Frequency and Types of Tumors in Mammals and Birds of the Philadelphia Zoological Garden

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The post mortem records of the Philadelphia Zoological Garden are continuous since 1901. Reviews of these records for each decade through 1931 have shown that the frequency and types of malignant tumors did not change appreciably during this period (7, 8, 17). The frequency for all taxonomic groups was generally proportional to longevity, which often had been limited by nutritional disease. The types and locations of the tumors were not unusual, except perhaps in certain groups of birds.

During 1935 the traditional and often inadequate diets then common to zoological gardens were replaced in the Philadelphia Zoological Garden by controlled diets (19, 20). Since then, the frequency of tumors has increased in animals of a number of taxonomic groups.

The present review will determine whether this increase may be explained by increased longevity or whether other factors must be suggested. At the same time, we may also determine whether the types and locations of the more common tumors have changed with improved nutrition. This study will compare the records for 1901 to 1934 with those from 1935 to 1956, i.e., 33 years before and 21 years after diets were improved.

MATERIALS AND METHODS

The records of approximately 15,000 mammals and birds of over 40 orders and about 120 families have accumulated during this period of 54 years.

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However, approximately 75 per cent of this series (12, 107) have been representatives of five orders of mammals and four orders of birds. The predominance of these animals in this series reflects their continuing abundance in the collection of this zoological garden throughout the period of the study. The five orders of mammals are: Primates (sub-human), Carnivora, Artiodactyla, Rodentia, and Marsupialia; the birds: Psittaciformes, Galliformes, Anseriformes, and Passeriformes.

Few of the animals in this series were born in captivity. Thus, age at death rarely may be stated exactly, but must be given as the "exhibition age," i.e., the length of life in the zoo.

Inaccuracies from this source are believed to be distributed about equally among all taxonomic groups, for wild animals usually are imported as immature specimens.

Age may be expressed most conveniently in months, because a majority of the deaths fall into the lower age groups, which reflects the relatively high mortality rates of animals in zoological gardens. In discussing age there will be occasion to refer to estimates of "potential longevity." The basis for these estimates has been outlined earlier, although present evidence demands some upward revision of the published values (16, 17).

OBSERVATIONS

MAMMALS

Frequency of Malignant Tumors

The records for the five orders of mammals and for nine of their families are given in Table 1. This table shows the number of post mortem examinations, the number and frequency, per hun-
The frequency of malignant tumors in five orders of captive wild mammals at the Philadelphia Zoological Garden

A period of 33 years (1901-1934) was compared with that of the same groups during a consecutive period of 21 years (1935-1955).

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>1901-1934</th>
<th>1935-1955</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tumor-bearers</td>
<td>AV. EXHIBITION PERIOD</td>
<td>Tumor-bearers</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>frequency (months)</td>
<td>All animals (months)</td>
</tr>
<tr>
<td>Primates:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cercopithecidae</td>
<td>595</td>
<td>7</td>
<td>1.2</td>
</tr>
<tr>
<td>Total for order</td>
<td>1022</td>
<td>7</td>
<td>0.7</td>
</tr>
<tr>
<td>Carnivora</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felidae</td>
<td>193</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Canidae</td>
<td>208</td>
<td>10</td>
<td>4.8</td>
</tr>
<tr>
<td>Procyonidae</td>
<td>127</td>
<td>7</td>
<td>5.1</td>
</tr>
<tr>
<td>Mustelidae</td>
<td>150</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Viverridae</td>
<td>57</td>
<td>4</td>
<td>7.0</td>
</tr>
<tr>
<td>Ursidae</td>
<td>64</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td>Total for order</td>
<td>801</td>
<td>31</td>
<td>3.9</td>
</tr>
<tr>
<td>Artiodactyla</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bovidae</td>
<td>257</td>
<td>3</td>
<td>1.2</td>
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<tr>
<td>Cervidae</td>
<td>284</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Total for order</td>
<td>641</td>
<td>7</td>
<td>1.1</td>
</tr>
<tr>
<td>Rodentia</td>
<td>461</td>
<td>16</td>
<td>3.5</td>
</tr>
<tr>
<td>Marsupialia</td>
<td>422</td>
<td>9</td>
<td>2.1</td>
</tr>
<tr>
<td>Total mammals</td>
<td>3477</td>
<td>73</td>
<td>2.1</td>
</tr>
</tbody>
</table>

in the numbers of these animals on exhibition from 1930 through 1945 also contributed to this reduction in the number of post mortems.

Nevertheless, the average exhibition age of this series of mammals after 1935 was twice that of the earlier period. A twofold increase in the frequency of malignant tumors for the series as a whole was associated with this increase in age at death.

However, inspection of Table 1 shows that the major contribution to this rise in frequency has come from the carnivores. The primates have had approximately the same rate of increase, about threefold, but with much smaller numbers of tumor-bearers. The artiodactyles have had less than a twofold increase in frequency, while the rodents and marsupials have shown a decrease of about the same magnitude. Still, the numbers of tumor-bearers in these last three orders are so small that the changes in frequency probably reflect chance variations.

From Table 1 it may be seen that the mean age at death increased in each of the orders and their component families during the 1935-55 period. Less frequently, the change in mean exhibition age of each group was accompanied by an increase in mean age at death of its tumor-bearers. A direct comparison between mean ages attained by animals of these taxonomic groups is hampered by the differences in their natural life-spans. This difficulty may be overcome, in part at least, by giving the average age of each family as a percentage of its potential longevity.

The family as a taxonomic unit is, of course, recognized to be rather heterogeneous. Still, present evidence suggests that the potential longevity for the families of mammals of this series may be estimated within reasonable limits of accuracy. The much greater heterogeneity of the orders does not permit useful values to be given for them, however.

Table 2 lists the nine families of mammals in the sequence of Table 1, with the percentage frequency of malignant tumors in each before and after 1935, and the mean ages of all animals and of the tumor-bearers of each family for the two divisions of the period as percentages of potential
longevity. Values for potential longevity of each family also are given.

From Table 2 it may be seen that prior to 1935 the average exhibition age of six families equaled or exceeded 20 per cent of their potential longevity. Four of these groups were carnivores, for which the frequency of malignant tumors was higher than the average for the series as a whole (Table 1). On the other hand, a mean exhibition age of more than 20 per cent of potential longevity was associated with below-average values for frequency of malignant tumors in the Bovidae and the Cervidae. Something of the opposite was found in the Procyonidae, which had the third highest frequency of tumors. However, the range in the magnitude of the increased frequency of malignant tumors from less than twofold (Canidae) to twenty-fold (Mustelidae) does not appear to be related solely to differences in mean ages attained. A review of the types and points of origin of malignant tumors of carnivores may suggest whether increased frequency reflects the action of factors other than age.

