that appears to affect a very high proportion of these animals. Unfortunately no conclusions about its aetiology have been revealed as yet despite a highly intensive study.

Surveys on the incidence of mycoplasmas in sheep and parrots were carried out with the Department of Infectious Diseases and on the endocrinology of puberty in the Orang-utan and White-faced Saki monkeys with the Department of Reproduction. The Veterinary Department is also involved in research projects on reproduction in wallabies, primates, blackbuck and big cats. The extensive work on Pumas culminated in the birth, by artificial insemination, of a female cub. Oestrus and ovulation were induced artificially and the dam was inseminated with fresh semen taken from the male on the same day by electro-ejaculation. This is only the second time that such techniques have been successful in large carnivores, the first time having been in a wolf in the United States. It is probably the first time that artificial induction of the female was used as well as artificial insemination.

With the help of a number of medical centres in London including notably the Cardio-thoracic Institute, the Westminster Hospital and St Bartholomew's Hospital, work continued on the physiology of immobilization of difficult ruminants. Although in general, satisfactory methods for the sedation and anaesthesia of large mammals have been standard practice for many years, a number of difficult groups remain, notably some of the antelopes, the Giraffidae, the hippopotamuses and to some extent, the equines. Problems with the antelopes and the equines become particularly acute when they are to be transported in travelling crates. Although narcosis or sedation is often the most practical method of introducing an animal to a transport crate, a number of subsequent losses have been recorded during the course of its journey. Combinations of drugs involving Etorphine are particularly noteworthy in this respect. It appears that when a combination of either Etorphine with Acepromazine or Etorphine with Xylazine is used to introduce some antelopes and equines to a crate, they appear to recover fairly quickly following the use of the narcotic antagonist, but then go into a state of severe excitement. This has been particularly noticeable with the oryx group, with Kudu and with all the equines with the general exception of the Common zebra. Measurement of the mean arterial blood pressure in Fallow deer, which show a very similar response to many of the antelopes in this respect, reveals that the blood pressure rises dramatically in many cases following the intravenous administration of Diprenorphine. The resting mean arterial blood pressure during the course of full narcosis usually lies between 80 120 mm of pressure, but may then double within a minute of the administration of the antidote. The animal then often leaps to its feet and may panic badly within the travelling box, further elevating the blood pressure. Observations of Scimitar-horned oryx and Addax under the same conditions in a loose box reveal that they behave in the same way although blood pressure was not recorded on these occasions. Animals which were otherwise very quiet and well acclimatized to their accommodation showed a distinct excitatory phase on rising to their feet and this continued for some half an hour with the animal colliding with the walls and any other objects in the way (even after the loose box had been darkened).

Other surveys which have been carried out in the Department have included examinations of the energy requirements of some small carnivores with Dr Alan Walker, the energy and fibre requirements of White rhinoceroses with Dr David Frape and a study of the digestibility of various foods by Scimitar-horned oryx in comparison with sheep as part of an SRC funded study for a PhD Thesis by Miss Catherine King under the supervision of Dr Eric Miller. A similar study also under the supervision of Dr Eric Miller has begun on the Reeves's muntjac. Professor Peter Harris of the Cardio-thoracic Institute has been looking at the pulmonary arterial blood pressure in small camelids kept at sea level (Regent's Park) and in the high Andes in Peru. A long-standing interest in the essential fatty acid requirements of

TABLE III

	Menagerie (1979)									Research Institute		External sources		Grand total
	Non-domesticated				Domesticated				Total menagerie					
	Acclim.	Unacclim.	New-born	Total	Acclim.	Unacclim.	New-born	Total		Non-dom.	Dom.	Non-dom.	Dom.	
Mammalia	203	31	77	311	6	1	11	18	329	21	20	29	2	401
Aves	145	26	5	176	0	0	0	0	176	0	0	54	15	245
Reptilia	66	46	10	122	0	0	0	0	122	0	0	27	0	149
Amphibia	10	4	0	14	0	0	0	0	14	0	0	0	0	14
Totals	424	107	92	623	6	1	11	18	641	21	20	110	17	809

browsing ruminants was further examined through a cooperative project with British Petroleum Nutrition. For some years attempts have been made to stabilize essential fatty acids in ruminant diets in such a way that they pass through the rumen largely unhydrogenated by the ruminal flora. In browsing ruminants it is thought that their requirements for certain fatty acids is probably very much higher than it is in some non-browsers and that standard commercial diets for domestic ruminants do not include these fatty acids in sufficient quantities. In order to try to improve the situation for these specialist feeders, we have, with B.P. Nutrition, been looking at a trial diet which includes some of these stabilized fatty acids in Black fallow deer. Examination of the circulating fatty acid levels before and after using this special diet has shown that they are still not reaching the duodenum in sufficient quantities to be absorbed. Work will continue to try to improve this diet which is badly needed for species such as Pudu, Timor deer, Moose, Kudu, and giraffe.

PATHOLOGY—1979

During the period from the 1 January to the 1 December 1979 inclusive, a total of 889 post morten examinations was carried out. This figure includes fish which are not included in Table III. Fifty-five domestic animals were examined and the non-domestic animals were divided into 401 Mammalia, 245 Aves, 149 Reptilia, 14 Amphibia and 25 Pisces.

In the collection at Regent's Park, carcases examined excluding those of domesticated species numbered 623.

Mammalia (Table IV)

Nutritional/metabolic disorders

The principal causes of death in the category were the same as those described in previous Scientific Reports. The most common reason for neonatal death was failure of the youngster to feed. Gregarious ungulates are particularly prone to this problem although deaths for this reason are seen in a wide range of mammalian species. Poor growth rates amongst species such as the Wild boar, Mouflon and Barbary sheep often lead to a few individuals being culled at between two and 12 months of age.

Gross obesity leading to severe fatty infiltration of the liver was again responsible for the deaths of a number of rodents, notably Thicket rats. Vitamin A deficiency was suspected as the cause of death in an adult Californian sea lion. The animal had been receiving 25,000 i.u's of vitamin A as the acetate in its supplementary tablets, but the liver levels of carotenoids were still extremely low (8 i.u's per gram of tissue). There is evidence from the post mortem examination of marine mammals in this laboratory that synthetic forms of vitamin A may not be absorbed or stored as efficiently as would be the case with terrestrial mammals.

Hand-reared animals often develop minor erosions and ulcers of the abomasal mucosa, possibly as a result of stress and the feeding of milks which may be adequate, but not optimal for their needs. These lesions sometimes lead to septicaemia and death. For example, a Waterbuck, a domestic lamb, two Maras and a Cotton-topped tamarin succumbed to this problem. Overgrowth, malocclusion, distortion and heavy wear of teeth also cause a number of problems every year. Rodents, rabbits and the Common marmoset colony were affected to a small degree and a number died or were destroyed because of dental problems during the year under review.

TABLE V
Aves (1979)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie								Research Institutes (0)		External sources (69)	
	Acclimatized (145)		Unacclimatized (26)		New-born (5)							
	Number affected	% affected	Number affected	% affected	Number affected	% affected	Total (176)	% of total deaths	Number affected	% affected	Number affected	% affected
Bacterial infections	38	26·2	7	17·9	2	40·0	47	26·7	—	—	13+7D	29·0
Viral/Rickettsial infections	—	—	—	—	—	—	—	—	—	—	—	—
Fungal infections	7	4·8	1	3·9	—	—	8	4·6	—	—	4	5·8
Parasitic infections	20	13·8	3	11·5	—	—	23	13·1	—	—	11+8D	27·5
(a) Arthropods	6	4·1	—	—	—	—	6	3·4	—	—	2+6D	11·6
(b) Helminths	11	7·6	2	7·7	—	—	13	7·4	—	—	9+2D	15·9
(c) Protozoa	3	2·1	1	3·9	—	—	4	2·3	—	—	—	—
Nutritional/metabolic	7	4·8	—	—	—	—	7	4·0	—	—	9+2D	15·9
Debility (including senility)	46	31·7	5	19·2	—	—	51	29·0	—	—	19+1D	29·0
Injuries and accidents	38	26·2	6	23·1	—	—	44	25·0	—	—	4	5·8
Neoplasia	4	2·8	—	—	—	—	4	2·3	—	—	0+1D	1·5
Euthanasia	4	2·8	1	3·9	—	—	5	2·8	—	—	10+6D	23·2
No diagnosis	22	15·2	3	11·5	2	40·0	27	15·3	—	—	14+1D	21·7
Others	25	17·2	8	30·8	1	20·0	34	19·3	—	—	13+1D	20·3

*Not necessarily the cause of death in all cases; D, domesticated animal.

Bacterial infections

As in most years, approximately 20% of all deaths in acclimatized animals were associated with disease due to bacteria. *Klebsiella pneumoniae* was responsible for a number of deaths amongst the small rodents in the Clore Pavilion, but only one small primate, a newborn Red-mantled tamarin died of a septicaemia caused by this organism. Klebsiella septicaemia was more significant as a cause of death in the marmoset colonies in the Wellcome building where a Common marmoset and two Cotton-headed tamarins died of the infection. A privately owned Kinkajou also succumbed to Klebsiella septicaemia (*K. pneumoniae*), an unusual species to be affected by this organism. *Yersinia pseudotuberculosis Type 2B* was responsible for the death of a Vervet monkey in the Collection, and *Pseudotuberculosis Type 2A* was isolated from the major organs of a De Brazza's guenon from another source. *Pasteurella pneumotropica* was isolated from the reproductive tract of a Multimammate mouse with oophoritis and from the liver and lung of an Egyptian gerbil. This organism was also isolated from the main organs of a domestic piglet from the Children's Zoo. *Pasteurella multocida* was found in limb contusions in a European hedgehog, the liver of an Indian mongoose and from the upper respiratory tract of a rabbit with severe rhinitis. *Bordetella bronchiseptica* was responsible for upper respiratory disease in another rabbit and for pneumonia in two young Silvery marmosets and two Harvest mice. A Fusobacterium species, probably *F. necrophorus*, was isolated from the jaw of a Red kangaroo and from subcutaneous abscesses in a number of laboratory mice. *Corynebacterium pyogenes* was found in a large spreading leg abscess on a young Scimitar-horned oryx, and Corynebacteria were found in a number of other animals including the lung of a newborn Mandrill. The organisms were probably significant in all these cases, but were not specifically identified.

Coliform septicaemias were recorded in a variety of young animals, especially ungulates and primates. Staphylococci and Streptococci caused septicaemias and localized lesions particularly in rodents. *Salmonella* species were recorded on only two occasions in mammals, a septicaemia caused by *Salmonella* typhimurium was found in a Brown mouse lemur and a Guinea-pig from the Children's Zoo was found to be a carrier of *S. urbana*. Extensive faecal screening of the in-contact animals in both cases failed to reveal any further carriers. An *Erysopelothrix* species was found in the congested liver of a Grasshopper mouse; *Bacteroides melaninogenicus* was isolated from a large pulmonary abscess in an Indian muntjac, and *Nocardia asteroides* was found in the liver and the mesenteric lymph nodes of a Bactrian camel. A placentitis in a Greater kudu appeared to have been associated with *Acinetobacter lwoffii* and resulted in a stillborn full term foetus. A heavy pure-growth of a *Branhamella* species was isolated from the liver of a neonatal Lion.

Viral infections

Large numbers of herpes virus particles of unknown significance were seen in the lung of a wild-caught Virginian opossum with pneumonia. These were associated with cysts thought to be a *Besnoitia* species. Equine herpes virus was also recovered from the tissues of a yearling Grevy's zebra from another collection. The animal had not grown well and although no histological evidence of a myopathy of skeletal muscle was evident, all the leg muscles were somewhat atrophied. A severe pneumonia, thought to have been caused by an arenavirus caused the death of a Celebes black ape from another collection.

Parasitic infections

Arthropods

A *Demodex* species caused severe dermatitis in a number of Dwarf hamsters which was further exacerbated by the presence of large numbers of *Ornithonyssus bacoti*. *O. bacoti* was also found in large numbers on the skin of an Egyptian gerbil, a Common hamster, and two Striped grass mice. A flea, identified as *Nosopsyllus fasciatus* was found on a European hamster. Mites of the species *Halarachne halichaeri* were found in the nasal passages of a Grey seal which had been in the Collection for many years but had shown no clinical signs of upper respiratory disease. A further outbreak of severe dermatitis in the Guinea-pigs at the Children's Zoo was caused by *Trixacarus caviae* mites and it would appear that the standard procedures for eradicating this parasite in Guinea-pigs do not appear to be very effective. The mite almost certainly remains on the host animal in relatively small numbers most of the time without causing any problem. In our experience at Regent's Park, a clinical problem does not arise with this mite until the numbers of Guinea-pigs build up and that probably the stress that results from this may contribute towards the onset of the dermatitis.

Mycotic infections

As usual these were relatively rare. *Candida parapsilosis* was isolated from the lungs of a Harvest mouse with severe acute pneumonia. *Candida albicans* was isolated from the buccal cavity of two young Maras and from the eye of a Collared peccary with severe conjunctivitis. It is probable that the cases in the Maras were secondary to some stressing factor as this is a very common secondary infection in this species after they have already lost condition for other reasons.

Helminths

Helminthiasis is never a serious problem at Regent's Park, least of all in mammals. The faeces of most species are regularly screened for evidence of helminth infestation and in addition to the gross examination of the digestive tract at post mortem examination, smears from different levels of the tract are routinely examined. A single *Dipetalonema* species was found in the peritoneal cavity of a Long-haired spider monkey. Small numbers of *Strongyloides* species were found in two Squirrel monkeys kept in the Nuffield laboratories, a few *Parascaris equorum* were found in the small intestine of a Common zebra and three Maras that died during the period were all infested with *Graphidiodes affinis* in the stomach. A tiger and a puma both contained small numbers of *Toxascaris leonia* in the small intestine. Both these animals were from other collections. The most unusual finding of the period was of *Spinturnex* species nematodes in the intestines of a wild Greater horseshoe bat.

Protozoa

Balantidium species in very small numbers were found in three Pig-tailed macaques and a Long-haired spider monkey. Cysts of a *Besnoitia* species were found in many organs from a wild-caught Virginian opossum.

Neoplasia

Lymphosarcomas were diagnosed in a Fennec fox, a Coatimundi and a laboratory mouse.

A mammary myxoma was found in a Golden hamster, a follicular adenoma in the thyroid of a Grey seal, and adenocarcinomas involving the mamary glands in two Thicket rats. A squamous cell carcinoma of the left mandible in a Blotched genet had totally eroded the bone and the animal had to be destroyed. A Spotted genet was found to have a renal carcinoma.

Accidents and injuries

As usual, injuries made up a significant portion of the causes of death in some groups of mammals, notably rodents, primates and ungulates. A fractured radius in a young female Kudu was successfully repaired surgically, but the animal died three days later, probably from shock. A Bighorn sheep ruptured her uterus and died of internal haemorrhage during parturition, a male Gemsbok that had been crated for shipment to New Zealand became very excited in it's crate at the airport and died of heat stress before treatment could be provided. Multiple injuries caused by adult members of the group led to the death of a newborn Common zebra foal. A Serval which had sustained bite wounds from a companion died ultimately of further extensive injuries which were self-inflicted. This is the third Serval in the author's experience which has exacerbated relatively minor wounds by self-inflicted damage and has had to be destroyed as a result.

Miscellaneous problems

Amongst the most interesting series of cases which have been examined in recent years have been three Siberian tigers from the stock at Marwell Zoological Park. All three were males and all showed various degrees of blindness with or without ataxia. This Collection has also noted another case which was not thoroughly examined at the time but which was also a male. All the animals were the progeny of studbook no. 211 and 216. These parents also had the same father, and the mothers were sisters. In one animal there was evidence of Wallerian degeneration of the inferior cerebellar peduncle and the external arcuate fibres. There was also degeneration and areas of glyosis in some of the tracts of the spinal cord. This animal, which was much younger than the other two, also had minor degenerative changes of the ocular lens and retina on one side. The other animals which were eight months of age, were both blind. One of them became ataxic just before it died. The other was destroyed but had shown no inco-ordination. These animals had dense cataracts with vitreous opacities and an atrophic retina. Considering the degree of inbreeding which has already occurred in this race of tiger in captivity, the time has probably come when an extensive post mortem examination, particularly of the nervous system and eyes of all Siberian tigers which die, should be undertaken in order to try to track down the family lines which may be particularly prone to these problems. It may then be possible to find a genetic marker linked to these abnormalities.

Pulmonary and cardiac failure occurred in an adult Ring-tailed lemur as a result of thoracic obstruction caused by a large organized haematoma. No cause for the original haemorrhage could be found.

Aves (Table V)

Nutritional and metabolic disorders

Nutritional osteodystrophy was recorded in two external cases, a Racing pigeon and a European eagle owl, both of which were young adults. The deaths in young Sacred ibis have

TABLE IV
Mammalia (1979)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie								Research Institutes (41)		External sources (31)	
	Acclimatized (209)		Unacclimatized (32)		New-born (88)		Total (329)	% of total deaths				
	Number affected	% affected	Number affected	% affected	Number affected	% affected			Number affected	% affected	Number affected	% affected
Bacterial infections	40+1D	19·6	9	28·1	15+3D	20·5	68	20·7	6+11D	41·5	8+1D	29·0
Viral/Rickettsial infections	1	0·5	—	—	—	—	1	0·3	0+1D	2·4	2	6·5
Fungal infections	1	0·5	—	—	—	—	1	0·3	—	—	3	9·7
Parasitic infections	25+2D	12·9	4	12·5	—	—	31	9·4	3+2D	12·2	8	25·8
(a) Arthropods	15+2D	8·1	4	12·5	—	—	21	6·4	—	—	2+1D	9·7
(b) Helminths	5	2·4	—	—	—	—	5	1·5	2	4·9	5+1D	19·4
(c) Protozoa	5	2·4	—	—	—	—	5	1·5	2+2D	9·8	—	—
Nutritional/metabolic	8	3·8	2	6·3	26+4D	34·1	40	12·2	0+1D	2·4	3	9·7
Debility (including senility)	15	7·2	4	12·5	—	—	19	5·8	5+3D	19·5	—	—
Injuries and accidents	29	13·9	5	15·6	10+5D	17·1	49	14·9	3+5D	19·5	2	6·5
Neoplasia	11	5·3	—	—	—	—	11	3·3	1+1D	4·9	0+2D	6·5
Euthanasia	42+4D	22·0	4+2D	18·8	5+3D	9·1	60	18·2	5+12D	41·5	5+5D	32·3
No diagnosis	84+1D	40·7	11	34·4	29	33·0	125	38·0	3+1D	9·8	3+1D	12·9
Others	27+1D	13·4	3+2D	15·6	4	4·6	37	11·3	4+2D	14·6	12+3D	48·4

*Not necessarily the cause of death in all cases; D, domesticated animal.

been recorded above (Clinical section). *Amyloidosis* was a moderately frequent finding during this period and was diagnosed in a Bar-headed goose, a Mallard and a Chilean flamingo. *Haemosiderosis* probably contributed to the deaths of two white-bellied Go-away birds, a Swainson's toucan and a Crowned hornbill. Fruit eating birds are particularly prone to this problem. Deficiencies of essential amino acids were relatively frequent in Psittacines from external sources where the owners were either feeding inadequate quantities of protein in the diet or where the biological value of the protein being fed was low. Amongst the animals which came to post-mortem as a result of this were four Yellow-fronted Amazon parrots, a Lesser sulphur-crested cockatoo and a Grey parrot. Low vitamin A levels in the liver probably contributed to the death of a Cormorant. Problems were once again experienced in the keeping of some of the very small birds, particularly honeycreepers and hummingbirds. Deaths from debility and secondary infections occurred in two Brown violet-eared humming birds and a Red-legged honeycreeper.

