Trends in Tissue-Specific Cancers

by

Ashley Peraza

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Graduate Supervisory Committee:

Carlo Maley, Co-Chair
Amy Boddy, Co-Chair
Cristina Baciu

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ABSTRACT

A big part of understanding cancer is understanding the cellular environment it thrives in by analyzing it from a microecological perspective. Humans and other species are affected by different cancer types, and this highlights the notion that there may be a correlation between specific tissues and neoplasia prevalence. Research shows that humans are the most susceptible to adenocarcinomas and carcinomas which include the following tissues: lungs, breast, prostate, and pancreas. Furthermore, research shows that adenocarcinoma accounts for 38.5% of all lung cancer cases, 20% of small cell carcinomas, and 2.9% of large cell carcinoma. The incidence of the most common cancer types in humans is consistently increasing annually. This study analyzes trends of tissue-specific cancers across species to examine possible contributors to vulnerability to cancer. I predicted that adenocarcinomas would be the most prevalent cancer type across the tree of life. To test this hypothesis, I reviewed over 130 species that reported equal to or greater than 50 individual necropsy pathology records across 4 classes (Mammalia, amphibia, Reptilia, aves) and ranked them by neoplasia prevalence. This information was then organized in tables in descending order. The study's resulting tables and data concluded that the hypothesis was correct. I found that across all species adenocarcinomas were the most common cancer type and account for 30.4% of malignancies reported among species. Future research should investigate how organ size contributes to neoplasia prevalence.

DEDICATION

This research is dedicated to my father-in-law Cedric M. Allison who lost his life to non-smoking induced lung cancer, and adenocarcinoma. He inspired this study because he wanted to make a difference in how cancer is detected and highlight its predictive nature. Our family believes that if Cedric's cancer had been detected earlier, he would have had a better chance of recovery. Unfortunately, Cedric succumbed to this disease on February 2, 2022. May he rest in peace and celebrate the discoveries made in his name.

ACKNOWLEDGEMENTS

Special thanks to my team of undergraduate and high school student researchers for their enormous contributions toward this project, my faculty committee members for providing me endless amounts of support and mentorship, and my family who have stayed on the sidelines as I try to accomplish my dreams.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

BACKGROUND

General Overview of Evolutionary Theory

Evolutionary theory is arguably the most fundamental theoretical framework to prioritize in cancer research across species from a cellular level or organismal level. The theory of evolution is described as the notion that species gradually change over time and are genetically related (Tollis et al., 2017). It uses information from genetic variation in a population that has effects on the phenotypes of a species. Some derivatives of the theory are life-history, biological, and behavioral strategies which vary depending on the environmental context of the species. This biological perspective is especially important for understanding the development of cancer, cancer suppression mechanisms, and identifying effective cancer therapies. Somatic evolution is responsible for tumor cells' broad range of phenotypes(Lucas & Keller, 2014). For example, some phenotypes involve rapid proliferation while others experience quiescence. Life history theory is comparable to an evolutionary blueprint for understanding diversity among cancer cells and the potential implications of neoplasia prevalence differences within species.

Furthermore, the life-history theory derivative suggests that cancer susceptibility should be influenced by evolutionary trade-offs. Trade-offs can be described as a negative phenotypic or genetic linkage between fitness components within a population (Fabian & Flatt, 2012). A genetic trade-off is observed in a population when there is an evolutionary change in a trait that increases fitness for the population and is also correlated to a different trait that decreases fitness for the population. A well-known example of this can be observed in seen in somatic maintenance and cellular reproduction. Somatic maintenance is the process that describes the expenditure of energy to avoid or repair the damage, which ends up preserving the integrity of the organism (Lucas & Keller, 2014). Cancer cells experience trade-offs between maximizing growth and survivability (Fabian & Flatt, 2012). In other words, these mutated cells depend on their flexibility and tolerance to an unstable environment or conditions to survive, replicate, and ultimately develop the disease. These cells can reproduce rapidly (fitness component) at the expense of an increased likelihood of cell death - a process known as apoptosis (negative phenotype) (Lucas & Keller, 2014).