**Types of Malignant Tumors**

The anatomical distribution of malignant tumors in mammals of the five orders is shown in Table 3. To save space the records of the animals for the first and second segment of the study are combined. The types of tumors found in mammals during each of the two segments will be given in the text under the heading of the order.

**Primates.**—Of the thirteen neoplasms found in primate animals, twelve were epithelial. Among the latter were four renal carcinomas. These occurred in three male and one female rhesus monkeys (Macaca mulatta). A description of the tumors together with the familial relationship of the tumor-bearers was reported previously (18). Two of the remaining eight epithelial neoplasms were pancreatic carcinomas occurring in a female green guenon (Cercopithecus aethiops sabaeus) and a female yellow baboon (Papio cynocephalus). Two were adenocarcinomas of the gall bladder, one each in a male and female Guinea baboon (Papio papio). The remaining four consisted of two squamous-cell carcinomas, one esophageal in a male Japanese macaque (Macaca fuscata) and one epidermal in a male Moor macaque (Macaca maurus); a carcinoma of the lung in a male squirrel monkey.

### Table 2

**The Frequency of Malignant Tumors in Nine Families of Mammals at the Philadelphia Zoological Garden**

<table>
<thead>
<tr>
<th>FAMILY</th>
<th>1901-1934 Per cent of Potential Longevity Attained</th>
<th>1935-1955 Per cent of Potential Longevity Attained</th>
<th>Estimated Potential Longevity (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per cent frequency/All animals/Tumor-bearers</td>
<td>Per cent frequency/All animals/Tumor-bearers</td>
<td></td>
</tr>
<tr>
<td>Cercopithecidae</td>
<td>1.2/7/44</td>
<td>8.1/15/68</td>
<td>360</td>
</tr>
<tr>
<td>Felidae</td>
<td>2.6/25/89</td>
<td>8.9/42/97</td>
<td>180</td>
</tr>
<tr>
<td>Canidae</td>
<td>4.8/21/64</td>
<td>8.0/27/70</td>
<td>180</td>
</tr>
<tr>
<td>Procyonidae</td>
<td>5.1/16/34</td>
<td>8.5/35/62</td>
<td>180</td>
</tr>
<tr>
<td>Mustelidae</td>
<td>0.8/8/10</td>
<td>17.0/29/46</td>
<td>180</td>
</tr>
<tr>
<td>Viverridae</td>
<td>7.0/27/59</td>
<td>20.0/45/60</td>
<td>180</td>
</tr>
<tr>
<td>Ursidae</td>
<td>6.8/21/46</td>
<td>17.0/54/77</td>
<td>360</td>
</tr>
<tr>
<td>Bovidae</td>
<td>1.2/24/67</td>
<td>5.1/32/65</td>
<td>240</td>
</tr>
<tr>
<td>Cervidae</td>
<td>0.4/23/7</td>
<td>0.8/30/34</td>
<td>200</td>
</tr>
<tr>
<td>6 Families of carnivores</td>
<td>3.9/20/50</td>
<td>12.0/55/65</td>
<td></td>
</tr>
<tr>
<td>9 Families of mammals</td>
<td>2.2/17/40</td>
<td>6.5/29/67</td>
<td></td>
</tr>
</tbody>
</table>
tumors and the variety of organs involved, differences in the tumor types in the two segments will be considered only in the general discussion.

Carnivora.—Felidae: In the first period, two carcinomas of the intestinal tract, one of the jejunum and the other of the rectum, were found in a male tiger (*Panthera tigris*) and a male lion (*Panthera leo*). In contrast, no intestinal neoplasms were found in the second period; however, three carcinomas of the biliary tract were seen.

An adenocarcinoma of the uterus occurred in a female lion and a carcinoma of the thyroid in a female leopard (*Panthera pardus*) in the first period. Four thyroid carcinomas occurred in the second period in an equal number of males and females, including a leopard, a lion, a puma (*Felis concolor*), and a Sumatran tiger (*Panthera tigris sondaica*). The thyroid tumors are believed to be related to a lack of supplemental iodine, since all occurred before 1950, at which time supplemented with thyroid tumors, in order of frequency, were the wolf (*Canis lupus*), the coyote (*Canis latrans*), the raccoon dog (*Nyctereutes procyonoides*), and the red fox (*Vulpes fulva*).

A renal and skin carcinoma were noted in two animals in each period. A carcinoma of the pancreas was described in the early period; a carcinoma of the liver and a lymphosarcoma were seen in the later period. A lung carcinoma in a male red fox was noted in the second period.

Viverridae: A lung carcinoma occurred in each period, one in a male two-spotted palm civet (*Nandinia binotata*) and the other in a male, large, grey mongoose (*Herpestes ichneumon*). The male members of the family had a frequency of 17 per cent malignant tumors, whereas in the females it was 6 per cent. The malignant tumors in the males included, in addition to those of the lung, carcinomas of the nasal mucosa, liver, and cecum in three separate genets (*Genetta genetta*),

**ANATOMICAL DISTRIBUTION OF MALIGNANT TUMORS IN MAMMALS FROM 1901 TO 1955**

<table>
<thead>
<tr>
<th>ANATOMICAL SYSTEMS</th>
<th>PRIMATES</th>
<th>CARNIVORA</th>
<th>ARTIODACTYLA</th>
<th>Rodentia</th>
<th>MARSHOPHIA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermis and hypodermis</td>
<td>1C</td>
<td>4C</td>
<td>1S</td>
<td>1C</td>
<td>6C</td>
<td>1C</td>
</tr>
<tr>
<td>Upper digestive</td>
<td>1C</td>
<td>5S</td>
<td>1C</td>
<td>1C</td>
<td>5C</td>
<td>1C</td>
</tr>
<tr>
<td>Intestinal</td>
<td>1C</td>
<td>1C</td>
<td>1C</td>
<td>1C</td>
<td>5C</td>
<td>1C</td>
</tr>
<tr>
<td>Hepatic, biliary and pancreatic</td>
<td>4C</td>
<td>8C</td>
<td>1C</td>
<td>1C</td>
<td>13C</td>
<td>1C</td>
</tr>
<tr>
<td>Genital</td>
<td>1C</td>
<td>4C</td>
<td>4C</td>
<td>6C</td>
<td>16C</td>
<td>1C</td>
</tr>
<tr>
<td>Endocrine†</td>
<td>10C</td>
<td>10C</td>
<td>1C</td>
<td>4C</td>
<td>20C</td>
<td>1C</td>
</tr>
<tr>
<td>Urinary</td>
<td>4C</td>
<td>5C</td>
<td>1C</td>
<td>4C</td>
<td>1C</td>
<td>1C</td>
</tr>
<tr>
<td>Respiratory</td>
<td>1C</td>
<td>14C</td>
<td>1C</td>
<td>2C</td>
<td>20C</td>
<td>1C</td>
</tr>
<tr>
<td>Cardio-vascular</td>
<td>1S</td>
<td>1S</td>
<td>1S</td>
<td>1S</td>
<td>1S</td>
<td>1S</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>4S</td>
<td>5S</td>
<td>2S</td>
<td>1S</td>
<td>13S</td>
<td>1S</td>
</tr>
<tr>
<td>Skeletal</td>
<td>1S</td>
<td>1S</td>
<td></td>
<td></td>
<td>2S</td>
<td>1S</td>
</tr>
</tbody>
</table>