Bacterial infections

Staphylococcal septicaemias caused the deaths of a Fischer's lovebird a Black and a White ibis, a Java sparrow and a Spoonbill. Coliform septicaemias were also a significant cause of death; amongst the victims were a Spotted-flanked and Black-billed barbet, a white-bellied Go-away bird, a Rothschild's grackle, a Bengalese finch, a Laysan teal and a Banded rail. The only death thought to have been caused by a *Salmonella* sp. was that of a Mealy rosella, although a Sharp's starling, a Crested pelican and a Jackson's hornbill were carriers. The Salmonella in all these cases was *S. typhimurium.*

A moderate number of cases involving *Mycobacterium avium* were seen during the year. These involved a Laughing kookaburra, a Ruff, a Reeves's pheasant, a Sharp's starling, a Cockatiel, a Redshank, an Everett's white-eye and a d'Arnaud's barbet. Unusually *Yersinia* was not isolated from a single bird in the collection in 1979 but was seen in two Aerial toucans, a Toco toucan and a Black hornbill from external sources. *Klebsiella aerogenes,* which is often carried by birds in their digestive tracts, but which does not often affect them clinically, was however, almost certainly the cause of death in a young Rhea and a Buff-tailed coronet. *Erysipelothrix rhusiopathiae* was responsible for the death of a European eagle owl, a Pekin robin, a Chinese necklace dove, a Grey-headed gallinule and a White-cheeked touraco. A *Corynebacterium* which proved to be impossible to type, caused the death of a Whit-cheeked touraco, and a septicaemia due to *Actinobacillus lignieresi* was responsible for the death of a Sacred ibis.

Fungal infections

A pulmonary granuloma, containing *Aspergillus fumigatus* was the cause of death in a Green jay and a generalized Aspergillosis also caused by *A. fumigatus* led to the death of a Golden eagle. Both these birds were from external sources. Internally, aspergillosis was responsible for the deaths of a Mountain witch dove, a Sacred ibis, an Eider duck and a Razorbill. *Candida albicans* was the cause of death in Grey parrot, and a Zebra finch, while *C. guilliermendii* was found in the buccal cavity of a Brown violet-eared humming bird. *Candida parapsilosis* was isolated from the liver and lung of a Zebra finch.

Parasitic infections

Arthropods

Dubinia psittacina mites were, as usual, frequently found on the feathers of Budgerigars from external sources. A Canary, also from external sources had three species of mites, *Proctophyloides pinnatus, P. serini* and an *Analges* species. A Lady Amherst's pheasant from the collection was found to have large numbers of *Megninia* sp. feather mites. Subcutaneous mites were found in a Scarlet ibis, these were *Ibisidectes debilis* and *Neottialges endocinae.* Other subcutaneous mites were found in an Aerial toucan from external sources. These were *Toucanectes ramphastas.* Lice were also fairly frequent and they included a *Menacanthus* species from the Aerial toucan, a *Ciconiphilus* species from a Mute swan, *Campanulotes* and *Colombicola* species from a Domestic pigeon, *Ischnocera* species and *Anaticola phoenicopteri* from a Chilean flamingo and an *Ischnocera* species and a *Bruelia* species from an Azure-winged magpie.

Helminths

Capillaria species contributed to a number of deaths including a Fischer's lovebird, a Red-billed hornbill, two Azure-winged magpies and an Australian stilt. *Syngamus trachea* nematodes led to the death of another Red-billed hornbill, but were a secondary finding in a Rhea. A large number of Cyathostoma nematodes in the trachea of a Common shelduck had caused obstruction. *Cyathostoma* was a secondary finding in an Eider duck and a Black swan. All three of these deaths were external cases. Amongst the more unusual findings were a number of cestodes, although it is unlikely that these caused any significant clinical problems. *Fimbriaria fasciculatis* were found in the intestine of a Australian stilt. *Drepanidotaenia lanceolata* in the gizzard and small intestine of a Greater Snow goose, and *Bernenolipidid* cestodes which have not yet been identified, in the small intestine of a North Island Brown kiwi. Microfilaria, probably *Singhnema sonneratta* were found in the lung and heart of a Sonnerat's jungle fowl. Unidentified trematodes were also found on histology in this animal, but not at the gross post mortem. Both these parasites had probably caused a tracheitis and haemorrhagic pneumonia.

Protozoa

Coccidia, usually an *Eimeria* species, are a frequent finding in many of the small birds, but there has been no evidence in recent cases that they have been pathogenic.

Neoplasia

Lymphoid leukosis was diagnosed in a Princess of Wales parakeet and a Black-casqued hornbill was destroyed humanely after an adenoma of the large intestine was discovered. A subcutaneous lipoma was a secondary finding in a Rosy-faced lovebird that died of liver failure.

Accidents and injuries

Once again these were amongst the most significant causes of death. Multiple surface injuries and injuries to the head and neck were the most frequent findings. Wing fractures led

to the death of a Turquoisine parakeet and a tibial fracture together with rupture of the atrium of the heart caused the death of a Rosy flamingo. There were 14 fatal cases involving head and neck injuries, six cases involving damage of the limbs, and nine cases of generalized injuries.

Miscellaneous problems

Cervical, vertebral and leg bone deformities were recorded in five young gallinaceous birds hatched in the Collection. This type of problem occurs every year and is thought to be due to incorrect incubation conditions just prior to hatching. Very often the problem does not become apparent until the birds are several weeks, or even months old.

Obstruction of the intestinal tract is not infrequent. Chronic obstructive proctitis in a Crested pelican led to its death and large quantities of urates impacted in the cloaca caused severe debility in a Maribou stork. Necrotic ulcerative enteritis in an Elliot's pheasant and a Common shelduck caused their deaths. Other conditions which regularly cause mortality every year include egg-peritonitis, arteriosclerosis, endocarditis and liver and renal failure from various causes.

Reptilia (Table VI)

Bacterial infections

Salmonella species and *Aeromonas liquefaciens* were the two most significant primary causes of death in this group during the year. Eleven different species of *Salmonella* were isolated, *S. arizonae* and *S. oranienberg* being the most frequently found. Small snakes, iguanas, and skinks were most frequently affected and in about half of the cases the organisms probably contributed to death. *Aeromonas* was more frequently seen in tortoises and terrapins, but the organism was also associated with necrotic proctitis in an African house snake and multiple subcutaneous abscesses in an Egyptian cobra. Amongst the more unusual cases was a vertebral osteitis associated with a heavy growth of *Pseudomonas* in a Pope's pit viper, widespread necrotic abscesses in the liver and spleen of a Hawksbill turtle caused by an unidentified *Mycobacterium* and severe dermatitis in a Reticulated python which appeared to be associated with a *Nocardia* sp.

Parasitic infections

The level of infestation with helminth parasites in snakes remains relatively high, although with the exception of newly-imported animals, clinical cases caused by parasitism are not common.

Helminths

During the year only five cases were thought to have contributed to death. A heavy infestation of *Kalicephalus* nematodes in the buccal cavity and small intestine of a Corn snake caused extreme debility and *Rhabdias* nematodes in the lung of a Grass snake led to subacute pneumonia. Both these animals had only been in the reptile house for about a month. Of the cases examined from outside sources, *Rhabdias* sp. also caused pneumonia in a Red-sided garter snake, *Augusticaecum halapterum* nematodes caused severe debility in a Spur-thighed tortoise and *Ophiotaenia* cestodes led to debility in a Royal python. Amongst

TABLE VI
Reptilia (1979)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie								Research Institutes (0)		External sources (27)	
	Acclimatized (66)		Unacclimatized (46)		New-born (10)							
	Number affected	% affected	Number affected	% affected	Number affected	% affected	Total (122)	% of total deaths	Number affected	% affected	Number affected	% affected
Bacterial infections	20	30·3	14	30·4	3	30·0	37	30·3	—	—	10	37·0
Viral/Rickettsial infections	—	—	—	—	—	—	—	—	—	—	—	—
Fungal infections	—	—	3	6·5	—	—	3	2·5	—	—	—	—
Parasitic infections	15	22·7	7	15·2	—	—	22	18·0	—	—	11	40·7
(a) Arthropods	—	—	—	—	—	—	—	—	—	—	—	—
(b) Helminths	15	22·7	6	13·0	—	—	21	17·2	—	—	11	40·7
(c) Protozoa	—	—	1	2·2	—	—	1	0·8	—	—	—	—
Nutritional/metabolic	7	10·6	3	6·5	—	—	10	8·2	—	—	6	12·2
Debility (including senility)	10	15·2	12	26·1	—	—	22	18·0	—	—	4	14·8
Injuries and accidents	3	4·5	2	4·3	—	—	5	4·1	—	—	—	—
Neoplasia	1	1·5	—	—	—	—	1	0·8	—	—	—	—
Euthanasia	2	3·0	2	4·3	—	—	4	3·3	—	—	3	11·1
No diagnosis	25	37·9	20	43·5	9	90·0	54	44·3	—	—	5	18·5
Others	17	25·8	8	17·4	—	—	25	20·5	—	—	7	25·9

*Not necessarily the cause of death in all cases; D, domesticated animal.

the secondary findings *Acanthocephala* were only found once in small cysts in the mesentery of a Cottonmouth. *Rhabdias* and *Polydelphus* nematodes were the most frequent findings in Boids, while *Kalicephalus* and *Rhabdias* spp. were the most frequently seen in other snakes. Amongst the more unusual findings were *Mesocoelium menodi* trematodes in two Jackson's chameleons, trematodes of the species *Infidum infidum* in a Boipevussu snake, *Pseudalaeuris yumanae* nematodes in the caecum of a Desert iguana, *Tangua tiara* cestodes in a Bose's savannah monitor, and *Hexametra* nematodes in a Speckled king snake.

Neoplasia

A single case of an ovarian fibrosarcoma was diagnosed in a Cottonmouth.

Fungal infections

Three young Loggerhead turtles from a batch of this species confiscated by H. M. Customs developed varying degrees of dermal necrosis and pulmonary abscesses. *Candida parapsilosis* was isolated from one of these cases and although the organism was not isolated from the others, it is probable that they also died of the same cause.

Nutritional and metabolic disorders

Nutritional bone disease is still frequently seen in external cases and in animals presented to the collection which have come from private sources. Common iguanas are most frequently seen with this condition, but a young Paraguay caiman which had been donated, was also found to be suffering from the problem. Vitamin A deficiency is still a frequent finding in terrapins and turtles presented for examination from outside sources.

Newly imported reptiles often fail to feed readily and starvation is still a relatively frequent cause of death in this category. Tube feeding with a liquidized balanced diet is often attempted, but this is particularly difficult in venomous snakes and in the Testudinae if it is required over a long period. Amongst the external patients, Royal pythons still remain the greatest problem in this respect. The hospital still sees a relatively large number of cases which are brought for treatment by private owners after several months of inappetance.

Accidents and poisoning

There were very few cases in this category during the period. Multiple vertebral fractures led to the death of a Pope's pit viper and hyperthermia caused by the failure of a thermostat controlling the water heater of its tank led to the death of a Phayre's Soft-shelled turtle. A Red-sided garter snake almost certainly died as a result of organosphophate poisoning after an insecticide containing the toxin had been used. This animal was particularly debilitated and had a heavy infestation of skin mites. The use of such substances is often associated with some risk in debilitated reptiles.

Miscellaneous cases

Chronic necrotic enteritis associated in most cases with either protozoal or bacterial infection, mainly with a *Proteus* sp. remains a problem in a wide variety of reptiles. Intestinal necrosis was seen in a Leith's tortoise, a Gila monster and in a Jackson's

TABLE VII
Amphibia (1979)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie								Research Institutes (0)		External sources (0)	
	Acclimatized (10)		Unacclimatized (4)		New-born (0)		Total (14)	% of total deaths				
	Number affected	% affected	Number affected	% affected	Number affected	% affected			Number affected	% affected	Number affected	% affected
Bacterial infections	6	60·0	3	75·0	—	—	9	64·3	—	—	—	—
Viral/Rickettsial infections	—	—	—	—	—	—	—	—	—	—	—	—
Fungal infections	—	—	—	—	—	—	—	—	—	—	—	—
Parasitic infections	2	20·0	2	50·0	—	—	4	28·6	—	—	—	—
(a) Arthropods	—	—	—	—	—	—	—	—	—	—	—	—
(b) Helminths	2	20·0	2	50·0	—	—	4	28·6	—	—	—	—
(c) Protozoa	—	—	—	—	—	—	—	—	—	—	—	—
Nutritional/Metabolic	—	—	—	—	—	—	—	—	—	—	—	—
Debility (including senility)	—	—	1	25·0	—	—	1	7·1	—	—	—	—
Injuries and accidents	2	20·0	—	—	—	—	2	14·3	—	—	—	—
Neoplasia	—	—	—	—	—	—	—	—	—	—	—	—
Euthanasia	2	20·0	—	—	—	—	2	14·3	—	—	—	—
No diagnosis	4	40·0	2	50·0	—	—	6	42·9	—	—	—	—
Others	5	50·0	1	25·0	—	—	6	42·9	—	—	—	—

*Not necessarily the cause of death in all cases; D, domesticated animal.

chameleon where it had actually caused complete obstruction. Necrotic proctitis and multiple cloacal abscesses are also a relatively frequent finding and during this period the most notable cases involved an Eastern copperhead, an Algerian skink and an African house snake. Stomatitis and severe oesophagitis were seen in a Red-eared terrapin and an Indian python, both from external sources. Renal failure is also relatively common. Chronic glomerular nephritis was diagnosed in a Puff-adder, interstitial nephritis with renal abscesses in a Red-eared terrapin and renal gout with extensive deposition of urate crystals on a number of viscera was seen in a Mediterranean Spur-thighed tortoise, a Boa constrictor and a Boipevussu snake. Mineralization of the myocardium was seen in a Red-eared terrapin and a degenerative cardiomyopathy of unknown aetiology diagnosed in a Common iguana.

Amphibia (Table VII)

Bacterial infections

Because of the temperature and humidity at which many of the amphibia are kept, carcasses are often presented in varying degrees of decomposition. *Aeromonas liquefaciens* is almost always isolated in these cases and may not always be significant. Nevertheless in the few cases where the carcasses are fresh, *Aeromonas* still seems to be the main bacterium causing death. An African and an American bullfrog died of the disease during the period, as also did two Axolotls and a Greater siren. A less usual finding was of an unidentified *Corynebacterium* sp. from the liver of a Surinam toad. The same animal also contained very large numbers of encysted unidentified nematodes.

Parasitic infections

Rhabdias nematodes were found in the lungs of an African bullfrog and *Ophiotaenia* cestodes in the intestines of a Common rain frog.

PATHOLOGY—1980

During the period from 1 January to 31 December 1980 inclusive, a total of 660 post-mortem examinations were carried out. This figure includes fish which are not included in Table VIII. Thirty-four domestic animals were examined. The non-domesticated animals were divided into 318 Mammalia, 167 Aves, 109 Reptilia, 13 Amphibia and 19 Pisces. The total number of carcasses examined at Regent's Park but excluding those of domesticated species numbered 607. This was a comparable figure with recent years.

Mammalia (Table IX)

Nutritional/metabolic disorders

A small number of neonatal animals, notably ruminants from the Mappin Terraces, died after being abandoned by their mothers. Two Polar bear cubs, twins, born during the year also died of maternal neglect. A Scimitar-horned oryx calf developed coliform septicaemia, but the primary problem was almost certainly essential fatty acid and vitamin E deficiency. Generalized haemosiderosis was an unusual finding in a Red panda; a Tree shrew died of diabetes mellitus and a young Sable antelope developed a severe ruminal disturbance which involved a degree of mucosal congestion and mild ulceration. This was thought to have been

TABLE VIII

	Menagerie (1979)									Research Institute		External sources		
	Non-domesticated				Domesticated				Total menagerie					Grand total
	Acclim.	Unacclim.	New-born	Total	Acclim.	Unacclim.	New-born	Total		Non-dom.	Dom.	Non-dom.	Dom.	
Mammalia	193	35	54	282	3	1	3	7	289	22	3	14	13	341
Aves	97	33	8	138	4	0	0	4	142	0	0	29	7	178
Reptilia	45	31	14	90	0	0	0	0	90	0	0	19	0	109
Amphabia	10	3	0	13	0	0	0	0	13	0	0	0	0	13
Totals	345	102	76	523	7	1	3	11	534	22	3	62	20	641

TABLE IX
Mammalia (1980)

	Menagerie								Research Institutes (25)		External sources (27)	
	Acclimatized (196)		Unacclimatized (36)		New-born (57)							
*Major groups of diseases etc. encountered at post-mortem examination	Number affected	% affected	Number affected	% affected	Number affected	% affected	Total (289)	% of total deaths	Number affected	% affected	Number affected	% affected
Bacterial infections	44	22·4	6	16·6	9+1D	17·5	60	20·7	9+3D	48	2+3D	18·5
Viral/Rickettsial infections	—	—	—	—	—	—	—	—	—	—	1	3·7
Fungal infections	1	0·5	—	—	—	—	1	9·3	—	—	—	—
Parasitic infections	18	9·1	—	—	5	8·7	23	7·9	—	—	1+3D	14·8
(a) Arthropods	13	6·6	—	—	5	8·7	18	6·2	—	—	0+2D	7·4
(b) Helminths	2	1·0	—	—	—	—	2	0·6	—	—	1	3·7
(c) Protozoa	3	1·5	—	—	—	—	3	1·0	—	—	0+1D	3·7
Nutritional/metabolic	5	2·5	7	19·4	12+1D	22·8	25	8·6	1	4	1+1D	7·4
Debility (including senility)	18	9·1	4	11·1	—	—	22	7·6	1	4	1+1D	7·4
Injuries and accidents	42	21·4	8	22·2	13	22·8	63	21·7	4	16	3+1D	14·8
Neoplasia	12	6·1	—	—	—	—	12	4·1	—	—	3	11·1
Euthanasia	30+3D	16·8	5	13·8	3	5·2	41	14·1	5	20	2+10D	44·4
No diagnosis	89+1D	45·9	11+1D	33·3	17+2D	33·3	121	41·8	4	16	1+1D	7·4
Others	38+2D	20·4	11	30·5	6	10·5	57	19·7	6	24	3+8D	40·7

**Not necessarily the cause of death in all cases; D, domesticated animal.*

caused by the use of low-level benzimidazole anthelmintics. Another Sable antelope housed with it showed no similar signs although it had been given the same treatment. The only case of nutritional osteodystrophy in a mammal during the year was seen in a Capuchin monkey from another zoo.