Selective Pressures in Evolution

A selective pressure is an evolutionary force that shapes what adaptive traits develop for a species to survive (Tollis et al., 2017). Certain animals have certain traits based on their life-history variables. For example, mice have very short lifespans, fast reproduction, and many offspring. So, they are pressured to focus on reproduction and not tumor suppression (low somatic maintenance) (Abegglen et al., 2015). Elephants, on the other hand, have a long lifespan, reproduce slowly, and have few offspring, so they were able to focus on the development of tumor suppressor genes in their evolution (high somatic maintenance) (Abegglen et al., 2015). Other variables, such as metabolic rate, may impact cancer risk because larger animals tend to have lower basal metabolic rates than smaller ones (Tollis et al., 2017). Relating to cancer rates across species then, the free radicals produced due to metabolism may propel tumor initiation, supporting Peto's paradox (no correlation between size and cancer rates), since smaller animals tend to have smaller masses, higher metabolic rates, and higher cancer rates (Dang, 2015).

Lifespan can impact cancer risk because the longer an animal lives, the higher the risk of cancer should be. This is because they will experience more cell divisions over the course of their lifespan. However, if a long-lived animal does not have high neoplasia rates, it indicates possible tumor suppression mechanisms (Tollis et al., 2017). Adult weight can impact cancer rates similarly to lifespan, since the heavier the animal, the more cells they have, and so the animal should have more neoplasms unless they have evolved ways to battle cancer (Tollis et al., 2017). Therefore, the life history variables max longevity (life span), metabolic rate, and adult weight (body mass), may be related to cancer incidences.

Cancer Prevalence in Humans

The American Cancer Society has reported that the most common cancer type diagnosed in humans are adenocarcinomas with especially high rates of breast cancer in women and prostate cancer in men (American Cancer Society, 2018). Shockingly, the organization projected that in 2022, over 30% of novel cancer diagnoses will account for women with breast cancer and 27.3% for men with prostate cancer (Buchholz & Richter, 2022). Other common cancer types seen in humans include colorectal, melanoma, bladder, and cancer in the uterus (Buchholz & Richter, 2022). It is worth noting that there is an apparent sex bias in human cancers that can be a key contributor to the high cancer prevalence seen in reproductive tissues (Dorak & Karpuzoglu, 2012). Studies consistently showed that males have significantly higher cancer prevalence than females at any given age (Dorak & Karpuzoglu, 2012; Kim et al., 2018). In fact, the incidence of cancer was reported as about 20% higher in men than in women and the mortality rate was reported as 40% higher in men in the United States (Kim et al., 2018). There are several hypotheses that dive into the reason behind his concept. One hypothesis can evaluate the difference in male and female regulation on a genetic or molecular level. For example, gene polymorphism and altered enzymes that are involved in drug metabolism have been found to drive differences between the two genders (Kim et al., 2018). Another can investigate the role pheromones have on somatic maintenance. A clear trend such as the one seen in humans is neither explicitly observed in animals. In fact, there are minimal studies that investigate the correlation between sex as a biological variable and cancer incidence across species.