* No tumors found in the nervous system.
† Except gonads.
C = carcinoma.
S = sarcoma.
a carcinoma of the pancreas in an Indian para-
doxure (Paradoreus hermaproditus), and a car-
cinoma of the liver in an African civet (Civettictis
civetta). The tumors in the female included a
lymphosarcoma in a white-whiskered palm civet
(Paguma larvata leucomyctes) and a carcinoma of
the urinary bladder in a Large Indian civet
(Viverra zibetha).
Procyonidae: Six carcinomas of the nasal sinus
were noted in the early period, five in females
and one in a male. One such carcinoma was
noted in the second period in a female. All seven
occurred within an 11-year period, between 1924
and 1935 and while these animals were housed
in the Small Mammal House. The species involved
were two crab-eating raccoons (Procyon cancri-
vorus), a white-nosed coati (Nasua narica), two
ring-tail coats (Nasua nasua), a kinkajou (Potos
flavus), and a ring-tail cat ( Bassariscus astutus).

An adenocarcinoma of the duodenum was ob-
served in the first period; an adrenal carcinoma
and a renal carcinoma occurred in the second
period.
Ursidae: Mammary carcinomas were seen in
both periods in the bears (Euarctos americana
and Ursus horribilis), which were on exhibition
for 18 and 25 years.
Neoplasms of the tongue were noted in both per-
iods: in the first, a carcinoma in a male black
bear (Euarctos americana) and in the second,
a malignant melanoma in a female Japanese brown
bear (Ursus arctos yesoensis). The remaining tu-
mors noted occurred mainly in endocrine organs.
These included carcinomas of the thyroid gland,
pancreas, and adrenal gland in each of three
separate bears.
Mustelidae: In the first period one malignant
neoplasm, an adenocarcinoma of the duodenum
was found in a male skunk ( Mephitis mephitis).
In the second period, two thyroid carcinomas
were found, one in a male grison (Grison vittata)
and the other in a female American badger (Taxi-
dea taxus). The thyroid carcinomas which occurred
in the second period may be related to social
pressure rather than to iodine deficiency (22).
In addition there were an adenocarcinoma of
the nasal sinus in a female Indian marten (Martes
flavigula), a carcinoma of the mouth in a male
American badger, a pulmonary carcinoma in a
skunk, a carcinoma of the uterus in a silver-blue
mink (Mustela vison), a lymphosarcoma in a female
Florida spotted skunk ( Spilogale ambarelaia),
and one sarcoma each in a female polecat (Mustela pu-
torius) and a female European badger (Meles
meles) in the orbit and spleen, respectively.
Artiodactyla.—Among the members of the fam-
ily Bovidae, a lymphosarcoma occurred in a
male Dorcas goat (Capra hircus) and in a male
wool-less sheep (Ovis aries), one occurring in each
of the two periods. A squamous-cell carcinoma
occurred in the rumen of a female white-tailed
gmn (Connochaetes gnou). In the second period
an adenocarcinoma of the uterus was found in
a gemsbok (Oryx gazella), a blesbok (Damaliscus
albifrons), and a sable antelope (Hippotragus
niger).
The members of the family, Cervidae, included
one tumor-bearer in each period. In the first,
a female white-tailed deer (Odocoileus virginianus)
bore a lymphosarcoma and a carcinoma of the
urinary bladder. In the second period, a male
white-tailed deer also had a lymphosarcoma.
Tumors in other members of the Artiodactyla
included an adenocarcinoma of the uterus in two
European wild boars (Sus scrofa) and a carcinoma
of the gall bladder in a male alpaca (Lama pacos).
Rodentia.—Carcinomas of the mammary gland
were observed in four animals. These included
two white-footed mice (Peromyscus leucopus),
one waltzing mouse (Mus musculus molossinus),
and one Malaccan porcupine (Hystrix brochymura).
The frequency of mammary tumors among female ro-
dents is 2 per cent. No mammary tumors were
observed in the second period.
A carcinoma of the kidney occurred in a fox
squirrel (Sciurus niger) and in a western fox squir-
rel (Sciurus niger rustinvar). Carcinomas of the
thyroid gland were found in a male and a female
coyu rat ( Myocastor coypus). In the second period
a thyroid carcinoma and a renal carcinoma
appeared in each of two coypu rats. The thyroid
neoplasms were associated with thyroid hyper-
plasia that followed crowding and group conflict
(22). A uterine carcinoma was found in a coypu
rat in the first period and in a Brunick's pacaran
(Dinomya branickii) in the second period.
In the early period, an adenocarcinoma of the
lung was noted in a male coypu rat, a squamous-
cell carcinoma of the larynx in a female Azara's
agouti (Dasyprocta azarae), an adrenal carcinoma
in a female Venezuelan agouti (Dasyprocta vene-
ziele), a gastric carcinoma in a male greater Egy-
ptian gerbil (Gerbillus pyramidum), and two lympho-
sarcomas—one in a male Richardson's kangaroo
rat (Dipodomyys ordii richardsoni) and the other
in a male paca (Cuniculus paca).
In the second period an adenocarcinoma of
the urinary bladder was found in a male African
brush-tailed porcupine (Atherurus africanus).
Marsupialia.—The tumors in the first period
included adenocarcinomas of the lungs in a male red kangaroo (*Macropus rufus*), a male rabbit-eared bandicoot (*Thylacomys lagotis*), and an opossum (*Didelphis marsupialis virginianan*); a squamous-cell carcinoma of the fundus of the stomach in a male red kangaroo; a carcinoma of the rectum in a male common dasyure (*Dasyurus viverrinus*); a squamous-cell carcinoma of the perineum in a Tasmanian devil (*Sarcophilus harrisi*); and a lymphosarcoma in a male opossum.

In the second period a mammary adenocarcinoma and a hepatoma were seen in one female great gray kangaroo (*Macropus giganteus*).