Bacterial infections

Once again both *Klebsiella aerogenes* and *K. pneumoniae* were isolated fairly frequently from rodents and primates. The groups of Dwarf and Common hamster were most severely affected amongst the rodents, while a Thick-tailed bushbaby, a newborn Cotton-headed tamarin and an adult Common tree shrew died of Klebsiella septicaemia. Amongst the more unusual hosts which succumbed to *K. pneumoniae* were a young Greater kudu and an adult Brazilian tree porcupine. Staphylococcal pneumonia and septicaemias were more frequent than usual. Eight rodents, including two Steppe lemmings died of septicaemia, as also did a newborn Markhor. Streptococcal septicaemia contributed to the death of a young Orang-utan which sustained severe injuries from its mother, and streptococci also contributed to the death of a Lion cub, a Prairie marmot, a Scimitar-horned oryx and a Fat dormouse. A number of deaths in the colony of Spiny mice appeared to have been caused by a septicaemia due to a *Flavobacterium* sp. The species was not identified, but was recovered in pure culture from the liver and lungs of most of these cases. *Bacteroides uniformis* caused severe liver necrosis in a Reindeer and a *Pseudomonas* sp. was isolated from the liver and lungs of three Common marmosets from the laboratories, all of which had severe pneumonia. Tracheitis caused by *Bordetella bronchiseptica* was the cause of death in three Rabbits from the Nuffield Laboratories.

Fungal infections

The only infection of note in this category was the histological finding of large numbers of yeasts associated with a severe bronchopneumonia in a Slow loris. The yeasts which were probably a *Candida* sp. were not found on gross examination and therefore no atempt was made to culture them.

Parasitic infections

Arthropods

Ornithonyssus bacoti continued to be a severe problem in the rodent colonies of the Clore pavilion. The colonies of hamsters were most severely affected although cases were also seen amongst the Striped grass mice, Grasshopper mice, Multimammate mice and Steppe lemmings. In three animals the resulting dermatitis was severe enough to have been a major contributory factor to their deaths. The colonies are virtually isolated from the rest of the house and no problems have been experienced with this mite elsewhere in the Collection. The problem can usually be minimized by temporarily rehousing the stock and thoroughly cleansing the exhibits. It is also necessary to use sterilized bedding and to ensure that the numbers in each group do not build up excessively.

Helminths

Helminth infestations are very rarely a problem in mammals at Regent's Park and the only

findings of note were of a *Syphacia* sp. in the large intestine of a Siberian chipmunk and of *Grammocephalus clathratus*, the bile duct worm of the African elephant. This latter finding was particularly interesting because the elephant concerned had been here for over 15 years and must have brought the infestation with her when she came as a calf.

Protozoa

The only protozoal finding of interest was that of Sarcocystis in the heart muscle of a Mouflon. The infestation would have been clinically insignificant, but it is interesting to note that this animal was born to stock which has been in the zoo for at least three decades.

Neoplasia

A relatively large number of neoplastic lesions were identified during the period, but this may well be due to the fact that histology is being carried out more frequently on any lesions suspected of being neoplastic. Most of the neoplasms tend to be either in small primates, of rodents, and amongst them was a squamous cell papilloma of the anal region in one Dwarf hamster, multiple subcutaneous fibromas in three others, hepatocellular carcinomas in two Siberian chipmunks, an adrenal cortical carcinoma in a Common hamster and a thyroid adenoma in a Thick-tailed bushbaby. In the larger mammals, a cholangiocarcinoma was found in a Blotched genet and a hepatocellular carcinoma in a Bornean small-toothed palm civet. Both of these animals were old. A thyroid medullary carcinoma was found in a Mouflon. Amongst the cases received from outside the Collection of lymphocarcinoma was found in the abdomen of a Black mangabey and an osteosarcoma associated with large numbers of herpes viruses was found in the tibia of a Squirrel monkey. Multiple myelolipomas were found in the spleen and liver of a Cheetah which died of catarrhal pneumonia.

Accidents and injuries

As usual, injuries accounted for a relatively large number of deaths, principally involving small rodents, primates and ungulates. Many of the injuries tend to be generalized and often inflicted by companions. Long bone fractures were relatively infrequent as also were dystokias, both causing only one death in the period.

Miscellaneous cases

There is always a relatively large number of mammals where no diagnosis can be made often because the carcase is too decomposed for useful examination. This is particularly true of small mammals, especially rodents coming from the Clore pavilion. The more secretive animals, and especially those kept in relatively large numbers, might only be inspected at 24-h intervals and where they are kept in heated housing the carcasses begin to decompose rapidly. Amongst the more noteworthy cases were lesions of the cardio-vascular system. An old Malayan giant squirrel died of generalized arteriosclerosis and a Ruffed lemur succumbed to massive thrombosis of the right ventricle. The African elephant "Toto", became inappetant, she deteriorated and died after a brief period of lameness. A large

pulmonary haematoma was found in the right side of the thorax pressing against the diaphragm. As this animal had a tendency to place its forefeet on the horizontal rails of its outside enclosure, it was thought that she had probably slipped off, causing minor damage to the joints of the forelimb and producing the pulmonary haemorrhage. On post-mortem examination there was massive lymphatic and vascular congestion of the abdominal viscera and it was likely that the haematoma was applying pressure to the posterior vena cava.

Aves (Table X)

Bacterial infections

Coliforms were the most prominent and significant bacteria of the period in birds, causing fatal septicaemias in nine cases including a Crested wood partridge with chronic peritonitis, a Shiny cowbird with a perforated intestinal ulcer, a debilitated Brown violet-eared humming-bird and a wild Magpie which also had a large femoral abscess from which *Escherichia coli* was isolated. A septicaemia caused by *Salmonella dublin* led to the death of a Brush bronze-winged pigeon and *S. typhimurium* was isolated from the yolk sac of a newly hatched Ruff. A *Klebsiella* sp. was isolated from a cervical abscess in a Sarcred ibis and from the lungs of a Black swan. The species was not identified but the bacterium was probably the cause of death in both cases.

Pneumonias caused by staphylococci were found in a Golden song sparrow and a Bicheno's finch. A European eagle owl succumbed to septicaemia caused by a *Pseudomonas* sp. and unidentified corynebacteria were isolated from the main viscera of a Grey-headed gallinule and a Common peafowl.

Yersinia were only found on two occasions, in the liver and spleen of a Speckled pigeon and in the large intestine of a Grey starling. The starling was probably only carrying the organism. *Mycobacterium avium* was the cause of death in an Oystercatcher, a Rockhopper penguin, a White pelican and a Chinese painted quail. Large numbers of acid-fast organisms were found in the liver of a privately kept budgerigar but unfortunately the organism was not grown in culture. If this was a mycobacterium it would be an unusual finding in a psittacine.

Viral and Rickettsial infections

Duck virus enteritis caused the deaths of three Common shelducks, a Cuban tree duck and a Gadwall from the Collection. Fortunately the outbreak was limited to one exhibit. A Muscovy duck from another collection was also found to have the infection. An unidentified pox virus was isolated from a number of small granulomatous lesions on the skin of a Purple honeycreeper and examination of the liver and spleen of this animal by electronmicroscopy revealed the presence of large numbers of a Chlamydia, although the significance of this finding is unknown.

Fungal infections

Aspergillus fumigatus was responsible for, or contributory to, the deaths of eight birds. These were mainly waterfowl, but also included a Red-crowned parrakeet, a Green cardinal and a Sacred ibis.

TABLE X
Aves (1980)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie								Research Institutes (0)		External sources (36)	
	Acclimatized (101)		Unacclimatized (33)		New-born (8)		Total (142)	% of total deaths				
	Number affected	% affected	Number affected	% affected	Number affected	% affected			Number affected	% affected	Number affected	% affected
Bacterial infections	19	18·8	8	24·2	6	75·00	33	23·2	—	—	6+4D	27·7
Viral/Rickettsial infections	7	6·9	—	—	—	—	7	4·9	—	—	1	2·7
Fungal infections	4	3·9	2	6·0	—	—	6	4·2	—	—	1+1D	5·5
Parasitic infections	24	23·7	3	9·0	—	—	27	19·0	—	—	8	22·2
(a) Arthropods	7	6·9	—	—	—	—	7	4·9	—	—	3	8·3
(b) Helminths	17	16·8	2	6·0	—	—	19	13·3	—	—	5	13·8
(c) Protozoa	—	—	1	3·0	—	—	1	0·7	—	—	—	—
Nutritional/metabolic	1	0·9	2	6·0	—	—	3	7·1	—	—	—	—
Debility (including senility)	37+1D	37·6	7	21·2	—	—	45	31·6	—	—	8+1D	25·0
Neoplasia	8+1D	8·9	—	—	—	—	9	6·3	—	—	2	5·5
Euthanasia	3	2·9	1	3·0	—	—	4	2·8	—	—	4+1D	13·8
No diagnosis	12	11·8	6	18·1	3	37·5	2	14·7	—	—	8+2D	27·7
Others	15+2D	16·8	8	24·2	1	12·5	26	18·3	—	—	6	16·6

*Not necessarily the cause of death in all cases; D. domesticated animal.

Parasitic infections

Arthropods

A relatively small number of infestations with lice and mites were found. The only cases of pathological significance involved large numbers of *Cytodites nudus* mites in the lungs of two Sonnerat's jungle fowl. *Ornithonyssus sylvianus* mites were found in the plumage of a Nepal hill mynah, and *Megninia* sp. mites were found in association with *Goniodes sp.* lice in a Brown Eared pheasant. A Common peafowl was harbouring *Lipeurus pavo* lice in relatively large numbers. This is a common finding on this species. The most unusual finding was of *Lunaceps* sp. lice on an Oystercatcher which is not normally considered to be its true host. *Orchopeas howardi* fleas were found on a wild Herring gull chick hatched on buildings in Regent's Park.

Helminths

Hymenolepidid cestodes were present in the small intestine of a Red and Yellow barbet and three Wattled starlings contained tapeworms of the genus *Dilepis.*

Amongst the nematodes, *Syngamus trachea* once again caused the occasional problems, with deaths in four Wattled starlings, a Malayan glossy starling, a Green cardinal and a Brent goose. *Heterakis gallinarum* and *Porrocaecum ensicaudatum* were also present in the intestines of one of the Wattled starling. *Heterakis longispiculum* was present in the caecal sacs of a Crested wood partidge. *Cyathostoma* sp. were present in the bronchi of a Mandarin duck. Two trematodes of interest were found during the period. *Cyclocoelum mutabile* in the respiratory tract of a Moorhen, and *Platynosomum illiciens* in the bile duct of a Red-billed toucan.

Protozoa

Although coccydia are a relatively frequent finding in passerine birds, it is very rare for them to be of pathological significance. One bird, a Bicheno's finch, newly arrived to the Collection, succumbed to a very heavy infestation of *Eimeria* sp.

Neoplasia

A relatively larger number of cases than usual were noted. Lympholeukosis was confirmed in an Aylesbury duck, a Green and Gold tanager and a White-throated jay thrush. Hepatocellular carcinomas were seen in a Red-crested pochard and a Nepal hill mynah. An ovarian adenocarcinoma was seen in a Greater flamingo, a bile duct carcinoma in a Lesser flamingo and bilateral thyroid carcinomas were seen in a Pochard and a Lesser sulphur-crested cockatoo. A facial fibrosarcoma was seen in a senile Cockatiel, and a mesothelioma in an Ferruginous hawk sent from a private collection.

Accidents and injuries

As in previous periods, injuries to the head, neck and limbs constitute a significant cause of death amongst birds in the Collection. Such injuries are usually caused either by companions or by collisions with the sides of the enclosure. Probably the most unusual case in this section was the finding of numbers of broom bristles which had penetrated the gizzard wall of a

Gentoo penguin causing peritonitis. This species seems to be particularly susceptible to picking up, and suffering from the adverse effects of foreign bodies.

Miscellaneous problems

A Great condor chick was hatched, but efforts to hand-rear it failed and it was found to have ulcerative gastro-enteritis. It had been decided to use the tinned carnivore diet ZF6 and it is possible that the high carbohydrate content of this diet was indigestible to the young bird, and that this had predisposed it to the lesions. On another occasion, minced whole carcasses, probably of mice, would be used, together with suitable vitamin and mineral supplements.

Arteriosclerosis was not as frequently found as usual. Cases of pathological significance were only seen in a Tarictic hornbill and a Pinkfooted goose, both old animals. Rupture of the atria of the heart caused the death of a Diamond dove and a massive pulmonary venous thrombosis led to the death of a Grey parrot which was privately owned.

Reptilia (Table XI)

Bacterial infections

Proteus species appeared as a primary cause of death more frequntly than usual, particularly in the unacclimatized animals. A necrotic stomatitis from which an almost pure growth of a *Proteus* sp. was isolated was responsible for the death of a Blue-tongued skink. A large liver abscess associated with the same organisms caused the death of a Burton's carpet viper and multiple abscesses led to a septicaemia in a Casqued-headed lizard. Septicaemia also followed large numbers of facial abscesses in a North-western Garter snake. A severe oviductitis from which a pure growth of *Proteus* was isolated, was responsible for the death of a Cochin China water dragon. Mixed infections of *Proteus* and *Pseudomonas* were also prominent. Both were associated with mandibular osteitis in a Flap-necked chameleon and with pneumonia and nephritis in a young Jacaré cayman. *Salmonella,* in this case *S. arizonae* was only responsible for the death of one reptile, a Leopard ground gecko, although a number of other reptiles were intestinal carriers of *Salmonella* species. Aeromonas was only significant on one occasion in a Pancake tortoise. Amongst the more unusual findings were an organism with growth characteristics of a *Shigella* founds in the liver of a Red-eared terrapin and an unidentified *Mycobacterium* sp. from the lungs of a Hawksbill turtle.

Parasitic infections

Helminths

Nematodes were considered to have been a major contributory factor to death on only two occasions. Large numbers of a *Rhabdias* sp. were found in the lung of a Dice snake and a heavy burden of a *Kalicephalus* sp. was found in the upper digestive tract of a Corn snake. Both these genera notably *Rhabdias* were found on a number of other occasions but not in significantly large numbers to have caused a pathological problem. *Hexametra* sp. nematodes were found in the oesophagus and small intestine of a Burton's carpet viper, a Ravergier's racer snake and in the small intestine and mesentery of a Palestine viper. *Abbreviata* sp. were present in the upper digestive tract of an Agama lizard. In the same animal, numbers of *Strongyluris elegans* larvae were found in the buccal cavity.

TABLE XI
Reptilia (1980)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie											
	Acclimatized (45)		Unacclimatized (31)		New-born (14)				Research Institutes (0)		External sources (19)	
	Number affected	% affected	Number affected	% affected	Number affected	% affected	Total (90)	% of total deaths	Number affected	% affected	Number affected	% affected
Bacterial infections	12	26·6	7	22·5	—	—	19	21·1	—	—	4	21·0
Viral/Rickettsial infections	—	—	—	—	—	—	—	—	—	—	—	—
Fungal infections	—	—	—	—	—	—	—	—	—	—	—	—
Parasitic infections	18	40·0	10	32·2	—	—	28	31·1	—	—	12	63·1
(a) Arthropods	—	—	—	—	—	—	—	—	—	—	—	—
(b) Helminths	14	31·1	6	19·3	—	—	20	22·2	—	—	9	47·3
(c) Protozoa	4	8·8	4	12·9	—	—	8	8·8	—	—	3	15·7
Nutritional/metabolic	5	11·1	1	3·2	—	—	6	6·6	—	—	2	10·5
Debility (including senility)	9	20·0	9	29·0	—	—	18	20·0	—	—	2	10·5
Injuries and accidents	1	2·2	3	9·6	—	—	4	4·4	—	—	5	26·3
Neoplasia	1	2·2	—	—	—	—	1	1·1	—	—	—	—
Euthanasia	4	8·8	1	3·2	—	—	5	5·5	—	—	1	5·2
No diagnosis	19	42·2	19	61·2	1	7·1	39	43·3	—	—	5	26·3
Others	12	26·1	7	22·5	13	92·8	32	35·5	—	—	5	26·3

*Not necessarily the cause of death in all cases; D, domesticated animals.

Nematodes of the genus *Thelandros* were present in moderate numbers in the large intestine of a Flap-necked chameleon, a Leopard ground gecko and a Chuckwalla lizard. Cosmocercoid nematodes were seen in the large intestine of a Greater plated lizard. *Oochoristica* sp. cestodes were seen in the small intestine of a Casqued-headed lizard and *Oochoristica tuberculata* were found in a Lesser cerastes viper. Tapeworms of the genus *Ophiotaenia* were present in the small intestine of a Curly-tailed lizard. In all these cases the cestodes were not causing significant problems.

Protozoa

Large numbers of flagellates are a frequent finding in the small and large intestines of a wide variety of reptiles but they are rarely thought to cause clinical problems. *Trichomonas* sp. were identified in three Boa constrictors, a Common iguana, a Western diamond backed rattlesnake and an African spur-thighed tortoise.

Other diseases

Injuries of the spinal column were, as usual, a frequent finding in animals presented for examination from external sources, particularly from private owners. These injuries are most often caused by careless handling, by being crushed under foot, or by having some heavy object drop on them. Two Boa constrictors and a North-western Garter snake died following injuries to cervical veterbrae. Hypothermia and hyperthermia are also common causes of death in external cases usually following failure of the thermostatic control of the temperature of their enclosures. Two privately owned Florida king snakes died of hyperthermia after their vivarium had been placed on top of a central heating radiator.

Deformities of the vertebral column are still fairly frequent findings in newly hatched snakes and these are thought to be caused by incorrect conditions of incubation. During this period, 13 young Boa constrictors and two Montpellier snakes came into this category.

Necrotic enteritis and chronic ulceration of the intestinal mucosa continue to be a major problem in some groups of reptiles. Athough these lesions are sometimes clearly associated with protozoa or bacteria it is frequently not possible to define the exact cause. On occasions the degree of necrosis is so severe that it causes complete obstruction of the intestinal tract. Two Aldabra Giant tortoises, a Mediterranean spur-thighed tortoise, two Boa constrictors and a Royal python were all affected in this way.

Amphibia (Table XII)

Bacterial infections

Aeromoniasis was as usual the most common cause of death in this category. Two more unusual findings were large numbers of acid-fast bacilli which failed to grow on culture in the lungs of a Giant toad and a mixed infection of a *Klebsiella* and a *Citrobacter* sp. which appeared to be associated with a severe generalized necrotic dermatitis in another Giant toad. *Rhabdias* sp. nematodes were the most frequent parasitic finding and were almost certainly the cause of death, producing severe pneumonia in an American toad and two Giant toads. A heavy infestation of *Batrachostrongylus longispicularis* in the small intestine of a Malayan horned frog contributed to its death.