Humans and other animals are commonly affected by different cancer types, highlighting the variation in organ-specific cancer risk across species. One reason for this discrepancy is represented by environmental factors, such as smoking, poor diets, and pollution. Lung cancer is one result of this, with 1 in 16 people developing lung cancer, and 10-20% of smokers developing cancer, making it one of the most common cancers in humans (American Cancer Society, 2021). In fact, it is the second most common cancer for men and women (Buchholz & Richter, 2022). Other very common cancers that are so pervasive due to the environment are colorectal (colon and rectum) cancers, bladder cancer, and skin cancer (American Cancer Society, 2021). Human diet, alcohol consumption, smoking, pollution, exposure to chemicals while working, and ultraviolet exposure all contribute to the frequency of certain cancers. Additionally, other cancers like breast and prostate are sex-specific, with ⅛ of women and men developing their respective types (American Cancer Society, 2021). These cancers have inherited risk and are very common because of the growth effects of hormones such as estrogen, progesterone, and testosterone (American Cancer Society, 2021). On the contrary, the least common cancers in humans include appendix cancer, gallbladder cancer, penile cancer, and small bowel cancers (Siegel et al., 2022). It is possible that certain, usually larger organs, are more easily repaired than other, usually smaller ones, so they have never developed the need for cancer-resistant mechanisms, making them more susceptible to carcinogenesis than others.

The American Cancer Society (2018) reported nearly 2 million new cases of cancer are projected for 2022 with more than 25% of those cases will result in death. An astonishing 350 individuals succumb to lung cancer, the leading cause of cancer death, daily in the United States alone (ACS Medical Content and News Staff, 2022). It is not surprising then to discover that incidence has only continuously increased over the years. For breast cancer, there is a 0.5% increase on average annually and 0.43% annually for prostate cancer (Siegel et al., 2022). Although percentages are seemingly small they include thousands of people. Small cell lung cancer (SCLC) is characterized by its high malignant rate from cells that mimic neuroendocrine traits highly malignant tumor derived from cells exhibiting neuroendocrine characteristics and takes ownership of 15% of lung cancer cases (Siegel et al., 2022). In contrast, non–small cell lung cancer (NSCLC) makes up the remaining 85% of cases which are further categorized into 3 major pathologic subtypes: adenocarcinoma, squamous cell carcinoma, and large cell carcinoma (Cruz et al., 2011). According to a study conducted by Cruz et al. (2011), adenocarcinoma accounts for 38.5% of all lung cancer cases, with squamous cell carcinoma coming in second accounting for 20%, and large cell carcinoma accounting for 2.9%. In fact, adenocarcinomas are the most common cancer type globally (Cruz et al., 2011). An adenocarcinoma is a specific cancer type that begins to mutate in the mucusproducing glandular cells of the body. A handful of organs have these specialized glands such as breasts, lungs, prostate, pancreas, and colon; therefore, adenocarcinoma has the potential of developing in any of these organs.

Adenocarcinomas/Adenomas

Adenocarcinomas are the most common type of cancer that affects organs across species. Adenocarcinomas and adenomas grow in the cells found in glands that line the organs also known as glandular epithelial cells. If the glandular cells grow or change this can cause tumors to form. The tumors found in the glandular cells that are non-cancerous are known as adenomas and the ones that are cancerous are known as adenocarcinomas. Adenocarcinomas account for almost all prostate cancers, most breast cancers, about 96% of colorectal cancers, 95% of pancreatic cancers, and 40% of lung cancers (Cleveland Clinic, 2021). Adenocarcinoma is also capable of spreading throughout the body. Invasive adenocarcinoma is cancer that breaks off from the tumor and travels through the body via the bloodstream or lymph system. The main treatments for adenocarcinomas include surgery to remove cancer and some surrounding tissue, chemotherapy to kill all the cancer cells, and radiation therapy which is usually used with surgery and chemotherapy. Radiation uses imaging that helps target the tumors and leave the healthy tissue intact. Since adenomas are noncancerous there is no treatment required however there are medications that can help shrink the tumors as well as surgery to remove them. The average age for humans to be diagnosed with adenocarcinomas is 66, with most cases being diagnosed from the age of 61 to 73 years old (Cleveland Clinic, 2021). Survival rates for adenocarcinomas vary depending on the location of the adenocarcinoma. Cancer data collected by an organization known as Cancer Research

UK showed that women with breast cancer that has not spread to the rest of the body had a 5-year survival rate of around 85% (Hausser & Alon, 2020). However, a woman with adenocarcinoma in the lung that is not invasive would have a survival rate of 33% (Cancer Research UK, 2020).