### Frequency and Types of Benign Tumors

The records for the five orders of mammals and for nine of their families are given in Tables 4 and 5. Inspection of Table 4 shows that a fourfold increase in the frequency of benign tumors for the series as a whole was associated with the

### Table 4

**The Frequency of Benign Tumors in Five Orders of Captive Wild Mammals at the Philadelphia Zoological Garden**

A period of 33 years (1901–1934) was compared with a subsequent period of 21 years (1935–1955).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primates:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cercopithecidae</em></td>
<td>285</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Carnivora:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Felidae</em></td>
<td>193</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td><em>Canidae</em></td>
<td>208</td>
<td>4</td>
<td>1.9</td>
</tr>
<tr>
<td><em>Procyonidae</em></td>
<td>137</td>
<td>5</td>
<td>3.6</td>
</tr>
<tr>
<td><em>Mustelidae</em></td>
<td>136</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td><em>Viverridae</em></td>
<td>57</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td><em>Ursidae</em></td>
<td>64</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Total for order</td>
<td>361</td>
<td>9</td>
<td>1.6</td>
</tr>
<tr>
<td>Artiodactyla:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bovidae</em></td>
<td>237</td>
<td>3</td>
<td>1.2</td>
</tr>
<tr>
<td><em>Cervidae</em></td>
<td>284</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Total for order</td>
<td>521</td>
<td>5</td>
<td>0.8</td>
</tr>
<tr>
<td>Rodentia:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rattus</em></td>
<td>461</td>
<td>6</td>
<td>1.3</td>
</tr>
<tr>
<td><em>Marsupialia</em></td>
<td>429</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Total mammals</td>
<td>3477</td>
<td>85</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Table 5

**Anatomical Distribution of Benign Tumors in Mammals from 1901 to 1955**

<table>
<thead>
<tr>
<th>Anatomical systems*</th>
<th>Primates</th>
<th>Carnivora</th>
<th>Artiodactyla</th>
<th>Rodentia</th>
<th>Marsupialia</th>
<th>Total†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermis and hypodermis</td>
<td>2E</td>
<td>1E</td>
<td>1F</td>
<td>3F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper digestive</td>
<td>1E</td>
<td>1E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intestinal</td>
<td>1E</td>
<td>1F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatic, biliary and pancreatic</td>
<td>3E</td>
<td>13E</td>
<td>3E</td>
<td>1E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genital</td>
<td>3E</td>
<td>6E</td>
<td>5E</td>
<td>1E</td>
<td>1E</td>
<td>3F</td>
</tr>
<tr>
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<td>5E</td>
<td>2E</td>
<td>5E</td>
<td>1E</td>
<td>4E</td>
<td>2E</td>
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<tr>
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<td>1E</td>
<td>2E</td>
<td>9E</td>
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</tr>
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<td>3E</td>
<td>4E</td>
<td>1E</td>
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<td>Cardiovascular</td>
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<td>1E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nervous</td>
<td>1F</td>
<td>1F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* No tumors found in the lymphatic and skeletal systems.
† Includes species belonging to small orders not listed separately.
Except gonads.

*E* = benign epithelial neoplasm.
*F* = benign fibrous neoplasm.
increase in age at death. As was true with the malignant neoplasms, the major contribution to the rise in frequency of benign neoplasms has come from the primates and carnivores, which have each shown a seven-fold increase. The artiodactyles have had a twofold increase, while the rodents have shown a decrease of the same magnitude, and the marsupials have undergone little or no change. Although the mean age at death increased in each of the orders and their component families during 1935–55, only the mean exhibition age of the carnivores demonstrated an increase in the mean age at death of its benign tumor-bearers.

Among the primates, the benign tumors were found mostly in the endocrine and genito-urinary systems. There were three adenomas of the adrenal cortex, two of the thyroid, four in the kidney, one ovarian, one uterine, and one vaginal. Two adenomas were found in the biliary system, one hepatic and one papilloma in the pharynx. The great majority of the benign tumors were noted in the second period when more sections were taken at post mortem, and, since many of these were microscopic in size, some may have been missed in the first period. No relationship between the malignant tumors described above and these benign tumors could be established, because of differences in sites and the species involved. The renal adenomas occurred in two baboons, a lemur, and an ape, while the carcinomas described above occurred in rhesus monkeys.

The great majority of benign tumors in the carnivores occurred in the endocrine and digestive systems. The latter included the liver, bile ducts, and pancreas. The number of benign neoplasms was considerably greater in the second period than in the first. This may be accounted for on the basis that the great majority of the adenomas, particularly those of the adrenal cortex, were microscopic in size and that more were discovered in the second period when more sections were taken than in the first.

In comparing Tables 3 and 5, it may be seen that the greatest number of benign as well as malignant tumors occurred in the endocrine system and that the hepatic, biliary, and pancreatic systems accounted for a large number of tumors, both malignant and benign. Only in the instances of the felines and canines have the benign thyroid tumors occurred in the same species as have the malignant ones, and therefore a possible relationship might have existed between the development of adenomas and carcinomas. The adenomas of the thyroid gland occurred in the Canidae and Felidae before and shortly after the addition of iodine to the diet and therefore appear to have borne a relationship to the lack of supplementary iodine in the diet.

The same species of Felidae which had malignant tumors of the liver, bile ducts, and pancreas also had adenomas involving the same systems. Although benign and malignant neoplasms were found in other families of carnivores, they did not involve the same species.

A bronchial adenoma was noted in a male dingo (Canis dingo) in the second period.

The benign tumors observed in the artiodactyles consisted almost entirely of adenomas in the Bovidae and Cervidae, adenomas of the bile ducts in the Bovidae, fibroadenomas of the mammary glands, and fibromas of the skin in the Cervidae.

In the rodents, both malignant and benign renal neoplasms occurred in the Sciuridae. These included two female western fox squirrels (Sciurus niger niger) and a female gray squirrel (Sciurus carolinensis). A mammary adenoma was found in an agouti (Dasyprocta aguti) in the first period when the mammary carcinomas were also seen in related species of rodents.

In the marsupials, thyroid adenomas made up the bulk of the benign tumors. One each was found in a male and female rufous rat kangaroo (Aepyprymnus rufescens) and a male and female Tasmanian devil (Sarcophilus harrisii). A hematoma was seen in the same female great gray kangaroo which bore the mammary adenocarcinoma.

Summary

For the primates, carnivores, and artiodactyles there was a significant increase in the frequency of neoplasms in the later period of improved nutrition. Some but not all of the increase in frequency can be attributed to greater longevity. The roles of nutrition and environment are considered as factors that may influence tumor frequency.

As may be seen from Tables 3 and 5, epithelial neoplasms were considerably more numerous than those of mesenchymal tissues. There were differences among the orders in regard to the organ or system most frequently involved with neoplastic change. Among the primates the genito-urinary and accessory digestive organs, such as the liver, biliary system and pancreas, and endocrine organs appeared to be most frequently involved by neoplastic change. Sex and the change in diet were not found to have a significant effect on the organs involved. No relationship between the development of benign and malignant neoplasms could be found.
Among the carnivores, the organs most frequently involved with neoplastic change were those of the endocrine glands and respiratory system. Next in frequency came the organs of the digestive system. The thyroid carcinomas and adenomas appeared before or shortly after the introduction of supplementary iodine to the diets of the Felidae and Canidae and, therefore, seem to have a relationship to the lack of dietary iodine. The development of benign and malignant thyroid neoplasms could be related, since some of the same species were involved.