TABLE XII
Amphibia (1980)

*Major groups of diseases etc. encountered at post-mortem examination	Menagerie								Research Institutes (0)		External sources (0)	
	Acclimatized (10)		Unacclimatized (3)		New-born (0)							
	Number affected	% affected	Number affected	% affected	Number affected	% affected	Total (13)	% of total deaths	Number affected	% affected	Number affected	% affected
Bacterial infections	4	40	1	33·3	—	—	5	38·4	—	—	—	—
Viral/Rickettsial infections	—	—	—	—	—	—	—	—	—	—	—	—
Fungal infections	—	—	—	—	—	—	—	—	—	—	—	—
Parasitic infections	11	11	—	—	—	—	11	84·5	—	—	—	—
(a) Arthropods	1	1	—	—	—	—	1	7·6	—	—	—	—
(b) Helminths	9	9	—	—	—	—	9	69·2	—	—	—	—
(c) Protozoa	1	1	—	—	—	—	1	7·6	—	—	—	—
Nutritional/metabolic	—	—	—	—	—	—	—	—	—	—	—	—
Debility (including senility)	2	2	1	33·3	—	—	3	23·0	—	—	—	—
Injuries and accidents	1	1	—	—	—	—	1	7·6	—	—	—	—
Neoplasia	—	—	—	—	—	—	—	—	—	—	—	—
Euthanasia	—	—	—	—	—	—	—	—	—	—	—	—
No diagnosis	3	3	1	33·3	—	—	4	30·7	—	—	—	—
Others	2	2	—	—	—	—	2	15·3	—	—	—	—

*Not necessarily the cause of death in all cases; D. domesticated animals.

Whipsnade Park

(D. G. Ashton)

The highly variable winter weather of 1978/79 resulted in twice the normal annual number of post-mortem examinations and this, coupled with the increasing volume of material submitted for detailed examination and for research which was mentioned in the last report, considerably stretched the Whipsnade veterinary resources. The examination of faeces samples for mycobacteria from ruminants with chronic diarrhoea by the Institute for Research on Animals Diseases at Compton continued. Four positive isolations were mentioned in the last report and to date 30 more animals have been examined but no further isolations have been recorded.

CLINICAL WORK

Malignant catarrhal fever

After the outbreak of malignant catarrhal fever (MCF) in the herd of Sitatunga, a serological survey was carried out on 19 species of ruminants at Whipsnade in co-operation with Dr Neil Edington of the Royal Veterinary College using an indirect immunofluorescent test developed for use in cattle. Titres of less than 1 : 128 were disregarded to avoid false positive results due to a possible cross reaction with orphan herpes virus. Individuals of 11 species were significant titres to the MCF Wildebeeste associated herpes virus are shown in Table XIII.

TABLE XIII

Serological survey for antibodies to MCF herpes virus: species where titres exceeded 1 :128

Species	No. +ve/No. tested	Range
American bison	3/8	1 : 128
European bison	3/15	1 : 128—1 : 256
Cape buffalo	1/5	1 : 128*
Brindled wildebeeste	2/12	1 : 128 and 1 : 512
Musk ox	1/3	1 : 128
Nilgai	1/11	1 : 256
Scimitar-horned oryx	5/10	1 : 128—1 : 2048
Sitatunga	4/5	1 : 128—1 : 2048
Père David deer	1/3	1 : 1024
Red deer	1/1	1 : 1024
Formosan sika deer	1/2	1 : 256

*Serum collected from two animals shot in the wild had titres of 1 : 256 and 1 : 1024

All the Sitatunga, the Père David deer and the Red deer with significant titres were clinically affected. Clinical signs suggestive of the diseases were also seen in European bison, Cape buffalo, Scimitar horned oryx, Nilgai and Wildebeest. Individuals amongst these and the other three species sampled had positive titres but remained clinically normal. Where clinical signs were seen they were preceded by a stressing factor such as inclement weather,

social aggression or overcrowding within the group. Work is continuing on the incidence and effects of this virus in the Collection.

Toxoplasmosis in wallabies

Sera from 43 Red-necked wallabies were examined for toxoplasma antibodies. Twenty-nine animals had titres in excess of 1 in 4000 and 18 of these had titres of 1 in 16,000. There was an equal number of males and females in the sample but 19 of the animals with significant titres were females. There were 13 clinically normal animals in the group sampled but the others were suffering from a variety of conditions, mainly necrobacillosis. Two of the animals were affected by signs suggestive of toxoplasmosis. Eight of the normal animals had significant antibody titres. Thirteen faecal samples from these animals were examined for the presence of toxoplasma oocysts, but none were found. The parasite is evidently present in large numbers of the wallaby population, but the incidence of clinical cases in this species is low. Clinical cases have not been recorded in other mammals in the Collection.

Wallaby nematodes

Twelve Red-necked wallabies were examined in detail for the presence of gastro-intestinal parasites in order to learn more about the animal's worm burdens and their relationship to possible disease. The group was composed of three females and nine males. Body weights ranged from 4·5 to 25·0 kg. Three animals were juvenile, two were sub-adult and seven were adult. Eight animals were clinically normal at the time of euthanasia, two had injuries but were otherwise normal, one was found to have avian tuberculosis and one was destroyed with ataxia, possibly due to a toxoplasma infection. Table XIV summarizes the findings. The average total worm count in the stomach was 3200. No parasites were found in one animal and another had only a few *Filarinema asymetricus*. *Zonialaimus cobbi* was the most frequent finding and usually occurred together with *Rugopharynx zeta* in mixed infections in the sacculated stomach.

TABLE XIV
Parasites, sites and counts in 12 Red-necked wallabies

Nematode	Site	No. of Animals	Worm count	Comments
Zonialaimus cobbi	Sacculated stomach	8	500—16,000	Usually found together. Numbers of *R. zeta* tend to be much higher in mixed infections. Total worm burden in mixed infections 800—8000.
Rugopharynx zeta	Sacculated stomach	8	50—500	
Popovastrongylus sp.	Sacculated stomach	2	Very few	
Asymetricostrongylus (Filarinema) asymetricus	Pyloric stomach	1	A few	Closely associated with the mucosa.
Globocephalus trifidospicularis	Small intestine	1	200	

Although there was no marked relationship between total worm count and age, younger animals tended to have higher worm densities (i.e. more worms per unit volume of stomach contents) than the older ones. Both animals with clinical disease had higher than average total worm counts (5000 and 16,000) but one young adult in good condition had a count of 6000. There was no histological evidence of an inflammatory reaction of the stomach wall, although large numbers of eosinophils were present in the blood of two of the animals. As would be expected with nematodes of this type, there was no correlation between the worm count and the plasma pepsinogen levels, which were measured in six of the animals. These ranged fromn 150 to 190 mU/Tyrosine/litre. Two distinct egg sizes were seen in the faecal samples; a large Strongyle type (117–128mm × 58–70 mm) and a small Strongyle type (29–35 mm × 23 mm). Egg counts ranged from 0 to 1100 per gram of faeces for the large eggs and up to 4320 per gram for the small ones. The size of the large eggs corresponds fairly well with the egg sizes reported for *Zonialaimus* and *Rugopharynx*. *Popovastrongylus* eggs are 70–80 mm × 50–60 mm, but none were seen. The identity of the small eggs is unknown. One possibility is that they are *Rhabditida* sp. eggs which are ingested and pass through unchanged.

Anthelmintics

Trials with the anthelmintic fenbendazole (Panacur-Hoechst) in ruminants suggest that an oral dose rate of 1 mg/kg/day for five days for species with an average adult weight over 300 kg and 1·6 mg/kg/day for five days in smaller species was more effective than a single dose at the usual ruminant dose rate of 5–7 mg/kg. It is probable that an extended course of treatment reduces the likelihood that some individuals which do not feed on a particular day will not eat the drug and ensures a longer contact time between the drug and the parasite. In large carnivores a dose rate of 10 mg/kg for five days (using "4% pig wormer" or "22% granules") has proved very effective against ascarids in adult animals, and appears to have been effective against hookworm (*Uncinaria* sp.) in the Canadian timber wolves. Mebendazole given as "Mebenvet game bird wormer" (Crown Chemicals) has been used in gallinaceous species and waterfowl at the manufacturer's recommended inclusion rate of 1 : 6667 in the feed for 14 days with no ill effects. An Alexandrine parakeet given the same dose rate died soon after the drug had been given and similar deaths in parrots have been reported in another Collection, although in that case the correct dose rate had been exceeded. The therapeutic index of mebendazole in psittacines is probably low. In a trial of the drug conducted on Budgerigars at Regent's Park, two of ten Budgerigars became lethargic and inappetant after twice the recommended rate was used. When three times the usual dose rate was given to the same birds, one died and five more showed toxic signs. Levamisole ("Nemicide" ICI) is now used routinely in the drinking water for the anthelmintic treatment of birds at the manufacturer's recommended dose rate. This replaces Tetramisole ("Game bird wormer" ICI) which has now been withdrawn from the market.

SELECTED CLINICAL CASES

Equine influenza

In May 1979 the entire herd of Przewalski horses was affected by an outbreak of equine influenza virus type 2. The four young foals in the group became seriously ill and in spite of daily injections of a broad spectrum antibiotic, one died of pneumonia. The others

recovered. The source of the virus was never found. The herd is situated in the middle of the Park and is isolated from contact with other equines except Onagers. These animals and the other equines, including the domestic ponies in the Park, remained unaffected. There have been no new introductions into the Przewalski horse herd since 1974. Steps have now been taken to vaccinate this group and the two groups of Zebra with a killed combined equine influenza and tetanus vaccine ("Duvayn IET" Duphar).

Incidence of coronaviruses in the Park

A large number of cases of severe diarrhoea associated with the passage of quantities of fresh blood affected eight ungulate species over a four week period. The species affected were Swamp and Axis deer, Musk ox, Sitatunga, Bactrian camel, Guanaco, Llama and Vietnamese pot-bellied pigs. Only a small number of animals were affected in each group. In most cases the animals did not appear to be very ill and the mortality rate was low despite the alarming quantities of blood passed. An Axis deer, a Sitatunga and Guanaco died. Faecal samples from affected animals were found to contain coronaviruses in all cases. No significant bacteria were isolated. A large number of faecal samples from other animals with diarrhoea over the last two years have not contained coronaviruses. The spread of infection was difficult to follow because cases appeared in different areas of the Park. Initial attempts at symptomatic treatment were discontinued when it became clear that most animals recovered quickly without therapy. It is interesting to note that reports from the Ministry of Agriculture's Veterinary Investigation Centres for this period spoke of numerous findings of coronaviruses in farm animals. Three months later an outbreak of diarrhoea occurred in the Chimpanzee group, also apparently associated with the presence of coronaviruses. Parasitological and bacterial findings were not significant and no blood was seen. Again the illness was a mild one and no treatment was required.

Cheetahs and a live feline enteritis vaccine.

Seven of 14 Cheetah cubs born during the last 18 months have died. This compares with a one in seven mortality over the previous 11 years. Two of the deaths that occurred during the 18-month period followed vaccination with a live attenuated feline infectious panleucopenia vaccine ("Kavac" Duphar). A third cub became ill after vaccination but recovered. One of the cubs which died was smaller than the rest of the litter and was eaten by the mother two days after vaccination. The other was in poor condition at the time of vaccination and at post-mortem *Salmonella typhimurium* was isolated from the alimentary tract. The third cub exhibited enteritis and diarrhoea from which a *Campylobacter* sp. was isolated. This animal had not responded to amoxycillin or tetracycline therapy, but parenteral erythromycin led to its recovery in 48 h.

A total of 28 Cheetah cubs have now been vaccinated with the live virus vaccine, with animals reported ill on five occasions within nine days of being given the vaccine (including the three cases mentioned above) In no case was there any evidence of infection with panleucopenia virus. It is likely that the vaccination procedure or the vaccine itself may produce stress which then precipitates a subclinical infection if the animals are in suboptimal condition. All the cubs born during the 18-month period had the same sire and he was closely related to the three mothers involved. It is possible that in-breeding has resulted in an increased susceptibility of the cubs to disease.

Myopathy in hand-reared wallabies

A nutritional myopathy caused by deficiency of vitamin E and possibly selenium is well known in hand-reared macropods. It has been reported previously from Whipsnade and was seen again this year in two Red-necked wallabies. One animal survived and had very high plasma levels of creatine kinase, 176,000 iu/l (normal values less than 1000 iu). A considerable improvement occurred after it was given parenteral Vitamin E and selenium (Dystosel–Intervet). The diet used for rearing these animals is based on cow' milk and probably contains inadequate levels of these and other nutrients for the needs of this species.

Hand-rearing Humboldt's penguins

Investigation of the high mortality rates in hand-reared Humboldt's penguin chicks under three weeks of age has shown that dehydration was frequently the main cause of death. Analysis of three hand-reared chicks revealed a carcass water content of 76·9–78·7%, compared to a naturally reared bird which has a moisture content of 82·1%. Analysis of the fish being fed (mainly sprats) gave a moisture content ranging from 43·3 to 57·9% with an average of 52·9% and it appeared that significant water losses occurred during freezing and storage. Providing additional water either separately or with the fish improved the situation but did not eliminate the problem. The possibility of a concomitant electrolyte deficiency, particularly in view of the low sodium chloride content of marine fish, was considered and normal saline was added to the penguin diet instead of water, at a rate of 40 ml to every 100 g of liquidized fish. It was decided to use a mixture of herring and sprats because the herring had a higher moisture and sodium chloride content than the sprats. This diet has been working well, and its water and sodium chloride content approaches that of marine crustacea, which in the wild would form a higher proportion of the penguins' diet than fish.

Other alterations in the management of the young chicks were also made. They were housed in a hatching incubator where the ambient temperature was gradually decreased over the first three weeks at which age they were considered to be old enough not to need supplementary heating. A previous system using infra-red lamps erected over plastic water tanks which were used as rearing pens may have produced too high an ambient temperature particularly during warmer summer weather and this procedure would have exacerbated the dehydration problem.

Flamingo foot lesions

All three groups of flamingos have shown a high incidence of hyperkeratosis and dermal cracking over the joints on the solar surface of their feet. For most of the year, only the severely affected birds are lame, but in the winter, a larger proportion of the flock become affected, with some individuals showing weight loss and requiring treatment. This condition has been reported in other Collections and has previously been attributed to unsuitable and abrasive substrates. This is probably only a secondary factor because approximately 80% of the Rosy flamingos under six months of age already had lesions. These birds had never been confined on a concrete surface and only had access to a small area of concrete around the edge of the pond upon which they rarely stood. The lesions, both on gross and histological examination, show a striking resemblance to those described in domestic poultry which have been attributed to a biotin deficiency. The pelleted flamingo diet (BP Nutrition) had approximately 75 µg/kg of added biotin compared to the minimum recommended level of 200 µg/kg for poultry.

A group of eight Greater flamingos were put on an experimental diet having the same composition as the original, but containing 200 μg/kg of added biotin. Examination of their feet after five months on the new diet revealed no obvious improvement but after one year, six out of the seven surviving birds had virtually normal feet. Two and a half months later, however, five of the seven again showed lesions in spite of the fact that they had continued on the biotin rich diet, except for a break of two weeks when it was not available. The role of biotin in the formation of these lesions in flamingos is still not clear and this is also the case in domestic poultry.

A small working party was set up in conjunction with BP Nutrituion to review the nutritional requirements of flamingos. This review and the practical problems associated with the feeding of the previous two component diets (Flamingo diet and Expanded wheat), resulted in the development and marketing of a new Complete Flamingo Diet.

Peccary arthritis

Lameness was observed in the herd of Collared peccaries over a number of years, particularly after the animals have been disturbed. Old animals at post-mortem examination were found to have a proliferative type of osteoarthritis affecting the distal limb joints.

In order to investigate this problem further, 11 of the 12 animals in the group were examined radiographically and blood samples were taken. The ages of the animals ranged from one year to over 11 years. Six of the 11 showed arthritic changes consisting of new bone formation and osteosclerosis. All the animals over two years of age showed radiographically evident changes. The lesions were confined to the distal limb joints (particularly the interphalangeal joints) of both fore and hind legs. The limbs appeared to be randomly affected.

None of the animals had significant serological titres to *Mycoplasma hyorhinis, M. suipneumoniae, M. hyosynoviae, Chlamydia, Erysipelothrix rhusiopathiae* or *Brucella abortus* (and by extrapolation *B. suis*). Work on rheumatoid factor in these animals demonstrated its presence in one or two animals but it was absent in the rest. The aetiology of the condition remains uncertain.

Anaemia in Przewalski horse

A four and a half month old Przewalski foal developed a severe anaemia, associated with increased red cell fragility *in vitro,* very low plasma vitamin E levels (undetectable), raised fibrinogen levels (885 mg/l) and a high nematode egg count (2100 ascarid, 450 Strongyloides and 150 Strongyle eggs per gram). Anthelmintics and antibiotic treatment were instituted, together with administration of vitamin E. Two weeks later the animal was deteriorating and had a slight pyrexia (temperature 38·5°C). A blood transfusion was attempted using domestic pony blood but this was abandoned when signs of a transfusion reaction appeared. At this time vitamin B_{12} levels were 620 ng/l and folate levels 6·8 μg/l (both considered adequate). The vitamin A levels was 85 iu/l and vitamin E 0·4 μg/l. Up to this time no accurate PCV estimation had been made because of haemolysis of the samples, but four weeks after the symptoms were first noticed, the PCV was 12% and there was a severe normochromic anaemia with marked roleaux formation. Steroid treatment was instituted, along with general supportive therapy and the animal improved over the succeeding three months, the PCV reaching 38·15%.

The main plasma biochemical findings gave low values for urea (2·5–4·3 mmol/l), sodium 121–136 meq/l), osmolality (271–276) and total protein (58–67 mmol/l). The total conjugated and unconjugated bilirubin levels all rose (total 13–26, conjugated 3–9 and unconjugated 19–17 mmol/l). The overall picture suggested that red cell destruction was an important factor in the anaemia rather than faulty erythropoiesis. Liver enzyme levels were marginally elevated.

The very low vitamin E levels may have been of significance in that increased red cell fragility is a feature of vitamin E deficiency. Creatine kinase levels were within the normal range, and there were no clinical signs of myopathy. The cause of the anaemia remains uncertain, and it is interesting to note that a similar case occurred in the same species at Chester Zoo at about the same time. That animal also recovered, but both died later, apparently from other causes.

PATHOLOGY 1979

During the period 1 January to 31 December 1979 inclusive, 838 post-mortem examinations were carried out at Whipsnade Park (Table XV). These included three wild mammals and two wild birds found in the Park and 12 external cases. The criteria for the subdivisions in Tables XVI and XIX are the same as those used in previous Scientific Reports.

TABLE XV
Post-mortem examinations at Whipsnade 1979

	Acclimatized	Unacclimatized	Neonate/Stillborn	Total
Mammalia	637 (9)	0	41	678
Aves	143 (1)	1	12	156
Reptilia	3	0	0	3
Pisces	1	0	0	1
Totals	784	1	53	838

Figures in brackets denote euthanasia primarily for management purposes.

Mammalia (Table XVI)

Bacterial infections

Mycobacterium avium was isolated from two Red-necked wallabies, one with splenic and the other with hepatic lesions. *Salmonella typhimurium* Copenhagen group B was cultured from the small intestine but not from any other tissues of a Cheetah cub which died with symptoms of enteritis. *Yersinia pseudotuberculosis* was cultured from the major organs of three Red-necked wallabies. *Corynebacterium pyogenes* was isolated from deep wounds in two female Thomsons gazelle which were attacked by the herd male. The organism was also isolated from an area of necrotic osteomyelitis in the lower jaw of a Blackbuck and from a Chinese water deer with a hepatic abscess and pleurisy.