Carcinomas of the nasal sinuses were seen in members of the families, Procyonidae, Viverridae, and Mustelidae. Eight of the nine occurred within approximately a 10-year period, while these carnivores were housed in the Small Mammal House.

Five pulmonary neoplasms were distributed widely among the families of the carnivores, and four were found in males. The adenocarcinoma of the lung in the primate arose in a male during the same period of time.

Among the carnivores, neoplasms, both benign and malignant, of the accessory digestive tract organs were most numerous in the Felidae in the second period. The remaining tumors were distributed widely among the five other families. Since the same species of Felidae were affected with both benign and malignant neoplasms of the same accessory digestive tract organs, it is possible that the benign neoplasms may have been a step in the development of the malignant lesion. Because of the small numbers of neoplasms involved, no definite conclusions are warranted.

**BIRDS**

**Frequency of Malignant Tumors**

The records of four orders of birds and one of their families are given in Table 6, which shows the frequency, per hundred deaths, of tumor-bearers, and the average exhibition period, in months, for all birds and for tumor-bearers. The records are arranged to allow the values from 1901 to 1934 to be compared with those from 1935 to 1955. Birds with leukemia are not included as tumor-bearers because of the questionable neoplastic nature and early occurrence of the disease.

The number of necropsies per year for these four orders of birds averaged 321 during the first segment of the period of this study and 141 during the second. This difference reflects in part an increase in longevity as indicated by the difference in exhibition age before and after 1935.

In addition, a decrease in the number of birds on exhibition from 1933 to 1955 also contributed to this reduction in the necropsies. The average exhibition age of the series of birds after 1935 was almost twice that of the earlier period.

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Tumor-Bearers</th>
<th>All Tumor-Bearers</th>
<th>Tumor-Bearers</th>
<th>All Tumor-Bearers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Necropsies</td>
<td>No. frequency</td>
<td>No. frequency</td>
<td>No. frequency</td>
<td>No. frequency</td>
</tr>
<tr>
<td>Psittaciformes</td>
<td>Melopsittacus sp.</td>
<td>197</td>
<td>20</td>
<td>10.0</td>
<td>25</td>
</tr>
<tr>
<td>Galliformes</td>
<td>690</td>
<td>7</td>
<td>1.1</td>
<td>27</td>
<td>51</td>
</tr>
<tr>
<td>Anseriformes</td>
<td>601</td>
<td>5</td>
<td>0.8</td>
<td>57</td>
<td>122</td>
</tr>
<tr>
<td>Passeriformes</td>
<td>2977</td>
<td>9</td>
<td>0.3</td>
<td>28</td>
<td>72</td>
</tr>
<tr>
<td>Total birds</td>
<td>7296</td>
<td>51</td>
<td>0.7</td>
<td>90</td>
<td>65</td>
</tr>
</tbody>
</table>

**TABLE 6**

**THE FREQUENCY OF MALIGNANT TUMORS IN FOUR ORDERS OF CAPTIVE WILD BIRDS AT THE PHILADELPHIA ZOOLOGICAL GARDEN**

**A period of 83 years (1901–1934) was compared with a subsequent period of 21 years (1935–1955)**

- Psittaciformes
- Galliformes
- Anseriformes
- Passeriformes
- Total birds

The records of four orders of birds and one of their families are given in Table 6, which shows the frequency, per hundred deaths, of tumor-bearers, and the average exhibition period, in months, for all birds and for tumor-bearers. The records are arranged to allow the values from 1901 to 1934 to be compared with those from 1935 to 1955. Birds with leukemia are not included as tumor-bearers because of the questionable neoplastic nature and early occurrence of the disease.

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In addition, a decrease in the number of birds on exhibition from 1933 to 1955 also contributed to this reduction in the necropsies. The average exhibition age of the series of birds after 1935 was almost twice that of the earlier period.

- Psittaciformes
- Galliformes
- Anseriformes
- Passeriformes
- Total birds

The Galliformes have had a twofold increase in frequency of malignant tumors, whereas the Anseriformes have had a fivefold increase. This increase was associated with a slight increase in the exhibition age.

As was true with all mammals, the mean age at death increased in each of the orders during the 1935–55 period. The mean exhibition age was accompanied by an increase in mean age at
death of the tumor-bearers in all groups except Psittaciformes and Anseriformes. A direct comparison between mean ages attained by the birds of these orders is hampered by the differences in their natural longevity and by the extreme diversity of the material. Indeed, diversity was so great that we have not attempted to compare the mean ages attained by the birds of these several groups.

Types of Malignant Tumors

The anatomical distribution of malignant tumors in birds of the four orders are shown in Table 7. The records of the birds with tumors for the first and second segment of the study are combined. The types of tumors found in birds during each of the two periods will be given in the text under the heading of the order.

Psittaciformes.—The urinary tract had the greatest frequency of tumors. There were sixteen carcinomas of the kidney in the one species, the undulated grass parakeet (Melopsittacus undulatus). The frequency of renal carcinomas in this species was 7.6 per cent in the first period and 5.6 per cent in the second. The frequency of renal tumors for males and females was 7 and 9 per cent, respectively.

Fibrosarcomas in the undulated grass parakeet accounted for seven of the nine sarcomas. The two remaining sarcomas occurred in cockatoos (genus Kakatoë). Four per cent of the fibrosarcomas occurred in male undulated grass parakeets and 2 per cent in females. The primary sites of the fibrosarcomas were the skin, spleen, and intestinal tract.

Anatomical Distribution of Malignant Tumors in Birds From 1901 to 1955

<table>
<thead>
<tr>
<th>ANATOMICAL SYSTEMS*</th>
<th>Psittaciiformes</th>
<th>Galliformes</th>
<th>Anseriformes</th>
<th>Passeriformes</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermis and hypodermis</td>
<td>1C</td>
<td>1C</td>
<td>2C</td>
<td>4C</td>
<td>4C</td>
</tr>
<tr>
<td>Upper digestive</td>
<td>1C</td>
<td>3S</td>
<td>2S</td>
<td>3S</td>
<td>7S</td>
</tr>
<tr>
<td>Intestinal</td>
<td>3S</td>
<td>2S</td>
<td>2S</td>
<td>3S</td>
<td></td>
</tr>
<tr>
<td>Hepatic, biliary and pancreatic</td>
<td>2C</td>
<td>3C</td>
<td>4C</td>
<td>10C</td>
<td></td>
</tr>
<tr>
<td>Genital</td>
<td>5C</td>
<td>2C</td>
<td>3C</td>
<td>7C</td>
<td>12C</td>
</tr>
<tr>
<td>Endocrine</td>
<td>3C</td>
<td>1C</td>
<td>4C</td>
<td>6C</td>
<td></td>
</tr>
<tr>
<td>Urinary</td>
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<td>4C</td>
<td>1C</td>
<td>1C</td>
<td>1C</td>
</tr>
<tr>
<td>Respiratory</td>
<td>1S</td>
<td>3C</td>
<td>5C</td>
<td>8C</td>
<td></td>
</tr>
<tr>
<td>Lymphatic</td>
<td>4S</td>
<td>1S</td>
<td>2S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skeletal</td>
<td>1S</td>
<td>1S</td>
<td>2S</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* No tumors found in the cardiovascular and nervous systems.
† Includes species belonging to small orders not listed separately.
‡ Except gonads.
C = carcinoma.
S = sarcoma.