TABLE XVI
Mammalia (1979)

Main group of conditions encountered at post-mortem examinations*	Acclimatized (637)		Unacclimatized (0)		Neonate (41)		Totals (678)	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	Total (*n*)	Total deaths (%)
Bacterial infections	324	50·9	0	—	2	4·9	326	48·1
Viral infections	11	1·7	0	—	0	—	11	1·6
Mycotic infections	0	—	0	—	0	—	0	—
Parasitic infections								
(a) Arthropoda	6	0·9	0	—	0	—	6	0·9
(b) Helminths	40	6·3	0	—	0	—	40	5·9
(c) Protozoa	2	0·3	0	—	0	—	2	0·3
Nutritional/metabolic	77	12·1	0	—	13	31·7	90	13·3
Debility	4	0·6	0	—	0	—	4	0·6
Injuries/accidents	80	12·6	0	—	7	17	87	12·8
Neoplasia	0	—	0	—	0	—	0	—
Euthanasia	9	1·4	0	—	0	—	9	1·3

*Not necessarily the cause of death.

Haemolytic streptococci were cultured from the lungs of an adult Brindled gnu, a Thomsons gazelle and a Red kangaroo, all with pneumonitis. A mixed culture of staphylococci and *Escherichia coli* was found in a hepatic abscess in a Red-necked wallaby. A Formosan sika deer died with cystitis and an ascending nephritis. *E. coli* was isolated from the bladder and kidney and the infection was associated with dystokia caused by a decomposed foetus.

During the winter of 1978/79 over 400 Red-necked wallabies died in the Park. The principal lesions found were necrotic abscesses of the stomach and face. Cultures from these lesions revealed three genera of anaerobic bacteria, and mixed infections of aerobic organisms. The most frequent organisms found were fusobacteria (*Fusobacterium necrophorus* and *F. varium*) and *Bacteroides* sp. (*B. fragilis, B. uniformis, B. asaccharolyticus* and an unidentified *Bacteroides* sp.). Less frequently, clostridia were seen (*Clostridium sordellii, Cl. perfringens, Cl. septicum* and *Cl. sporogenes*). The aerobic organisms were mixtures of staphylococci, streptococci, *E. coli, Proteus* sp. and *Pseudomonas* sp.

Viral infections

A description of the viral infections encountered is given in the clinical section above.

Accidents and injuries

A Chimpanzee and a Squirrel monkey were killed within a few hours of birth by their mothers. Another neonatal Squirrel monkey died of an intra-abdominal haemorrhage. Three Formosan sika deer fawns were killed by European bison and one by a mowing machine. An adult male Arabian camel fractured its fourth lumbar vertebra while in transit to the Collection and was found dead on arrival. A Common zebra stallion collided with a

fence post and fractured his skull. A female Onager was found with her head trapped under a manger in the Asian house, but in spite of supportive treatment died within a few hours. Injuries of the head, neck and body, consistent with a collision, were the main post-mortem findings in 22 Red-necked wallabies. Aggression within groups of animals resulted in a number of deaths. Four female and one young male Thomsons gazelle were killed by the breeding male and the aggressor was exchanged for another male from the bachelor group to try to prevent further deaths. A young male American bison, two young Père David's deer stags, a male Blackbuck, a pregnant female Canadian timber wolf and a female Llama were also severely injured by other animals in their group.

Miscellaneous

A Bottle-nosed dolphin, the clinical care of which was described in the Scientific Report 1977–79 (*J. Zool., Lond.* (1980) **190** : 515) died after a prolonged period of inappetance and weight loss accompanied by occasional vomiting. The main post-mortem finding was a chronic glomerulonephritis.

Congenital defects were found in two animals. A cleft palate and only a single kidney (the left) were found in a neonatal Cheetah which was the product of a mother and son mating. A Mouflon lamb had a high ventricular septal defect with atrophy of the right ventricle.

An adult male Arabian camel died with a ruptured bladder following complete obstruction of the penile urethra by a 2 mm diameter calculus approximately 9 cm from the penile orifice.

The breeding pair of Servals both died with evidence of renal failure. Blood biochemistry on the female prior to death showed markedly elevated blood urea, creatine and inorganic phosphate levels. Both kidneys were enlarged. Examination of the female's serum for evidence of leptospirosis was negative.

Ragwort poisoning was strongly suspected on histological evidence in an old Père David's deer. A hand-reared Red-necked wallaby developed a myopathy of the hind leg and tail muscles resulting in paraplegia. Inhalation pneumonia following chemical immobilization was recorded in a 10-year-old male Blesbok with severe peridontal disease, and in a debilitated Scimitar-horned oryx. Partial obstruction of the duodenum caused by a localized peritonitis and adhesions apparently originating from the bile duct were the main findings in an adult Nilgai.

Dense opacities in both lenses caused blindness in two Red-necked wallabies and a third animal had unilateral cataract with a retinopathy of the other eye. These were suspected cases of toxoplasmosis and one animal had a dye-test antibody titre to *Toxoplasma gondii* of 1 : 16,000. Another animal exhibited signs of encephalitis. No bacteria could be isolated and this was probably also a *Toxoplasma* infection.

Three Przewalski foals died at birth. Two presented in abnormal postures in the birth canal (a breach presentation and an elbow flexion) and had to be given assistance. The third foal appeared to be a case of relative foetal oversize. Bacterial, virological and histological examination of the main organs revealed nothing of significance. Deaths due to dystokia also occurred in a Black sika deer, a Brindled gnu and three Swamp deer. Two of the Swamp deer had abdominal lipomatosis resulting in partial occlusion of the pelvic canal. One of the adults was destroyed because of recurrent dystokia problems associated with this condition. A Common zebra aborted a five-month-old foetus which was too decomposed for useful examination and a female Mara died with a severe post-partum haemorrhage.

Mortality in Red necked wallabies

During the first four months of the year 413 Red necked wallabies died due to the very severe weather. The post-mortems are categorized in Table XVII. Those animals in the cold stress category showed no gross pathology except marked pulmonary congestion.

Necrobacillosis accounted for 52% of the total deaths, with more than twice the number of cases being affected with gastric lesions than with facial. Stomach lesions were large (4–10 cm) necrotic abscesses, showing ulceration, and occasional perforation. The incidence of these lesions in previous years has been very low (less than 1%). The facial lesions were pathologically very similar and the portal of entry for the associated bacteia appeared to be the tooth-gum margin. There was almost invariably a purulent periodontitis with tracking of the infection into the surrounding soft tissues of the lower and upper jaws, cheeks, muscles of mastication and occasionally the tongue and soft palate. A more chronic form of the disease is responsible for an osteoemyelitis of the jaw, a common condition in captive macropods, however the cases at Whipsnade appeared to be more acute, and apart from the peridontal disease there were no gross bone changes. The bacterial findings of 46 of the necrobacillosis cases are shown in Table XVIII. Examination of direct smears from the lesions gave a more reliable indication of the organisms present because the anaerobic bacteria proved difficult to culture and, frequently, Clostridia overgrew the culture plates.

TABLE XVII
Breakdown of 413 Red necked wallaby post-mortems

Cause of death	Total	% of Total	% male	% in age groups			% deaths in			
				Y	YA	A	Jan.	Feb.	Mar.	Apr.
Gastric necrobacillosis	156	37·7	58	10	25·5	64·5	3·3	22·5	55	19·2
Cold stress	72	17·4	49	13	46·5	40·5	43	48·5	8·5	0
Facial necrobacillosis	57	14	63	3·5	30	67	3·5	25	44·5	27
Pneumonia and thoracic abscesses	31	7·5	64	20	20	60	36·5	46·5	6·5	10
Decomposed	57	14	53	22·5	10·5	67				
Miscellaneous	40	9·7								
Total	413									

Y = Young; YA = young adult; A = adult.

Mortality due to necrobacillosis was initially low and reached its peak in March, with a sharp decline in April, whereas the more acute conditions showed the highest mortality in January and February, with a marked fall off in March.

Necrobacillosis of macropods appears to be related to stressful conditions. Outbreaks occur in wild Kangaroos in Australia during unusually prolonged droughts, when animals tend to congregate round water holes. The epizootic which occurred at Whipsnade can be related to the severe winter weather, restriction of natural food intakes because of snow cover, overcrowding and heavy faecal contamination of the artificial feeding areas. A very large wallaby population (in the region of 800 animals) had built up in the Park over the preceding years.

TABLE XVIII
Bacterial findings in 46 necrobacillosis cases
Percentages with organisms present

	Filamentous gram −ve rods	Small gram −ve rods	Large gram +ve bacilli	Cocci	Other gram −ve rods
Smears					
Gastric lesions ($n = 31$)	81	77	32	39	39
Facial lesions ($n = 15$)	87	29	3	40	20
	Fusobacteria	Bacteroides	Clostridia	Streps/Staphs	
Culture					
Gastric lesions ($n = 31$)	48	64	51	26	—
Facial lesions ($n = 15$)	66	53	26	53	—

TABLE XIX
Aves (1979)

Main group of conditions encountered at post-mortem examinations*	Acclimatized (143)		Unacclimatized (1)		Neonate (12)		Totals (156)	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	Total (*n*)	Total deaths (%)
Bacterial infections	22	15·4	0	—	3	25	25	16·
Viral infections	0	—	0	—	0	—	0	—
Mycotic infections	3	2·1	0	—	0	—	3	—
Parasitic infections								
(a) Arthropoda	0	—	0	—	0	—	0	—
(b) Helminths	15	10·5	0	—	0	—	15	9·6
(c) Protozoa	0	—	0	—	0	—	0	—
Nutritional/metabolic	9	6·3	0	—	12	100	21	13·5
Debility	6	4·2	0	—	0	—	6	3·8
Injuries/accidents	37	25·9	1	100	2	16·6	40	25·6
Neoplasia	1	0·7	0	—	0	—	1	0·6
Euthanasia	1	0·7	0	—	0	—	1	0·6

*Not necessarily the cause of death.

Aves (Table XIX)

Bacterial infections

Mycobacterium avium was cultured from lesions in the air sacs of a Common teal, and *Mycobacteria*, probably *M. avium*, were found in a Red breasted goose and a Demoiselle crane. Acid fast organisms were also considered to have been the cause of death in a Snowy owl, an Eagle owl, a Sarus crane, a Demoiselle crane, a Coscoroba swan and a Muscovy duck. *Salmonella typhimurium* was isolated from the liver of a naturally reared Humboldt's

penguin chick which also showed skeletal deformities of the legs. *E. coli* infections caused pulmonary abscesses and air sacculitis in an Orange winged Amazon parrot, an acute bronchopneumonia in a Kori bustard, and a septicaemia in a Red-rumped parakeet. This organism was also considered the cause of death in a Red eared waxbill with enteritis, a Cordon bleu with hepatic necrosis a North American turkey with multiple granulomas, and a young Rhea with a septicaemia.

Mixed infections of *E. coli* and streptococci were found in a Hawaiian goose with egg peritonitis and a Chilean flamingo with a septicaemia. A pure culture of *Plesiomonas shigelloides* was grown from the kidneys of a Rosy flamingo which had nephritis.

A variety of organism, including haemolytic and non-haemolytic Streptococci, *E. coli, Proteus* and Corynebacteria (frequently grown together) were isolated from one Rockhopper and five Humboldt's penguin chicks mentioned in the Miscellaneous section.

Mycotic infections

Aspergillus fumigatus infections were found in a young adult Humboldt's penguin, a Rosy flamingo and a Canada goose.

Parasitic infections

Syngamus trachea nematodes were found in five Impeyan pheasants, all except one of which had been treated with levamisole given by oesophageal tube on at least one occasion in the two weeks prior to death. A single specimen of this parasite was found in the trachea of a young Rhea. Tracheal nematodes (probably *Cyathostoma* sp.) were also recovered from a Hawaiian goose. A heavy infection of *Porrocaecum crassum* was considered to have been responsible for enteritis in a Mandarin duck. A Chiloe wigeon died with a number of proventricular cysts caused by the nematode *Echinuria uncinata.* Numerous cestodes, *Fimbriaria fasciolaris,* were recovered from the small intestine. *Amidostomum* sp. were found in seven Red breasted geese killed by foxes, and a Snow goose. The number of nematodes recovered in six of the Red breasted geese was two to nine, however one individual had 53. Numerous *Capillaria* were recovered from the gizzard of a Hooded crane with a localized necrotic enteritis. Several *Paradeletrocephalus minor* were recovered from the small intestine of three young Rhea, and large numbers of *Heterakis gallinarum* were found in the caecal sacs of a Reeves's pheasant.

Accidents and injuries

A Cassowary chick was crushed by the parent bird. A Bare eyed cockatoo, an Indian ring necked parakeet, and a Red-rumped parakeet received fatal injuries from their companions. Two Secretary birds died with broken wings, one survived amputation for several months but had difficulty in maintaining its balance, especially when rising to its feet, and had to be destroyed. An Emu fractured its leg and euthanasia was carried out. A Falcated teal died after becoming frozen in ice on its pond. Predators (mainly foxes) killed a large number of birds of which 25 came to post-mortem. These included seven Red breasted geese, seven Patagonian crested ducks, two Greater and two Lesser snow geese, two Cape barren geese, and single specimens of Hawaiian goose, Egyptian goose, Tufted duck, turkey, Guinea-fowl and Jungle fowl.

Miscellaneous

Frost bite was diagnosed in a Lesser sulphur crested cockatoo, an African grey parrot and a White backed vulture. The very cold winter also hastened the death of many older birds with a variety of chronic conditions such as nephrosis and arteriosclerosis.

A localized necrotic enteritis was seen in a debilitated Black necked swan, a Red breasted goose and a Lesser snow goose. No significant bacteria or parasites were found. A Hooded crane showed an acute localized enteritis associated with hepatic degeneration, no significant bacteria being isolated.

A Red breasted goose died with hepatic amyloidosis and nephrosis, and two other birds with visceral gout and nephrosis. Two Rosy flamingos and a Chilean flamingo had the foot lesions mentioned previously.

The Chilean flamingo had extensive ischaemic infarction of the pectoral muscles on one side caused by thrombi in the arteries supplying the area. Arteriosclerotic lesions were present in the aorta and its branches.

Nutritional problems were encountered in four young Rhea with impacted gizzards, and were considered the underlying cause of death in one Rockhopper and 13 Humboldt's penguin chicks (see Clinical section). One Rockhopper and four other Humboldt's penguin chicks referred to previously had infections of the lower respiratory tract ranging from acute alveolitis to bronchopneumonia. In two of these three was an acute bacterial ulcerative oesophagitis associated with *E. coli* and Corynebacteria. Three birds had liver failure, with large numbers of vacuolated hepatocytes and parenchymal aggregations of heterophils. There were no significant bacteriological findings in six chicks although pale enlarged kidneys associated with some degree of heterophil infitration were seen on histological examination.

Abnormalities of the leg tendons were found in a Common rhea and a Rosy flamingo chick. The flamingo had perosis of the right leg, and the rhea a congenital shortening of the gastrocnemius tendons.

TABLE XX
Post-mortem examinations at Whipsnade 1980

	Acclimatized	Unacclimatized	Neonate/ Stillborn	Total
Mammalia	173 (24)	0	82 (4)	255
Aves	85	0	12	97
Reptilia	2	0	0	2
Totals	260	0	94	354

Figures in brackets denote euthanasia primarily for management purposes.

PATHOLOGY 1980

During the period 1 January to 31 December inclusive 354 post-mortem examinations were carried out at Whipsnade Park (Table XX). These included one wild mammal and four wild birds found in the Park, and seven external cases. Tables XXI and XXII summarize the main post-mortem findings. The criteria for the subdivisions are the same as those used in previous Scientific Reports.

TABLE XXI
Mammalia (1980)

Main group of conditions encountered at post-mortem examinations*	Acclimatized (173)		Unacclimatized (0)		Neonate (82)		Totals (255)	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	Total (*n*)	Total deaths (%)
Bacterial infections	45	26·0		—	5	6·1	50	19·6
Viral infections	4	2·3	0	—	0	—	4	1·6
Mycotic infections	0	—	0	—	0	—	0	—
Parasitic infections								
(a) Arthropods	2	1·2	0	—	0	—	2	0·8
(b) Helminths	6	3·5	0	—	0	—	6	2·3
(c) Protozoa	6	3·5	0	—	0	—	6	2·3
Nutritional/metabolic	2	1·2	0	—	19	23·2	21	8·2
Debility	5	3·5	0	—	0	—	5	2·0
Injuries and accidents	48	27·7	0	—	13	15·9	61	23·9
Neoplasia	2	1·2	0	—	0	—	2	0·8
Euthanasia	24	13·9	0	—	4	4·9	28	11·0

*Not necessarily the cause of death.

TABLE XXII
Aves (1980)

Main group of conditions encountered at post-mortem examinations*	Acclimatized (85)		Unacclimatized (0)		Neonate (12)		Totals (97)	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	Total (*n*)	Total deaths (%)
Bacterial infections	22	25·9	0	—	0	—	22	22·7
Viral infections	0	—	0	—	0	—	0	—
Mycotic infections	2	2·4	0	—	0	—	2	2·1
Parasitic infections								
(a) Arthropoda	0	—	0	—	0	—	0	—
(b) Helminths	4	4·7	0	—	0	—	4	4·1
(c) Protozoa	0	—	0	—	0	—	0	—
Nutritional/metabolic	11	12·9	0	—	6	50	17	17·5
Debility	5	5·9	0	—	0	—	5	5·2
Injuries and accidents	20	23·5	0	—	1	8·3	21	21·6
Neoplasia	2	2·4	0	—	0	—	2	2·1
Euthanasia	0	—	0	—	0	—	0	—

*Not necessarily the cause of death.

Mammalia (Table XXI)

Bacterial infections

Mycobacterium avium was isolated from calcified lesions in an enlarged mesentric lymph node in a Red-necked wallaby. *Salmonella enteritidis* caused a severe generalized infection

in a 2-month-old Yak calf, and was isolated from the kidneys of a young orphaned Red-necked wallaby. *Yersinia pseudotuberculosis* was found in two 3–4-month old Axis deer fawns and an unweaned Hog deer which died during cold weather, and in four adult Maras. A chronic localized *Klebsiella* infection of the perirectal area and anus of an old Red panda resulted in pneumonia and septicaemia. Another Red panda died with pleurisy and pleural abscesses associated with gram negative organisms which did not grow in culture.

A severe foot infection in a Hog deer was caused by *Corynebacterium pyogenes. E. coli* infections were considered responsible for the deaths of a 6-week-old European bison calf with enteritis and cholecystitis, a neonatal Hog deer, a Red-necked wallaby with extensive abscessation of the neck and thoracic and peritoneal cavities, and a Mara with peritonitis. The organism was also cultured from the brain of a five day old Bactrian camel which died of an acute meningitis.

Haemolytic streptococci were associated with the stillbirth of a full term Cream pony foal and a severe bilateral panophthalmitis in a neonatal Swamp deer. A pure culture of an *Aeromonas* sp. cultured from the heart blood of another neonatal Swamp deer may also have been significant.