Galliformes.—The system affected with the greatest frequency of tumors was the urinary tract. The four renal adenocarcinomas occurred in an equal number of male and female golden pheasants (Chrysolophus pictus). The frequency of renal neoplasms among the pheasants was the same in both segments of the study. The frequency in the male was 0.9 per cent and in the female, 0.8 per cent.

The respiratory neoplasms consisted of a carcinoma of the lung in a male peafowl (Pavo cristatus), in a female red jungle fowl (Gallus g. bankiva), and an adenocarcinoma of the lung in a male silver pheasant (Genaecus nycthemerus). The frequency of pulmonary neoplasms was higher in the second period.

The sarcomas arose in three male ring-necked pheasants (Phasianus versicolor). The primary sites included subcutaneous tissue, kidney, spleen, and
skin. In the latter, the neoplasm was a malignant melanoma.

Two carcinomas of the bile ducts developed in male ring-necked pheasants. An adrenal carcinoma was noted in a male ring-necked pheasant and a testicular carcinoma in the same species. An ovarian adenocarcinoma was found in a wild turkey (Meleagris gallopava).

Neoplasms were more numerous among the pheasants (Phasianidae) which outnumbered the other families of Galliformes. There were malignant tumors in ten males and two females, or a frequency of 2.2 per cent in the male and 0.4 per cent in the female. There were five pheasants with malignant tumors in the first period and eight in the second, or a frequency of 0.9 per cent in the first and 2.4 per cent in the second period.

**Anseriformes.**—The system with the greatest frequency of neoplasms was the respiratory. The five carcinomas of the lung arose in the second period and were borne by one male and one female Shoveler duck (Spatula clypeata), a female cinnamon teal (Anas cyanoptera), a female canvas-backed duck (Nyroca valisineria), and a female black-bellied tree duck (Dendrocygna a. autumnalis). The frequency of pulmonary carcinomas in the second period was 1 per cent. None was found in the first period. The frequency was 0.8 per cent in the female and 0.2 per cent in the male.

Of the four sarcomas, one was a myxosarcoma of the pectoral muscle in a female bean goose (Anas f. fabalis), another was a fibrosarcoma of the wing in a male Rupell's spur-winged goose (Plectropterus gambensis ruppelli) and in a female Ross' goose (Chen rossii), and the fourth, a fibrosarcoma of the scalp in a male swan goose (Cygnopsis cygnoid). One squamous-cell carcinoma of the skin was found in a female bean goose (Anser f. fabalis).

Of the digestive tract tumors, there were two esophageal carcinomas, one arising in a female Mandarin duck (Dendronessa galericulata) and the other in a male wood duck (Aix sponsa). Adenocarcinomas of the intestine were seen in a male mallard duck (Anas platyrhynchos) and in a male Canadian goose (Branta canadensis). An adenocarcinoma of the gall bladder arose in a male white-fronted goose (Anser albifrons), a hepatic carcinoma in a male rosy-billed duck (Metopipha pepeosaca) and a female red-headed duck (Nyroca valisineria), a biliary adenoma of the liver in a male Brazilian tree duck (Dendrocygna discolor), and a hepatoma in a female Muscovy duck (Cairina moschata).

A carcinoma of the ovary was borne by a Bahama pin-tail duck (Anas bahamensis), a carcinoma of the testis by both a rosy-billed duck and a swan goose (Cygnopsis cygnoid).

Among the Anseriformes, there was an increase in the occurrence of malignant neoplasms in the second period as compared with the first. The frequency in the males was 1.7 per cent and in the females, 2.5 per cent. The malignant tumors of the digestive system were more frequent among the males than the females, whereas the reverse was true of the pulmonary neoplasms. Tumors of the lower digestive tract were seen in the first segment of the study, and those of the upper tract and accessory organs in the second.

**Passeriformes.**—The genito-urinary system had the highest frequency of malignant tumors in the species of Passeriformes. Among the genital tumors were a carcinoma of the ovary in a canary (Serinus canarius), a testicular carcinoma in a red-beaked weaver (Quelea quelea), a carcinoma of the oviduct in a red-beaked weaver, a testicular carcinoma in an Indian laughing thrush (Trochalopteron lineatum), and a seminoma in a Jardin's babbler (Turdoides bicolor). The frequency of genital tumors was higher in the second period as compared with the first, that is, 0.4 per cent and 0.06 per cent, respectively. The frequency of genital tumors in the male and female was approximately the same.

The renal tumors included a carcinoma in a female American robin (Turdus migratorius) and in a male European black bird (Turdus merula), a carcinoma in a male Java sparrow finch (Padda oryzivora) and in a male long-tailed grass finch (Poephila acuticauda). The frequency of renal tumors was higher in the second period than in the first and higher in the male than in the female.

The neoplasms of the digestive system included an adenocarcinoma of the stomach in a male black-headed finch (Munia malacca), an adenocarcinoma of the pancreas in a male fan-tailed grackle (Quiscalus macrurus), a carcinoma of the liver in a female orange-headed ground thrush (Geokichla c. cirta), a carcinoma of the liver in a female hooded pitta (Pitta eucellata), and a carcinoma of the bile ducts in a male Senegal fire finch (Lagonosticta s. senega.

A fibrosarcoma of the head was noted in a male masked Chinese thrush (Dryonastis perspicillata), a carcinoma of the skin over the mandible in a female Chapman's black thrush (Turdus serranus fuscobrunneus), and a carcinoma of the orbit in a female chaffinch (Fringilla c. coelebs).

**Miscellaneous orders.**—Among the tumors found in the families of birds not listed separately in Tables 6 and 7 and added into the grand total of tumors were the following: three testicular
carcinomas, one pulmonary carcinoma, four carcinomas of the digestive system, including two of the pylorus—one intestinal, and one hepatic. These were scattered widely among several orders of birds.

Frequency and Types of Benign Tumors

The records of the four orders and one family of birds are given in Tables 8 and 9. Inspection of Table 8 shows that a fivefold increase in frequency of benign tumors for the series as a whole was associated with the increase in age at death for both the tumor-bearing birds and the total population. No benign tumors were observed in the undulated grass parakeet in the second period; however, some were noted in both periods in other species of Psittaciformes.

Although there was an increase in the average exhibition period of the Galliformes, this was not accompanied by an increase in the frequency of benign tumors. No benign tumors were noted among the Anseriformes in the first period; however, five were observed in the second. There was only a slight increase in the mean age at death of the total population in the second period.

The frequency of benign as well as malignant tumors was lowest among the Passeriformes. The frequency of benign tumors increased fivefold among the Passeriformes in the second period, while the mean age at death of the population increased only slightly in comparison.

The organ systems affected by benign tumors are shown in Table 9. In the benign as well as the malignant neoplasms, the epithelial type predominated. The systems most involved with benign tumors were the urinary followed by the hepatic, biliary, and pancreatic. Because the same organs were involved with malignant tumors, a relationship between benign and malignant neoplasms was considered. In the case of the Psittaciformes, the renal neoplasms occurred in the same species, the undulated grass parakeet, as did the malignant tumors. This was also true for the Galliformes, in which instance the renal adenomas and carcinomas occurred in the golden pheasant. Since no malignant renal tumors were noted in the Anseriformes, no counterpart could be found for the renal adenomas, which appeared

TABLE 8

THE FREQUENCY OF BENIGN TUMORS IN FOUR ORDERS OF CAPTIVE WILD BIRDS AT THE PHILADELPHIA ZOOLOGICAL GARDEN

A period of 33 years (1901-1934) was compared with a subsequent period of 21 years (1935-1955).

<table>
<thead>
<tr>
<th>Order</th>
<th>Number of birds</th>
<th>Av. exhibition period (months)</th>
<th>Tumor-bearing birds</th>
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<tr>
<td></td>
<td></td>
<td>1901-1934</td>
<td>1935-1955</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psittaciformes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melopsittacus sp.</td>
<td>197</td>
<td>3</td>
<td>1.5</td>
<td>26</td>
<td>28</td>
<td>66</td>
</tr>
<tr>
<td>Total for order</td>
<td>1218</td>
<td>6</td>
<td>0.5</td>
<td>41</td>
<td>30</td>
<td>309</td>
</tr>
<tr>
<td>Galliformes</td>
<td>660</td>
<td>2</td>
<td>0.3</td>
<td>27</td>
<td>44</td>
<td>362</td>
</tr>
<tr>
<td>Anseriformes</td>
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<td>0</td>
<td>57</td>
<td>57</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Passeriformes</td>
<td>2877</td>
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<td>0.1</td>
<td>28</td>
<td>73</td>
<td>287</td>
</tr>
<tr>
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<td>11</td>
<td>0.1</td>
<td>30</td>
<td>38</td>
<td>7286</td>
</tr>
</tbody>
</table>

TABLE 9

ANATOMICAL DISTRIBUTION OF BENIGN TUMORS IN BIRDS FROM 1901 TO 1955

<table>
<thead>
<tr>
<th>Anatomical system*</th>
<th>Psittaciformes</th>
<th>Galliformes</th>
<th>Anseriformes</th>
<th>Passeriformes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermis and hypodermis</td>
<td>4E</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>5F</td>
</tr>
<tr>
<td>Intestinal</td>
<td>1E</td>
<td>2E</td>
<td>2E</td>
<td>2E</td>
<td>6E</td>
</tr>
<tr>
<td>Hepatic, biliary and pancreatic</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>3E</td>
</tr>
<tr>
<td>Endocrine</td>
<td>1E</td>
<td>2E</td>
<td>2E</td>
<td>2E</td>
<td>6E</td>
</tr>
<tr>
<td>Urinary</td>
<td>2E</td>
<td>2E</td>
<td>3E</td>
<td>3E</td>
<td>6E</td>
</tr>
<tr>
<td>Respiratory</td>
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<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>3E</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>3E</td>
</tr>
<tr>
<td>Skeletal</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>1E</td>
<td>3E</td>
</tr>
</tbody>
</table>

* No tumors found in the upper digestive, genital, lymphatic, and nervous systems.
† Includes species belonging to small orders not listed separately.
‡ Except gonads.
§ = benign epithelial neoplasm.
¶ = benign fibrous neoplasm.
in a female bean goose (Anser f. fabalis) and a male Brazilian tree duck (Dendrocygna discolor). Although renal carcinomas and adenomas occurred in the Passeriformes, they did not appear in the same species. Renal adenomas were noted in a male great weaver (Hyphantornis grandis), a male green glossy starling (Lamprocolius chalybeus), and a female Baya weaver (Ploceus baya).

The benign neoplasms which arose in the hepatic, biliary, and pancreatic systems were not found in the same species of birds that had the malignant tumors of the same organs. Under tumors of the dermis and hypodermis, the four listed under Psittaciformes consisted of multiple lipomas in two female roseate cockatoos (Kakatoe roseicapilla) and in two male white-fronted parrots (Amazona leucocephala).

Among the families not listed separately but added in the total of benign tumor-bearers in Table 9 were four animals with tumors of the kidney, five with neoplasms of the digestive organs, and two with tumors of the lungs. The tumors of the lungs were classified as pulmonary adenomatosis and arose in female toucan barbets (Semnornis rhamphastinus). Although this lesion has been diagnosed in man, various domestic, wild, and laboratory mammals (9, 13, 30), the barbet appears to be the only bird in which these lesions have been described. The remaining benign tumors were distributed widely in birds of several orders.

Summary

Among the birds there was a significant increase in the frequency of malignant neoplasms in the later period. The increase in frequency may be partly attributed to greater longevity, since both the frequency of malignant neoplasms and the average exhibition period increased in the second segment. This held true for all birds except the Anseriformes and members of the genus Melopsittacus. In these two groups, the average exhibition period showed little or no increase, despite the increased frequency of malignant tumors.

Epithelial neoplasms were considerably more numerous than those of mesenchymal tissue. From the totals in Tables 7 and 9, it may be seen that the genito-urinary system was the most frequent site of neoplastic change. In the Psittaciformes and Galliformes, the urinary system was most frequently the site of neoplastic change, whereas in the Passeriformes, both genital and urinary systems were most frequently involved. The digestive organs and the lungs were the most frequent sites of neoplastic change in the Anseriformes.

The development of benign and malignant neoplasms could be related in some species, such as in the undulated grass parakeet and the golden pheasant, in which both benign and malignant renal neoplasms occurred.

DISCUSSION

The occurrence of neoplasms in captive wild mammals and birds increased in frequency from 1935 to 1955 over that of the previous period from 1901 to 1934. There was a concomitant increase in longevity which was attributed in part to better nutrition of the animals in the second segment of the study.

A similar study recently made on the changing frequency of arteriosclerosis in the mammals and birds at the Philadelphia Zoological Garden indicated that other factors not related to diet were important in the development of vascular lesions (92). It should be noted that the material described in the study of arteriosclerosis covered a period of 40 years, including the intervals of 1916–1930 and 1981–1955, whereas the present one encompasses a span of 50 years.