Necrobacillosis was diagnosed in 19 wallabies, nine had infections of the jaw and facial area, six of the stomach and four of the foot.

Viral infections

Mucosal disease was suspected in a 3-year-old Cape buffalo with ulceration and necrosis of the abomasom and a serological titre of 1/60 to the virus neutralization test for Bovine virus diarrhoea was found in this animal. A second buffalo died with similar post-mortem findings, but no serology was carried out. A 7-month-old Nilgai died with localized haemorrhagic enteritis, pneumonia and haemorrhage from areas of the upper respiratory tract. A serum antibody titre of 1/256 to the herpes virus of malignant catarrhal fever was found. This virus could have been responsible for the symptoms.

Parasitic infections

Large numbers of gastro-intestinal nematodes were the main findings in three North American bison, and a European bison, the last having died with type 2 Ostertagiasis. Nematode parasites identified from these animals were *Ostertagia ostertagi, Skrjabinagila lyrata, Trichostrongylus* sp., *Trichuris* sp. and *Dictyocaulus viviparous.* These deaths were associated with raised plasma pepsinogen levels (3720–8340 mUTyrosine/l).

A Thomsons gazelle had large numbers of *Camelostrongylus mentulatus* and *Strongyloides* sp. *Trichuris cervicaprae* was identified from a Roan antelope. An adult Mara was found in a debilitated condition with a heavy gastric parasite burden, probably *Graphidioides.*

Damalinia sedecimdecembrii lice were identified from the North American bison mentioned above.

Coccidiosis was diagnosed in a young Windsor white goat which also had large numbers of *Linognathus stenopsis* lice. An outbreak of *Trixacarus caviae* mange in the Guinea pigs resulted in several animals having to be destroyed.

Toxoplasma gondii was considered responsible for the nervous signs and cataracts found in an adult Red-necked wallaby. The animal had a dye test titre of 4000 units (1 : 16,000).

The disease was also suspected in four other animals with signs of encephalitis—one of which had a titre of 4000 units. The identity of parasites found in Red-necked wallabies is given in the introductory section of this report.

The nematodes *Kiluluma stylosa* and an *Oxyuris* sp. (probably *O. karamoja*) were identified from the caeca of two White rhinoceros which died of injuries. A 2-month-old Musk ox calf with diarrhoea and melaena had a heavy burden of *Teladorsagia (Ostertagia) circumcincta* and *T. trifurcata.* Large numbers of a *Trichuris* sp. were found in the large intestine.

A wild Hare had an ulcerative enteritis associated with heavy infections of a *Passalurus* sp. and a *Graphidium* sp. *Toxocara affinis* nematodes were found in the small intestine of a Cheetah cub.

Accidents and injuries

Two young White rhinoceros died apparently from shock several days after being attacked by the adult bull. Intraspecific aggression resulted in the deaths of a number of animals including two Lion cubs, a Blesbok, two Thomson's gazelle, a Nilgai, a Canadian timber wolf, a Fallow deer, two Sika deer (one neonate) and a Père David's deer. A 4-month-old Brown bear cub was killed by its mother and two newborn Squirrel monkeys suffered a similar fate.

A number of animals including Mouflon, Chinese water deer and Soay sheep were badly injured by Canadian timber wolves which escaped from their enclosure. Two neonatal Axis deer fawns were badly injured, presumably by Arabian camels occupying the same paddock and a Formosan Sika deer of a similar age was killed by European bison.

A 2-day-old Nilgai calf was run over by the train and an adult Moose died after becoming entangled in the enclosure fence. It suffered a fractured tibia and scapula. Nine Red necked wallabies died of injuries suggestive of having been hit by vehicles. A young Sitatunga was destroyed after sustaining a fractured carpus.

Miscellaneous

A 2½-year-old male Common zebra died of grass sickness within 2 weeks of being released into a paddock where two other zebras have died of the same disease over the past four years. The animal also had an early steatitis. An adult Mountain zebra mare died with severe diarrhoea. No organisms of significance were isolated from her but as her foal died with similar signs (outside the period of this report) and *Salmonella typhimurium* was cultured in that case, it is likely that this organism was also responsible for the death of the mother. A 9-year-old female Cheetah died with chronic liver failure, while at Regent's Park. The lobular architecture of the liver was defaced by irregular areas of mature fibrous connective tissue. A second animal died with diffuse chronic interstitial nephritis. The aetiology of these two cases is unknown. Three Cheetah cubs from different litters died. A 6-week-old cub succumbed to peritonitis associated with a perforated duodenal ulcer and a ruptured hepatic abscess. A 12-week-old animal in poor condition died of enteritis, and a 16-week-old cub of inhalation pneumonia, while undergoing treatment for severe diarrhoea. Necrosis and perforation of the small intestine resulted in fatal peritonitis in a sub-adult Lioness, a Coati mundi and a Brindled gnu. In the last case the initiating cause appeared to be trauma.

A female Scimitar horned oryx which became excited after being crated prior to its transport to the Collection from another Zoo died 36 h later with typical signs of capture

myopathy despite intensive treatment for the condition. An adult female Thomson's gazelle died with similar signs after being repeatedly harassed by the herd male.

Respiratory problems were diagnosed in a number of animals. An old Yak which had had intermittent attacks of partial respiratory obstruction was found to have a collapse of trachea caused by distortion of the tracheal rings. An adult Scimitar-horned oryx died of inhalation pneumonia four days after being transported from Regent's Park. A sub-adult Roan antelope developed an acute fatal bronchopneumonia during a cold winter spell and three Red necked wallabies died with pulmonary consolidation. A 9-month-old Musk ox calf was destroyed in a debilitated condition with tubular nephrosis and signs of a focal acute bronchopneumonia.

In addition to the Roan antelope mentioned above, two others died during the cold windy conditions in December, apparently being unable to withstand the weather with the limited shelter available in the paddock. Cold stress was also thought to be responsible for the deaths of two Common waterbuck in the same paddock.

A Red necked wallaby was destroyed with dense bilateral cataracts. Histologically there was pronounced vacuolation of the lens but with no evidence of any inflammatory change. It is unlikely that these changes were due to toxoplasmosis, although the animal had a dye test titre of 1000 units (1 : 4000).

Congenital abnormalities included a case of chondrodystrophy in a Fallow deer (from the group where four previous cases have occurred; Baker, Ashton, Jones & Noddle (1979) *Vet. Rec.* **104**: 450–453), and a similar though less severe condition in a Guanaco calf. A European bison was destroyed with minor deformities of the external nares, upper lip and dental pad. The lower jaw of this animal was 2·5 cm shorter than the upper jaw.

Dystokia led to a number of perinatal fatalities. These included a Przewalski foal born to a mother which had had three dead foals in succession, all apparently due to relative foetal oversize; a Common zebra foal, a Reindeer calf and a Fallow deer also died during birth. These three all had intracranial haemorrhages. Dystokia was also considered to have been the cause of death in a Hog deer fawn and a Yak calf. Stillbirths for which no cause was found included two Swamp deer, a Musk ox calf and a Common zebra foal which was aborted after approximately five months gestation. A neonatal Thomson's gazelle which was thought to have died from exposure also had hypothyroidism, possibly due to iodine deficiency.

Seven Formosan Sika fawns died in July. Three were stillborn and four died soon after birth. Adverse weather conditions may have been responsible for some of the cases, but the degree of inbreeding in the group could also be causing reduced viability.

Deaths in young animals caused by maternal neglect included a 10 day old Chimpanzee with head injuries, pneumonia and enteritis.

Neoplasia

A lymphosarcoma was diagnosed in a 13-year-old captive bred Common hippopotamus. There was generalized lymph node enlargement, and histological examination of the nodes suggested a reticulum cell sarcoma.

Aves (Table XXII)

Bacterial infections

Mycobacterium avium was isolated from a Gargany teal, and large numbers of acid fast organisms were seen in lesions from a North American turkey, and a Helmeted guineafowl.

Acid fast organisms were also seen in smears made from intestinal granolomas seen in a Sarus crane which died of severe anaemia caused by haemorrhage from these lesions. The bird also had widespread amyloidosis. A Mallard with septic arthritis and anaemia contained significant antibodies to *M. avium* type 6. *Escherichia coli* was responsible for a salpingitis in a White naped crane. Streptococci were isolated from lesions of synovitis in a Rosy flamingo and caused a secondary septicaemia in a Red breasted goose with hepatic amyloidosis and ascites. Corynebacteria caused a septicaemia in a Chilean flamingo. The significance of the isolation of *Clostridium perfringens* and *Bacteroides ruminicola* from the intestinal contents of one of two Coscoroba swans which died with a necrotic enteritis is uncertain.

Mycotic infections

Extensive lesions of chronic aspergillosis were found in an adult King penguin. Although no acid fast organisms were seen the bird was serologically positive for *M. avium* serotype 3. Aspergillus infections were also diagnosed in a Red breasted goose with hepatic amyloidosis, and in two Patagonian crested ducks.

Parasitic infections

Infestations of *Syngamus trachea* were found in an Impeyan pheasant, a Carolina duck and a Helmeted guineafowl. A debilitated North American turkey had a severe typhlitis, associated with a heavy *Heterakis* sp. infection. It also contained small numbers of *S. trachea* and a *Capillaria* sp. A Secretary bird which died with a necrotic, ulcerative enteritis was harbouring a number of *Porrocaecum* sp. nematodes (possibly *P. depressum*) in the small intestine. A *Deletrocephalus* sp. and *Paradeletrocephalus minor* were found in the small and large intestines respectively of an adult Rhea which died with an intestinal obstruction.

Large numbers of *Anaticola phoenicopteri* lice were seen on a Chilean flamingo and a similar number of *Ornithomya arichlara* were seen on a Kenya eagle owl.

Accidents and injuries

A young adult Manchurian crane died under anaesthesia while undergoing radiographic examination of a fractured humerus. A Chilean flamingo died, apparently of heart failure, while being restrained for blood sampling prior to export. A Rosy flamingo dislocated a tibio-tarsal joint and developed an ischaemic myopathy of the pectoral and leg muscles.

A number of young Common rheas injured themselves in the week following their movement to another enclosure and two had to be destroyed with fractured legs. A Bar headed goose was destroyed after being unable to adapt to having an injured leg amputated.

Intraspecific aggression resulted in the deaths of a Tawny owl, an Imperial pheasant, two Sonnerats jungle fowl, and six Red-rumped parakeets. All these deaths were thought to have been due to aggressive males.

Miscellaneous

The mortality amongst young penguin chicks left with their parents for rearing was again high. Both the Rockhopper chicks which were hatched and two Humboldt's chicks died of suspected heat stress and malnutrition during warm weather. A third Humboldt's chick died

after a bristle from a yard brush had penetrated the gizzard. The carcase of another Humboldt's chick which was being hand reared was found to be very oedematous probably due to the addition of too much saline to the liquidized fish diet (see Clinical section).

An adult Common rhea died after its intestine had become blocked by a 30 cm long plug of vegetable matter. Another Rhea died of a chronic peritonitis, apparently originating from two perforated ulcers in the duodenum.

A Rosy flamingo and a South African shelduck, both died of ruptured atria. A Chilean flamingo succumbed to thrombosis of the subclavian artery and ischaemic necrosis of the pectoral muscles. A Crowned crane which developed a cardiomyopathy, possibly ischaemic, died of heart failure. Severe arteriosclerosis was found in an old Impeyan pheasant and a Peacock.

Tenosynovitis, thought to be infectious in origin, was found in the region of the tarsal joint of an Impeyan pheasant but no organisms were cultured. A Red breasted goose had a septic arthritis and bumblefoot, although the cause of death was probably nephrosis. Nephrosis was also diagnosed in a Barrows goldeneye and a Sonnerats jungle fowl.

Liver lesions were found in a number of birds, and included three Red-breasted geese with hepatic amyloidosis and a Greylag goose, a Chiloe wigeon, a Tawny owl, and a Kenya eagle owl with hepatosis.

Neoplasia

A granulosa cell tumour of the ovary was found in a Reeves pheasant.

APPENDICES

CONTENTS

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Radiology: GEC Ltd for the loan of a television monitor for cine-radiography.
Reproduction: Dr R. A. Sidall (ICI Ltd) and Dr Hilary Box (University of Reading) for gifts of marmosets. The World Health Organization; Professor G. Abraham; Dr W. G. Breed (Department of Anatomy, University of Adelaide); Dr H. M. Dott (ARC Institute of Animal Physiology, Cambridge); Dr Devra Kleiman (Smithsonian Institute, National Zoo, Washington); Mrs P. Napier (British Museum (Natural History)); Dr A. S. McNeilly (MRC Reproductive Biology Unit, Edinburgh); Dr P. Samarajeewa; Dr Paul Watson (Royal Veterinary College); the staff of St Peter's and Hammersmith Hospitals; Bristol Zoo; Flamingoland; Jersey Wildlife Preservation Trust; and Twycross Zoo for loans or gifts of specimens, tissues, samples and materials. We are also grateful to Dr McNeilly for training a technician in prolactin assay techniques and to Dr Dott for laboratory facilities. Dr C. Wilson (Department of Obstetrics and Gynaecology, St George's Hospital Medical School) for assays of Orang-utan luteinizing hormone. Dr B. J. Everitt (Anatomy Department, Cambridge University) for neurochemical assays of marmosets. Professor J. A. Lucy (Department of Biochemistry, Royal Free Hospital Medical School) for the use of freeze-fracture apparatus. Professor S. L. Jeffcoate and Dr S. Soufi for advice on WHO assay protocols; and Drs N. D. Martensz and A. Dubey for advice on bioassay techniques.
Veterinary Science: Organizations and individuals who have loaned equipment including Corning Medical; Hawke Electronics Ltd., Professor P. Harris (Cardiothoracic Institute); Dr P. Pyle and Dr R. W. Gabriel (Luton & Dunstable Hospital); and Richard Wolf Ltd of West Germany. We are grateful to Hawke Electronics for their assistance with the programming of the computer and to Mr T. Norwood of Richard Wolf Ltd for his assistance and guidance in the use of fibre-optic laparoscopes. The department is very appreciative of the considerable help given by scientific friends and colleagues, without whose assistance the technical detail which is apparent in all aspects of the veterinary work would not be possible. Almost all histopathology is carried out by Dr P. F. Wadsworth (ICI Pharmaceuticals Division), Mr J. E. Cooper (Royal College of Surgeons), Dr E. D. Appleby (Royal Veterinary College), Dr A. C. Palmer (Cambridge University) and Dr R. Finlayson (Wellcome Museum of Medical Science). Professor A. Zuckerman, Professor D. W. Mackenzie, Dr R. J. Hay and Dr K. N. Tsiquaye (London School of Hygiene and Tropical Medicine) carry out many of the specialized microbiological studies. All routine clinical biochemistry is undertaken by Dr R. A. Gardner and his staff (Department of Chemical Pathology, University College Hospital). Miss G. Lewis and her staff (Central Veterinary Laboratory, Weybridge) examined blood and tissue levels of trace elements and vitamins A and E. Dr L. F. Khalil (Commonwealth Institute of Helminthology); Mr C. H. C. Lyal and Mr K. G. V. Smith (British Museum (Natural History)); Dr B. R. Laurence (London School of Hygiene and Tropical Medicine); and Mr G. H. Lowe (Public Health Laboratory, Cardiff) identified helminths, arthropod parasites, mites, Diptera larvae and intestinal flagellates. Dr D. G. Fleck (Public Health Laboratory, St George's Hospital) examined blood and tissues for the presence of toxoplasma antibodies. Dr B. Rowe and Dr L. R. Hill (Central Public Health Laboratory, Colindale); Dr N. S. Mair (Public Health Laboratory, Leicester); Dr A. T. Willis (Public Health Laboratory, Luton) identified and typed *Salmonella* and *Escherichia coli*, unusual Gram negative bacilli, *Pasteurella* spp., *Yersinia* cultures, and anaerobic bacteria. Mr P. R. J. Matthews, Mr P. Collins (ARC Institute for Research on Animal Diseases, Compton) and Dr B. J. Shreeve (Central Veterinary Laboratory) examined a number of cultures for the presence of *Mycobacterium* spp. Dr W. H. Allan and Dr G. A. Cullen (Central Veterinary Laboratory), in collaboration with Dr D. Roberts, assisted in the diagnosis of ornithosis, Newcastle disease, duck virus enteritis and other viral diseases. Dr R. G. Bird (London School of Hygiene and Tropical Medicine) examined tissues for the presence of viral particles and Dr T. H. Flewett (Regional Virus Laboratory, Birmingham) examined samples of faeces for the presence of viruses. Technical advice on nutrition was given by Dr D. Frape, Dr E. Miller, Dr A. Walker, Dr Marie Coates, Mr J. Eva and Mr D. Coomber. Clinical advice and assistance was also given by Dr N. Edington, Mr L. R. Thomsett and Mr D. G. Clayton-Jones (Royal Veterinary College). Advice on anaesthesia was given by Dr Barbara Weaver (Bristol Veterinary School), Dr P. Lees (Royal Veterinary College), Dr J. P. Blackburn (Westminster Hospital) and Professor M. de Burgh Daly (St Bartholomew's Hospital Medical College). Assistance with prosthetic surgery was given by Professor J. A. Hobkirk, Mr E. W. Pullen Warren and Dr T. Hill (Eastman Dental Hospital). Dr A. J. Stedman (Royal Veterinary College) gave assistance with environmental studies.

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2. STAFF

Scientific, Technical and Supporting Staff, September 1979–October 1981

Secretary:	E. D. Barlow, MA, MB, BChir, MRCPsych (from 11 June 1980)
	R. H. Hedley, DSc, PhD, FIBiol (until 11 June 1980)
Director of Science:	J. P. Hearn, MSc, PhD, FIBiol (from August 1980)
	L. G. Goodwin, CMG, MB, BS, FRCP, BPharm, S.BC, FIBiol, FPS(Hon.), FRS (until July 1980)
Assistant Director of Science:	H. G. Vevers, MBE, MA, DPhil, FLS, FIBiol
Assistant Director of Zoos:	D. M. Jones, BSc, BVetMed, MRCVS
Librarian:	R. A. Fish, FLA
Education Officer:	M. K. Boorer, BSc, DipEd

INSTITUTE OF ZOOLOGY

(Incorporating the Department of Veterinary Science, Nuffield Laboratories of Comparative Medicine, Wellcome Laboratories of Comparative Physiology and Curators' Research Units.)

Director: J. P. Hearn, MSc, PhD, FIBiol

Genetics Department

Head:	*Rachel A. Fisher, MB, BS, MSc, PhD
Research Fellows:	*J. G. Matthews, BVetMed, MRCVS, PhD
	D. B. Whitehouse, B.Sc, PhD
Research Assistant:	Wendy Putt
Postgraduate Research Student:	*Lynne Aplin, SRN, BSc
Technicians:	Angela Demetriou
	Linda Elliston
Head, Haematology Unit:	Christine M. Hawkey, PhD
Postgraduate Research Student:	P. C. Pearce, MIBiol, MPhil
Senior Technician:	M. G. Hart, AIST
Technician:	G. Leeser

*Denotes Fellowship or Studentship now completed and appointment taken elsewhere.