Factors over and above increased longevity must also be considered to account for the greater frequency of tumors, particularly since the latter has grown out of proportion to the increased life span in groups of animals such as the carnivores, the genus Melopsittacus, the Anseriformes, and Passeriformes. The mean age at death of the tumor-bearers was also greater in several orders and families and suggested the need for a longer incubation period for these tumors to appear.

Among the factors to be considered are the carcinogens in food and environment, infectious agents, physiological variables, dietary deficiencies, familial lesions, and physical trauma.

Food additives such as dyes, preservatives, and antistaling agents, as well as food contaminants such as insecticides, fungicides, antispurring and antimaturation agents, hormonal fattening agents, antibiotics, detergents, and radioactive substances are possible carcinogens for captive wild animals. Some of the above have been shown to be carcinogenic for animals under experimental conditions, while others have not been fully investigated (10, 11). Substances which may be found in the environment of the animals and are believed to contain carcinogenic fractions are cosmic rays, smog (exhaust fumes from factories and locomotives), radioactive substances, and insecticide, deodorizer, and paint vapors (12).

There are few experimental studies of the carcinogenic effects of environmental factors, and these have been carried out mainly on mice and...
rats (11). One investigation demonstrating the carcinogenic effect of hydrocarbons was performed on the undulated grass parakeet (25). Since this species of bird is especially susceptible to the development of neoplasms, a search for additional carcinogens such as those that might be found in seed preservatives and insecticides would possibly prove rewarding.

The occurrence of nasal sinus carcinomas in the carnivores housed in the Small Mammal Building during a 10-year period points to the need for investigating carcinogens which might have been inhaled by the animals and which are not species-specific, since the carnivores so affected belonged to three different families. At the time these tumors developed, none of the rodents or primates simultaneously housed in this building was affected. Moreover, with this building apparently unchanged in any way, no other examples of this tumor have appeared here or in other parts of the collection.

The lung carcinomas, which occurred predominantly in the second period, give rise to speculation on the role of the increasing amounts of carcinogenic chemicals in the air as a result of increased industrialization. The high frequency of lung cancer in the Anseriformes in the past 10 years would seem to emphasize the importance of air contamination, since these species are kept in outdoor pens throughout the year. During 1956, five additional carcinomas of the lung occurred in the members of the order Anseriformes (21).

Recently, there has been considerable interest in correlating increasing amounts of ionizing radiation in the environment with the rising incidence of lymphatic tumors in man (26). In the present study a slight increase in the frequency of lymphosarcomas has been noted in the later period, as follows: 0.9 per cent in the carnivores and 0.2 per cent in the artiodactyles. No increase in the frequency of bone tumors was observed.

Because filtrable agents are responsible for or contribute to neoplastic or neoplastic-like changes in a number of animals, they must be considered as possible etiologic factors in the development of tumors in captive wild animals. Among the conditions experimentally produced by a filtrable agent are some of the mammary tumors, leukemias, and parotid-gland tumors of mice; the Lucké renal carcinoma of the leopard frog; fibroma of deer; papilloma, fibroma, and myxoma of rabbits; and some forms of leukemia of chickens (5). In addition, the nasal adenoma of sheep might be included (4).

A lesion of questionable neoplastic nature has been described recently in rhesus monkeys in which an outbreak of subcutaneous tumors occurred. The lesions which could be produced experimentally by an agent regressed spontaneously (9).

The mammary tumors noted in the captive wild rodents may indicate the possibility of a milk factor similar to that described in mice. It should be noted that, even in mice, mammary tumors appear in the absence of the agent.

Infectious hepatitis is known to affect birds and carnivores in captivity, although the agent is different in the two groups (21). The lesions of hepatitis have been seen in association with liver neoplasms, malignant and benign. The relationship of infectious hepatitis and liver cancer in man has been postulated by several investigators (27, 29).

Pulmonary adenomatosis in the barbets might point to an agent of infectious origin, since viral and bacterial agents have been incriminated in similar lesions of sheep (6).

Factors which have been shown to influence the host's metabolism and thereby indirectly or directly influence tumor development are diet, temperature, inadequate exercise, and overcrowding. These affect the genesis of mammary tumors in mice (14, 28). The influence of stress due to crowded conditions and the conflict has been noted in the thyroid gland as taking the form of hyperplasia in rodents (24). The importance of stress in neoplastic development in the thyroid gland among captive wild species, where conflict is common, must be considered.

Parity, with the opportunity for lactation, is regarded on statistical evidence in woman as a defense against mammary cancer (28). Certain mammals, such as bears, when kept in captivity, commonly breed but kill the young at birth. The number of mammary tumors found in this collection, though small, represents a relatively high frequency of all animals examined.

The reproductive life of animals in captivity may be considerably altered from that in their native habitat. Some are rarely bred, whereas others, such as the rodents, reproduce at short intervals from maturation to death. Under laboratory conditions, mammary tumors can be induced in milk agent-free strains of mice by forced breeding (23).

Several dietary factors have been shown to influence the genesis of neoplasms in laboratory animals. These include the level of caloric intake and deficiencies of essential amino acids, vitamins, and minerals (31). Thyroid tumors have been induced in rats maintained on a low-iodine diet.
When fed to mice and rats, goitrogens alone are capable of producing thyroid neoplasms (9), and some types, such as cabbage and rapeseed, may play a part in the development of thyroid neoplasms in captive wild animals, although no definite proof can be found. In one zoological garden, thyroid neoplasms are frequent in the undulated grass parakeet; however, the composition of the diet is not known (92). In the present study a relationship between a dietary deficiency of iodine and thyroid cancer in the carnivores seems probable. The great majority of the thyroid neoplasms arose during the time when supplementary iodine was not included in the diet.

The renal carcinomas found in the rhesus monkeys have been considered previously as being familial in origin (18). A report of renal neoplasms in several rhesus monkeys has been made elsewhere; however, it is not known whether these tumor-bearers were related (1). Colony inbreeding may be of importance in the high frequency of tumors among the undulated grass parakeets. A similar high frequency of tumors among the undulated grass parakeets has been reported from another zoological garden (32).

The role of trauma in the development of neoplasms is still considered important by some investigators (15). Animals in captivity sustain considerable amounts of trauma, although in those developing neoplasms no direct correlation could be made.

It is apparent that there is no simple cause of cancer but that the neoplastic reaction is the result of a complex interplay of many factors, a few of which are mentioned here.

SUMMARY

The increased frequency of neoplasms seen in the period of 1935-1955 was associated with an increased mean age at death in most captive wild species. The increased longevity is attributed to better nutritional and environmental care in the second period (1935-1955) as compared with the first (1901-1934). The increase in tumor frequency seen in the second period can be explained in part by extended life spans; however, other agents must also be considered, such as the increased distribution of carcinogens in the environment and diet of the animals.

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Frequency and Types of Tumors in Mammals and Birds of the Philadelphia Zoological Garden

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