Infectious Diseases Department

Head:	G. R. Smith, PhD, MRCVS, DVSM, DipBact
Research Fellows:	*C. D. V. Black, SRN, Bsc
	*Vija Dent, PhD
Technician:	Janet C. Oliphant, BSc
Head, Immunology Unit:	A. Voller, PhD, DSc (Honorary Research Associate)
Research Assistants:	*Ann Bartlett, PhD
	D. E. Bidwell, PhD
Postgraduate Research Students:	*Isabella A. Quakyi, MIBiol, BSc
	*D. de Savigny, BSc, MSc (Guelph)
Technicians:	Daphne Green, HNC, AIST
	P. Turp, HNC

Nutrition Department

Head:	M. A. Crawford, PhD
Research Fellows:	Wendy Doyle, Dip. Dietetics
	W. R. Hare, BSc
	D. C. Kuhn, AB, MS (USA)
Postgraduate Research Student:	*Theresa L. Frankel, BVetSc (Sydney), Dip. Nutr. (Camb.)
Visiting Research Graduate:	S. C. Cunnane, PhD (Canada)
Senior Technician:	G. Williams, MIST, HNC, LIBiol
Technicians:	P. J. Drury, HND, MIBiol
	Melanie S. Duc
	Beverley J. Hine, BSc
	Therese B. Lenihan
	Pamela A. Stevens, SLT

Radiology Department

Head:	G. H. du Boulay, MB, BS, FRCP, DMRD, FRCR
Honorary Research Associate:	D. J. Boullin, MSc, PhD, MA
Radiographer:	Victoria Aitken, DSR

Reproduction Department

Head:	J. P. Hearn, MSc, PhD, FIBiol
Research Fellows:	A. F. Dixson, PhD (permanent staff)
	*Rosemary C. Bonney, PhD
	J. K. Hodges, PhD
	H. D. M. Moore, PhD
	Susan P. M. Schofield, PhD
Research Assistants:	Sally-Ann Eastman, PhD
	D. Fleming, MIBiol
	Cilla Henderson, BSc
	W. V. Holt, PhD
	K. Kendrick, PhD
Postgraduate Research Students:	*Heather M. Brand, MA
	C. R. Harlow, BSc
	*Jacqueline Hunter, BSc
	*Susan Kingsley, BSc
Visiting Research Graduate:	Asha Prakash, PhD (Delhi)
Technicians:	Deborah Bevan, HNC
	Sara Gems, HND
	Lynne George, HND
	T. J. Hartman, BSc
	A. J. Hill, BSc
	R. North, BSc

*Denotes Fellowship or Studentship now completed and appointment taken elsewhere.

Veterinary Science Department

Senior Veterinary Officer:	D. M. Jones, BSc, BVetMed, MRCVS
Veterinary Officer (London):	J. A. Knight, BVetMed, MRCVS
Veterinary Officer (Whipsnade):	*D. G. Ashton, MA, Vet. MB, MRCVS
Honorary Research Associate:	A. N. Worden, FRCPath
Hospital Superintendent:	A. K. Fitzgerald, RANA
Technicians (London):	J. Ffinch
	Judith Howlett, RANA
	R. Hutton
	Heather Pugsley, RANA
Technician (Whipsnade):	R. N. Cinderey, MIST
Senior Technician (Pathology):	S. Pugsley, AIAT, SLT
Technicians (Pathology):	Karen Brain
	R. Parsons, AIMLS

Curators' Research Unit

Curator of Aquarium:	H. G. Vevers, MBE, MA, DPhil, FLS, FIBiol
Curator of Birds:	P. J. S. Olney, BSc, DipEd, FLS
Curator of Mammals:	B. C. R. Bertram, MA, PhD, FIBiol (from January 1980)
Curator, Whipsnade:	V. J. A. Manton, MRCVS
Honorary Research Associate:	A. J. E. Cave, MD, DSc, FRCS, FLS

Supporting Staff (Current Appointments)

Administrative Assistant:	Constance Nutkins
Laboratory Superintendent (Nuffield Building):	P. R. E. Wallace, FIST
Laboratory Superintendent (Wellcome Building and Hospital):	G. F. Nevill, HNC
Senior Technician (Workshops):	W. G. Ray, AIST
Senior Animal Technician:	Barbara J. Murrill
Animal Technicians:	Suzanne Davis
	Denyse Gowling
	Michaela McNeil
	T. Noble, AIAT (i/c Nuffield)
	T. Shurety
	D. Stula
	Christine Walford
	Lorraine Wright
Electron Microscopist:	D. G. Taylor
Photographer:	T. Dennett
Secretaries:	Deborah Cropper
	Anna McGlashan
	Linda Mason
	Jean Ryan
Glasswashers:	Winifred Dyke
	Jacqueline McCorry
	Beryl Smith-Huchon

The Collections

Much of the Institute's research depends on close collaboration with Keeper and Overseer staff working at London and Whipsnade Zoos, whose efforts make them an essential part of the team.

Overseer, Birds:	R. Barrow

*Denotes Fellowship or Studentship now completed and appointment taken elsewhere.

Overseers, Mammals:	J. Lambden
	R. B. Willis
Overseer, Reptiles:	D. Ball, AIAT
Overseers, Whipsnade:	J. Datlen
	G. Stanbridge

For Headkeepers, please see Annual Report of the Zoological Society of London.

Publications Department

Journal of Zoology, Symposia, Transactions of the Zoological Society of London, Nomenclator Zoologicus:

Editor:	H. G. Vevers, MBE, MA, DPhil, FLS, FIBiol
Assistant Editor:	Marcia A. Edwards, PhD, FLS
Editorial Assistant:	L. G. Ellis
Administrative Assistant:	Unity M. M. McDonnell, MA

Zoological Record:

Editor:	Marcia A. Edwards, PhD, FLS
†Managing Recorder:	M. N. Dadd, BSc, FLS, MIInfSci
†Systems Analyst:	S. J. Rammell, BSc, AIInfSci
†Senior Recorder:	Judith M. Howcroft, BSc

†Transferred to BIOSIS UK Ltd from 16 July 1980.

International Zoo Yearbook:

Editor:	P. J. S. Olney, BSc, DipEd, FLS
Assistant Editors:	Pat Ellis
	Benedicte Sommerfelt

Education Department

Please see Annual Report of the Zoological Society of London.

Staff Movements

General

Members of the scientific staff took part in a Symposium entitled *Advances in the Veterinary Care of Zoo Animals*, organised by Mr D. M. Jones, which was held on 17 and 18 June 1981.

Two demonstrations, one on immunological control of fertility and one on reproduction in wild mammals, were presented by Professor J. P. Hearn, Mr Jones, Dr J. K. Hodges and Dr H. D. M. Moore at the 1980 and 1981 Soirées of the Royal Society.

Professor Hearn and Dr B. C. R. Bertram were elected Fellows of the Institute of Biology. Professor M. A. Crawford was appointed to a special Chair of Applied Biochemistry and Nutrition at the University of Nottingham School of Agriculture; he was presented with a Gold Medal at the Golden Jubilee International Congress on Essential Fatty Acids and Prostaglandins in November 1980 in recognition of his work linking the two fields.

Professor A. J. Worden's appointment as Honorary Research Associate was confirmed and he will shortly commence work on a research project with the Veterinary Science Department. Dr D. J. Boullin was appointed Honorary Research Associate (Radiology).

Following the death of Miss Patricia Wright in October 1980, Miss Connie Nutkins (formerly Secretary, Wellcome Laboratories) became Administrative Assistant to the Director of Science and Mrs Anna McGlashan (formerly Secretary, Genetics Department) became Secretary, Wellcome Laboratories.

Mr R. Barrow was appointed Overseer, Birds, following the retirement of Mr D. Newson in September 1981.

Departmental

Genetics and Haematology: Dr Rachel A. Fisher resigned as Head of Department in August 1981 to work in America. Dr J. G. Matthews resigned in March 1981 to return to veterinary practice. Postgraduate Research Student Lynne Aplin decided not to continue her course of study and left in 1980. P. D. Butcher was awarded a PhD by the Council for National Academic Awards in 1980 and is now at King's College, London. Two Laboratory Technicians joined the department in August 1981; Miss Linda Elliston to work on the Equidae research project and Miss Angela Demetriou to work in both the biochemical genetics and cytology sections.

Infectious Diseases and Immunology: After 14 years in the department, Dr Ann Bartlett left in June 1980 to become

a mother. D. de Savigny (Ontario Ministry of Health, Toronto, Canada) and Miss Isabella Quakyi (University of Accra) were awarded PhDs on completion of their studies and have returned to Canada and Ghana, respectively. Mrs Angela Young left in October 1979 to join the staff of the Public Health Laboratory, Luton. Mrs Janet Oliphant joined the department as Laboratory Technician in January 1980.

Nutrition: Miss Theresa L. Frankel was awarded a PhD on completion of her studies in 1979 and is now at Wolfson College, Cambridge. Mr W. R. Hare joined the department as Research Fellow in April 1980. Miss Beverley Hine joined as Laboratory Technician in March 1981, replacing Mr C. J. Cadwallader who has transferred to the Keeper staff. Dr S. C. Cunnane joined in July 1981 on a year's secondment from the Rowett Institute.

Radiology: Mrs Victoria Aitken has returned after six months' maternity leave; during her absence, Miss Jennifer Beckett, DSR, was employed as Radiographer.

Reproduction: Mr W. V. Holt, Histologist, was promoted to Research Assistant after successful completion of his PhD studies. Miss Susan Kingsley left in March 1980 on completion of her study period and is now working as research assistant at Queen Charlotte's Maternity Hospital, London; her PhD thesis has recently been submitted. Mrs Jacqueline Hunter obtained her PhD in May 1981 and is now working as a postdoctoral assistant at St George's Hospital Medical School. Mrs Heather Brand left in January 1981 on completion of her study period and is now writing her PhD thesis. Dr Rosemary Bonney resigned her Research Fellowship in December 1980 and Mr G. R. Watson resigned as Laboratory Technician in February 1981. Dr J. K. Hodges joined in December 1979 on a 3-year Research Fellowship. Three Research Assistants have joined the department: Mrs Cilla Henderson in November 1979 and Dr Sally-Ann Eastman in March 1981, both on Professor J. P. Hearn's MRC Programme Grant; and Dr K. M. Kendrick in October 1981 on Dr A. F. Dixson's Wellcome Trust Project Grant. Mr C. R. Harlow joined as MRC Postgraduate Research Student in October 1980. New appointments as Laboratory Technicians include Miss Sara Gems in November 1979; Mr A. J. Hill in April 1981; and Mr R. North in October 1981.

Veterinary Science: Mr D. G. Ashton resigned as Veterinary Officer (Whipsnade) in September 1981 and Miss Linda Juul as Technician (Pathology), also in September 1981. Mrs Heather Pugsley, Technician (Hospital), is on six months' maternity leave; Miss Jane Lawrie has been employed in her absence.

Visits abroad

Professor J. P. Hearn has visited China, Hong Kong (Chinese and Hong Kong Universities), Kenya (University of Nairobi and the Institute of Primate Research, Limuru), Korea, Peru and the USA to give lectures and technical advice on primate reproductive physiology as a WHO Consultant Adviser, and has also visited Geneva as a Member of the WHO Steering Committee, Task Force on Infertility Agents from Plants. He visited China as a Scientific Adviser to the World Wildlife Fund and was an invited speaker at the AAZPA Conference in New Orleans, USA.

Dr R. A. Fisher visited various American zoos, including Minnesota Zoo to sit on Committee advising Captive Breeding Group of Survival Services Commission on Przewalski horses; and Michigan State University Department of Medicine to set up horse paternity testing systems. Dr C. M. Hawkey and Mr D. M. Jones spent some time in Southern Sudan in 1981 in connection with the Jonglei Ecological Project (see text).

Dr A. Voller and Dr D. E. Bidwell conducted Workshops on Immunoparasitology for WHO in India, Malaysia and Korea. Dr Voller presented papers at the Analytica 80 Congress in Munich, W Germany; the Congress of Assays for Macromolecules, Tel-Aviv, Israel; Course on Use of Isotopes, Washington, USA; First Internal Congress on Clinical Chemistry for African and Mediterranean Region in Milan, Italy; Automation in the Laboratory, R.S. First Congress, in Chicago, USA; the Kenya Medical Association Conference, Nairobi; Annual Meeting of Italian Society of Allergy and Immunology in Siena, Italy; and gave the Plenary Lecture to Instituto Nacional de Agravias in Madrid, Spain. He also visited Geneva as a Member of the WHO Subcommittee on Standardization of Immunological Reagents.

Professor M. A. Crawford gave a paper on Polyunsaturated Fatty Acids (with Dr P. Budowski) in Paris; and presented papers at the Golden Jubilee International Congress on Essential Fatty Acids and Prostaglandins (with Mr G. Williams and Miss Pamela Stevens) in Minneapolis, USA; the 22nd International Conference on the Biochemistry of Lipids in Milan, Italy; Workshop on Nutrition/Lipid Requirements for Early Development (with Dr D. G. Kuhn) in Houston, USA; 3rd International Congress on Biological Value of Olive Oil in Crete; International Symposium on New Trends in Nutrition, Lipid Research and Cardiovascular Disease in Argentina; the International Conference on Biological Basis of Psychiatry in Stockholm, Sweden; and the 23rd International Conference for the Biochemistry of Lipids (with Drs S. Cunnane and D. G. Kuhn) in Nyborg, Denmark. Mr G. Williams visited the South-West Fisheries Center, La Jolla, California.

Professor G. H. du Boulay presented a paper at the International Meeting on Cerebral Blood Flow in St Louis,

USA; Dr D. J. Boullin attended the Federation of American Societies of Experimental Biology Conference in Atlanta, USA.

Drs R. C. Bonney, A. F. Dixson and S. P. M. Schofield, Mrs H. M. Brand, Mrs A. J. Hunter and Miss S. Kingsley contributed to the VIIIth International Congress of Primatology in Florence, Italy. Dr Dixson took part in discussions of EEC Group on Usage and Supply of Primates, Brussels, Belgium. Dr J. K. Hodges visited Kenya as a WHO Consultant Scientist; presented a paper to the Annual Meeting of the Society for the Study of Reproduction, Michigan, USA; visited China as a Scientific Adviser to the World Wildlife Fund; and visited San Diego Zoo and the National Zoo, Washington, for discussions on collaborative research projects. Dr H. D. M. Moore presented papers at a Symposium on the Comparative Biology of Primate Semen in Siena, Italy; the American Association of Zoo Veterinarians' Annual Conference in Washington; and the Gordon Conference on Fertilization and Activation of Development in New Hampshire. Dr W. V. Holt contributed to the 3rd Franco-British Meeting of the Society for the Study of Fertility and the Societé National pour l'étude de la Stérilité et de la Fécondité in Gaillon, France.

In addition to visits to the Sudan, Mr D. M. Jones also visited Kuwait and Doha zoos as a consultant. Mr J. Knight visited the National Zoo, Washington, when the male Giant panda "Chia chia" was sent on breeding loan. Mr D. G. Ashton attended as Co-ordinator at a meeting of the Working Party on Diseases of the Przewalski horse in Arnhem; and visited Skukuza, Republic of South Africa, to examine and discuss the chemical immobilizing equipment developed by Mr van Rooyen for use in the Kruger National Park.

Dr B. C. R. Bertram presented papers at the Symposium on Mammalian Behaviour, National Zoo, Washington; the IUDZG Meeting on Studbooks in Copenhagen; and visited Stockholm University Department of Zoology as guest lecturer; and the National Zoo, Washington, for discussion on Giant panda co-operative breeding. Mr P. J. S. Olney attended the Captive-breeding Specialist Group (S & C) meeting in Jersey.

Visiting Workers

A large number of research workers, at student, technical and professional levels, visit each year for training in techniques or to participate in collaborative studies. The Institute is recognized by WHO as a collaborating centre involved in their programmes of Nutrition, Reproduction and Tropical Medicine. In addition, large numbers of workers from other zoos visit the Department of Veterinary Science for training in veterinary aspects of zoo management. During the period of this Report, the following research workers spent varying lengths of time with the Institute:

Genetics and Haematology: J. Allan, MSc student (University of London) engaged in a project on the biochemical genetics of domestic cats. Miss B. A. Blofield (Principal Lecturer in Zoology, Goldsmith's College, University of London) to work on the effect of Malayan pit viper venom (Ancrod) on blood coagulation in birds (see text). M. Chapman, BVetMed, to gain experience in the preparation and interpretation of chromosomal data. Professor E. Hackel (Michigan State University) to consider whether the techniques used here could be useful in the MSU horse paternity laboratory. M. Looker, BSc student (Polytechnic of Central London) engaged in a project on the biochemical genetics of the Cervidae. Dr Katherine Ralls (National Zoo, Washington) visited the department with a view to setting up a similar facility at the National Zoo. Miss Michell Robinson (Department of Veterinary Science, Pretoria University) to learn isoelectric focusing techniques for horse paternity testing.

Infectious Diseases and Immunology: Dr S. Bonini (University of Rome, Italy) worked on an immunoassay for antibodies to pollen. Dr A. Siddiqui Ali (Khartoum) studied rodent malaria; Dr F. Baya (Malakal, Sudan) and Dr R. Ahmed (Baghdad, Iraq) both worked on the incidence of toxocariasis in their respective countries. Dr A. Zumla (Zambia) studied the levels of alpha-foetal protein and Hepatitis B surface antigen in primary hepatoma in Zambia. Dr M. King (Philippines) set up enzyme immunoassays for Caxsackie viruses. Dr M. Schlechter (Brazil) studied the serology of Chagas disease. Dr D. Wilson (USA) worked on ELISA for diagnosis of Varicella Zoster infections. Visiting workers were received for training in techniques of ELISA from Australia, Argentina, Belgium, Canada, China, France, Gambia, Gabon, India, Nigeria, Philippines, Switzerland, Thailand, UK, USA and Upper Volta.

Radiology: Dr A. Colchester (Institute of Aviation Medicine, Farnborough) has been carrying out research for his PhD under Professor du Boulay's supervision in which he has developed a cineangiographic method of measuring both calibre and flow in the cerebral arteries of baboons. Dr C. Dean (Middlesex Hospital Medical School, London) has studied muscle attachments to the skull bone in primates, using the Wellcome Animal X-Ray Museum.

Reproduction: M. McDonough (University of London) worked in the laboratory to test out radio-transmitter harnesses on owl monkeys and to learn behavioural techniques. Dr R. Van Aarde (Mammal Research Institute, Pretoria) studied reproductive biology techniques. Dr Christina Wang (University of Hong Kong Medical School) studied *in vitro* fertilization and Leydig cell culture techniques. Workers from University of Chollagong, Thailand; University of Nairobi, Kenya; and University of Wales were trained in radioimmunoassay techniques.

Veterinary Science: Miss Lindsay Bell (UK); Mr D. J. G. Burrows (Agriculture and Fisheries Department, Hong Kong); and Dr Jaafar Eskafy (Al-Areen Wildlife Park, Bahrain) gained experience and training in zoo animal medicine. Miss Catherine King (Applied Biology Department, University of Cambridge) studied nutrition of Scimitar-horned oryx for her PhD thesis. Professor Murray E. Fowler (Department of Medicine, University of California), who is producing a bibliography on zoo and wild animal medicine and surgery, examined Menagerie Records and used the Library facilities. Mrs Margaret Ryan (Paddington College) studied parasites at both Collections.

Curators' Research Units: Mr A. P. Verstraete (MRC, Carshalton) engaged on a project on Okapi and Giraffe dung.

3. PUBLISHED WORK BY MEMBERS OF STAFF

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4. GLOSSARY OF COMMON AND SCIENTIFIC NAMES OF ANIMALS MENTIONED IN THE TEXT

Aardvark	*Orycteropus afer*
Abdim's stork	*Ciconia abdimii*
Addax	*Addax nasomaculatus*
Aerial toucan	*Ramphastos vitellinus ariel*
African bullfrog	*Pyxicephalus adspersus*
African elephant	*Loxodonta africana*
African house snake	*Boaedon fuliginosus*
African spurred tortoise	*Geochelone sulcata*
Agama lizard	*Agama atricollis*
Aldabra Giant Tortoise	*Geochelone gigantea gigantea*
American bullfrog	*Rana catesbeiana*
American Grey fox	*Urocyon cinereoargenteus*
American toad	*Bufo americanus*
Arabian camel	*Camelus dromedarius*
Australian stilt	*Himantopus leucophalus*
Axis deer	*Axis axis*
Axolotl	*Ambystoma mexicanum*
Aylesbury duck	*Anas platyrhynchos* (domesticated)
Azure-winged magpie	*Cyanopica cyana*
Bactrian camel	*Camelus bactrianus*
Banded rail	*Rallus philippensis*
Barbary sheep	*Ammotragus lervia*
Bar-headed goose	*Anser indicus*
Barrow's goldeneye	*Bucephala islandica*
Beaver	*Castor fiber*
Bengalese finch	*Lonchura* sp. (domesticated)
Bicheno's finch	*Poephila bichenovii*
Bighorn sheep	*Ovis canadensis*
Black-billed barbet	*Lybius guifsobalito*
Blackbuck	*Antilope cervicapra*
Black-casqued hornbill	*Ceratogymna atrata*
Black fallow deer	*Dama dama*
Black hornbill	*Anthracoceros malayanus*
Black ibis	*Pseudibis papillosa*
Black mangabey	*Cercocebus aterrimus*
Black-necked swan	*Cygnus melanocoryphus*
Black rhinoceros	*Diceros bicornis*
Black sika deer	*Cervus nippon*
Black swan	*Cygnus atratus*
Blesbok	*Damaliscus dorcas*
Blotched genet	*Genetta tigrina*
Bornean small-toothed palm civet	*Arctogalidia trivirgata*
Boa constrictor	*Boa constrictor*
Blue-tongued skink	*Tiliqua scincoides*
Bottle-nosed dolphin	*Tursiops truncatus*
Brazilian tree porcupine	*Coendou prehensilis*
Brent goose	*Branta bernicla orientalis*
Brown bear	*Ursus arctos*
Brown eared pheasant	*Crossoptilon mantchuricum*
Brown mouse lemur	*Microcebus rufus*
Brown violet-eared hummingbird	*Colibri delphinae*
Brush bronze-winged pigeon	*Phaps elegans*
Budgerigar	*Melopsittacus undulatus*
Buff-tailed coronet	*Boissonneaua flavescens*
Burton's carpet viper	*Echis coloratus*
Californian sealion	*Zalophus californianus*
Canadian timber wolf	*Canis lupus*
Canary	*Serinus canaria*
Cape Barren goose	*Cereopsis novaehollandiae*
Cape buffalo	*Syncerus caffer*
Capuchin monkey	*Cebus apella*
Carolina duck	*Aix sponsa*
Casqued-headed lizard	*Laemanctus longipes deborrei*
Cassowary	*Casuarius* sp
Celebes black ape	*Macaca nigra*
Cheetah	*Acinonyx jubatus*
Chilean flamingo	*Phoenicopterus chilensis*
Chiloe wigeon	*Anas sibilatrix*
Chimpanzee	*Pan troglodytes*
Chinese necklace dove	*Streptopelia chinensis chinensis*
Chinese painted quail	*Excalfactoria chinensis*
Chinese water deer	*Hydropotes inermis*
Chuckwalla lizard	*Sauromalus obesus*
Coati	*Nasua nasua*
Coatimundi	*Nasua nasua*
Cochin China water dragon	*Physignathus cocincinus*
Cockatiel	*Nymphicus hollandicus*
Collared peccary	*Tayassu tajacu*
Common hamster	*Cricetus cricetus*
Common hippopotamus	*Hippopotamus amphibius*
Common iguana	*Iguana iguana*
Common marmoset	*Callithrix jacchus*
Common peafowl	*Pavo cristatus*
Common rain frog	*Breviceps mossambicus adspersus*
Common rhea	*Rhea americana*
Common shelduck	*Tadorna tadorna*
Common tree-shrew	*Tupaia belangeri*
Common waterbuck	*Kobus ellipoiprymnus*
Common zebra	*Equus burchelli*
Cordon bleu	*Uraeginthus bengalus*
Cormorant	*Phalacrocorax carbo*
Corn snake	*Elaphe guttata*
Coscoroba swan	*Coscoroba coscoroba*
Cotton-headed tamarin	*Saguinus oedipus*

Crane	*Grus*
Cotton-topped tamarin	*Saguinus oedipus*
Cream pony	*Equus caballus*
Crested pelican	*Pelecanus crispus*
Crested wood partridge	*Rollulus rouloul*
Crowned crane	*Balearica pavonina*
Crowned hornbill	*Tockus alboterminatus*
Cuban tree duck	*Dendrocygna arborea*
Curly-tailed lizard	*Leiocephalus schreibersii*
Dama gazelle	*Gazella dama*
d'Arnaud's barbet	*Trachyphonus darnaudii*
De Brazza's guenon	*Cercopithecus neglectus*
De Brazza monkey	*Cercopithecus neglectus*
Demoiselle crane	*Anthropoides virgo*
Deer	Cervidae
Diamond dove	*Geopelia cuneata*
Diana monkey	*Cercopithecus diana*
Dice snake	*Natrix tessellata*
Dolphins	Cetacea
Domestic pig	*Sus scrofa*
Domestic pigeon	*Columba livia* (domesticated)
Domestic sheep	*Ovis aries*
Dwarf hamster	*Phodopus sungorus*
Egyptian cobra	*Naja haje*
Egyptian gerbil	*Gerbillus gerbillus*
Egyptian goose	*Alopochen aegyptiacus*
Eider duck	*Somateria mollissima*
Elephant shrew	*Elephantulus rufescens*
Elliot's pheasant	*Syrmaticus ellioti*
Emu	*Dromaius novaehollandiae*
European bison	*Bison bonasus*
European eagle owl	*Bubo bubo bubo*
European hamster	*Cricetus cricetus*
European hedgehog	*Erinaceus europaeus*
Everetts white eye	*Zosterops everetti*
Falcated teal	*Anas falcata*
Fallow deer	*Dama dama*
Fat dormouse	*Glis glis*
Fennec fox	*Fennecus zerda*
Ferruginous hawk	*Buteo regalis*
Fire-footed squirrel	*Funisciurus pyrrhopus*
Fischers lovebird	*Agapornis fischeri*
Flap-necked chameleon	*Chamaeleo dilepis*
Florida kingsnake	*Lampropeltis getulus*
Formosan sika deer	*Cervus nippon*
Gadwall	*Anas strepera*
Garganey teal	*Anas querquedula*
Gaur	*Bos guarus*
Gelada baboon	*Theropithecus gelada*
Gemsbok	*Oryx gazella*
Gentoo penguin	*Pygoscelis papua*
Giant panda	*Ailuropoda melanoleuca*
Giant toad	*Bufo marinus*
Giraffe	*Giraffa camelopardalis*
Golden eagle	*Aquila chrysaetos*
Golden hamster	*Mesocricetus auratus*
Golden-lion tamarin	*Leontopithecus rosalia rosalia*
Golden song sparrow	*Passer luteus*
Gorilla	*Gorilla gorilla*
Grasshopper mouse	*Onychomys leucogaster*
Great condor	*Vultur gryphus*
Greater flamingo	*Phoenicopterus ruber*
Greater horseshoe bat	*Rhinolophus ferrumequinum*
Greater Indian hornbill	*Buceros bicornis*
Greater kudu	*Tragelaphus strepsiceros*
Greater plated lizard	*Gerrhosaurus major*
Greater siren	*Siren lacertina*
Greater snow goose	*Anser caerulescens atlanticus*
Green cardinal	*Gubernatrix cristata*
Green and gold tanager	*Tangara schrankii*
Green jay	*Cyanocorax yncas*
Grevy's zebra	*Equus grevyi*
Grey-headed gallinule	*Porphyrio poliocephalus poliocephalus*
Greylag goose	*Anser anser*
Grey parrot	*Psittacus erithacus*
Grey seal	*Halichoerus grypus*
Grey starling	*Sturnus cineraceus*
Guanaco	*Lama guanicoe*
Guinea-fowl	*Numida meleagris*
Guinea pig	*Cavia porcellus*
Hamster	*Cricetus cricetus*
Hare	*Pentalagus*
Harvest mouse	*Micromys minutus*
Hawaiian goose	*Branta sandvicensis*
Hawksbill turtle	*Eretmochelys imbricata*
Herring gull	*Larus argentatus*
Hog deer	*Axis porcinus*
Honeycreeper	*Cyanerpes* sp
Hooded crane	*Grus monacha*
Human	*Homo sapiens*
Humboldt's penguin	*Spheniscus humboldti*
Hummingbird	Apodidae
Hump-backed whale	*Megaptera novaeangliae*
Iguana	*Iguana iguana*
Imperial pheasant	*Lophura imperialis*
Impeyan pheasant	*Lophophorus impeyanus*
Indian elephant	*Elephas maximus*
Indian fruit bat	*Pteropus giganteus*
Indian mongoose	*Herpestes edwardsi*
Indian muntjac	*Muntiacus muntjak*
Indian rhinoceros	*Rhinoceros unicornis*
Indian ring-necked parrakeet	*Psittacula krameri manillensis*
Jacaré cayman	*Caiman crocodilus yacare*
Jackson's hornbill	*Tockus deckeni jacksonii*

Jaguar	*Panthera onca*
Java sparrow	*Padda oryzivora*
Jerdon's imperial pigeon	*Ducula badia cuprea*
Kenya eagle owl	*Bubo capensis mackinderi*
King penguin	*Aptenodytes patagonica*
Kinkajou	*Potos flavus*
Kori bustard	*Choriotis kori*
Kudu	*Tragelaphus strepsiceros*
Laboratory mouse	*Mus musculus*
Lady Amherst's pheasant	*Chrysolophus amherstiae*
Lar gibbon	*Hylobates lar*
Laughing kookaburra	*Dacelo norvaeguineae*
Laysan teal	*Anas platyrhynchus laysanensis*
Leopard	*Panthera pardus*
Leopard ground gecko	*Eublepharis macularius*
Lesser cerastes viper	*Cerastes vipera*
Lesser flamingo	*Phoeniconaias minor*
Lesser snow goose	*Anser caerulescens caerulescens*
Lesser sulphur-crested cockatoo	*Cacatua sulphurea*
Lion	*Panthera leo*
Llama	*Lama glama*
Long-haired spider monkey	*Ateles belzebuth*
Macaw	Psittacidae
Magpie	*Pica pica pica*
Malayan giant squirrel	*Ratufa bicolor*
Mallard	*Anas platyrhynchos*
Malayan horned frog	*Megophrys monticola nasuta*
Manchurian crane	*Grus japonensis*
Mandarin duck	*Aix galericulata*
Mandrill	*Mandrillus sphinx*
Mara	*Dolichotis patagonum*
Marabou stork	*Leptoptilos crumeniferus*
Margay	*Felis wiedii*
Markhor	*Capra falconeri*
Mealy rosella	*Platycercus adscitus palliceps*
Mediterranean spur-thighed tortoise	*Testudo graeca*
Minnie Downs River mouse	*Pseudomys australis*
Montpellier snake	*Malpolon monspessulanus*
Moorhen	*Gallinula chloropus chloropus*
Moose	*Alces alces*
Mouflon	*Ovis musimon*
Mountain zebra	*Hippotigris zebra*
Mountain witch dove	*Geotrygon versicolor*
Musk ox	*Ovibos moschatus*
Mute swan	*Cygnus olor*
Muscovy duck	*Cairina moschata*
Naked mole rat	*Heterocephalus glaber*
Nepal hill mynah	*Gracula religiosa intermedia*
Nilgai	*Boselaphus tragocamelus*
North American turkey	*Meleagris gallopavo*
North Island brown kiwi	*Apteryx australis mantelli*
North western garter snake	*Thamnophis ordinoides*
Okapi	*Okapia johnstoni*
Olive baboon	*Papio anubis*
Onager	*Asinus hemionus*
Orang utan	*Pongo pymaeus*
Orange-winged Amazon parrot	*Amazona amazonica*
Oriental small-clawed otter	*Amblonyx cinerea*
Oryx	*Oryx*
Ostrich	*Struthio camelus*
Owl monkey	*Aotus trivirgatus*
Owls	Strigidae
Oystercatcher	*Haemotopus ostralegus*
Palestine viper	*Vipera xanthina palaestinae*
Pancake tortoise	*Malacochersus tornieri*
Patagonian crested duck	*Anas specularioides specularioides*
Pekin robin	*Leiothrix lutea*
Père David's deer	*Elaphurus davidianus*
Pig-tailed macaque	*Macaca nemestrina*
Pink-footed goose	*Anser fabalis brachyrhynchus*
Pochard	*Aythya ferina*
Polar bear	*Thalarctos maritimus*
Pope's pit viper	*Trimeresurus popeorum*
Prairie marmot	*Cynomys ludovicianus*
Princess of Wales parrakeet	*Polytelis alexandrae*
Przewalski's horse	*Equus przewalskii*
Pudu	*Pudu pudu*
Puma	*Felis concolor*
Purple honeycreeper	*Cyanerpes caeruleus*
Rabbit	*Oryctolagus cuniculus*
Rat	*Rattus*
Ravergier's racer snake	*Coluber ravergieri nummifer*
Razorbill	*Alca torda*
Red-billed toucan	*Ramphastos tucanus*
Red-crested pochard	*Netta rufina*
Red crowned crane	*Grus japonensis*
Red-crowned parrakeet	*Cyanoramphus novaezelandiae*
Red deer	*Cervus elaphus*
Red-eared terrapin	*Chrysemys scripta elegans*
Red-eared waxbill	*Estrilda astrild*
Red kangaroo	*Macropus rufus*
Red-legged honeycreeper	*Cyanerpes cyaneus*

Red-mantled tamarin	*Saguinus fusicollis illigeri*
Red-necked wallaby	*Macropus rufogriseus*
Red panda	*Ailurus fulgens*
Red-rumped parakeet	*Psephotus haematonotus*
Red and yellow barbet	*Trachyphonus erythrocephalus*
Redshank	*Tringa totanus*
Reeves's muntjac	*Muntiacus reevesi*
Reeves's pheasant	*Symaticus reevesi*
Reindeer	*Rangifer tarandus*
Rhea	*Rhea americana*
Ring-tailed lemur	*Lemur catta*
Roan antelope	*Hippotragus equinus*
Rock cavy	*Kerodon rupestris*
Rockhopper penguin	*Eudyptes crestatus*
Rosy faced lovebird	*Agapornis roseicollis*
Rosy flamingo	*Phoenicopterus ruber ruber*
Rothschild's grackle	*Leucopsar rothschildi*
Royal python	*Python regius*
Ruff	*Philomachus pugnax*
Ruffed lemur	*Lemur variegatus,*
Sable antelope	*Hippotragus niger*
Sacred ibis	*Threskiornis aethiopicus*
Sarus crane	*Grus antigone*
Scarlet ibis	*Eudocimus ruber*
Scimitar-horned oryx	*Oryx tao*
Secretary bird	*Sagittarius serpentarius*
Serval	*Felis serval*
Sharpe's starling	*Cinnyricinclus sharpii*
Shiny cowbird	*Molothrus bonariensis*
Siberian chipmunk	*Tamias sibiricus*
Siberian tiger	*Panthera tigris*
Sika deer	*Cervus nippon*
Silvery marmoset	*Callithrix argentata*
Sitatunga	*Tragelaphus spekei*
Skink	*Scincus* sp.
Slow loris	*Nycticebus coucang*
Snowy owl	*Nyctea scandiaca*
Soay sheep	*Ovis aries*
Sonnerat's jungle fowl	*Gallus sonneratii.*
Sooty mangabey	*Cercocebus atys*
South African shelduck	*Tadorna cana*
Speckled pigeon	*Columba guinea*
Spectacled bear	*Tremarctos ornatus*
Spiny mouse	*Acomys cahirinus*
Spoonbill	*Platalea leucorodia*
Spotted-flanked barbet	*Tricholaema lacrymosum*
Spotted genet	*Genetta tigrina*
Squirrel monkey	*Saimiri sciureus*
Steppe lemming	*Lagurus lagurus*
Striped grass mouse	*Lemniscomys striatus*
Sugar glider	*Petaurus breviceps*
Surinam toad	*Pipa pipa*
Swainson's toucan	*Ramphastos ambiguus swainsonii*
Swamp deer	*Cervus duvauceli*
Tarictic hornbill	*Penelopides panini*
Tawny owl	*Strix aluco*
Teal	*Anas crecca*
Thicket rat	*Grammomys dolichurus*
Thick tailed bushbaby	*Galago crassicaudatus*
Thomson's gazelle	*Gazella thomsoni*
Tiger	*Panthera tigris*
Timor deer	*Cervus timorensis*
Toco toucan	*Ramphastos toco*
Tree shrew	*Tupaia*
Tufted duck	*Aythya fuligula*
Turquoisine parakeet	*Neophema pulchella,*
Vervet monkey	*Cercopithecus pygerythrus*
Vietnamese pot-bellied pig	*Sus scrofa*
Virginian opossum	*Didelphis virginiana*
Waterbuck	*Kobus ellipsiprymnus*
Wattled starling	*Creatophora cinerea*
Western diamond-back rattlesnake	*Crotalus atrox*
White-backed vulture	*Gyps africanus*
White-bellied go-away bird	*Corythaixoides leucogaster*
White-cheeked touraco	*Tauraco leucotis*
White-faced Saki monkey	*Pithecia pithecia*
White ibis	*Eudocimus albus*
White-naped crane	*Grus vipio*
White pelican	*Pelecanus onocrotalus*
White rhinoceros	*Ceratotherium simum*
White-throated jay thrush	*Garrulax albogularis*
Wild boar	*Sus scrofa*
Wildebeest	*Connachaetes taurinus*
Windsor white goat	*Capra hircus*
Wolf	*Canis lupus*
Yak	*Bos grunniens*
Yellow baboon	*Papio cynocephalus*
Yellow-fronted Amazon parrot	*Amazona ochrocephala*
Yellow mongoose	*Cynictis penicillata*
Zebra finch	*Poephila guttata*