Cancer Prevalence in Animals

The class of reptiles consists of snakes, turtles, crocodiles, lizards, and more, all with varying sizes, lifespans, habitats, diets, and environments. Such variability in the lifespans, diets, and environments of Reptilia species alongside the lack of studies done on reptiles in general make it difficult to predict their cancer rates and common cancer types. However, Lymphosarcoma, digestive system tumors, blood cancer, and hematopoietic system tumors were reported to be the most common cancers in reptiles, with lung cancer being the least common (Boddy et al., 2020). Overall, studies have shown an increase in neoplasia incidence, probably due to human interference causing increased lifespan (Albuquerque et al., 2018). Unfortunately, there is limited research on reptile's cancer types, suppression mechanisms, and mortalities.

Aves, or birds, are descendants of reptiles, differentiated from reptiles by their evolutionary history and unique features. Birds tend to be smaller, short-lived animals, species that have been affected by modern anomalies, including pollution, veterinarians, and habitat destruction (Dobson, 2012). Studies have reported low rates of cancer in wild birds, with an exception being anser albifrons (wild white-fronted goose), which had 23% diagnosed with multicentric mesenchymal tumors, possibly due to predispositions (Madsen et al., 2017). Many studies with wild birds have been limited to large-bodied ones, since those are the most accessible, calling for research to be done with more diverse populations. Cancer in birds does not make up a significant portion of their deaths, however, those with cancer often lead to death, with increased mortality in recent years (Madsen et al., 2017). Birds do have a high metabolic rate and rapid cell proliferation, but their low cancer rates may point to tumor suppression mechanisms (Miller, 2017). An independent study conducted by Kohlmeier et al. in 1992 focused particularly on Ave data, specifically from pets, which concluded that the most common malignant neoplasm in the class involved tissues such as the trachea, bronchi, or lung (Kohlmeier et al., 1992).

Whereas aves evolved from a reptile ancestor, reptiles likely evolved from an Amphibia ancestor about 300 million years ago. Amphibians, notedly unique for their regenerative abilities, represent a class whose neoplasia prevalence has also been poorly documented, yet, among observed populations, neoplasia seems relatively rare (Ruben et al., 2007). Physical regeneration beyond embryonic development presents a key trait that does not seem to have been evolutionarily conserved among more recently emerged classes of vertebrates and may represent an avenue for research into applications for human oncology (Corradetti et al., 2021). Two of the most common neoplasia among amphibians are renal carcinoma and squamous cell papilloma (in northern leopard frogs and Japanese fire-bellied newts, respectively) (Corradetti et al., 2021). While Amphibia neoplasia is rare, Amphibia renal carcinoma is heavily associated with herpesvirus in populations. Prognoses among individuals presenting with neoplasia are varied, ranging from spontaneous regression to rapid metastasis (Densmore et al., 2007).

Mammals, distinguished evolutionarily by their mostly placental gestation period, form a class with a remarkably varied range of lifespans. Despite these differences, however, genetic links have been observed among species reporting longer average lifespans, as well as among species with shorter lifespans (Farré et al., 2021). While the incidence of cancer among mammals has largely not been shown to correlate with body mass or lifespan, there are indications that it may correlate with reproductive strategies and other life-history traits (Boddy et at., 2020). Carcinoma associated with epithelial tissues linked with viviparous reproduction has been implicated in mammalian neoplasia prevalence and may provide further evidence of the role of reproduction in the development of cancer across mammal species (Bakiri et al., 2013). Carnivorous species are also shown to have higher rates of cancer, attributed to evolutionarily predictable traits such as their diet (Vincze et al., 2022). Studies have found links between conserved cancer suppression genes among mammals that correspond to the human genome, such as the Hippo pathway, which provide a possible path forward for the development of evolutionary medicine to treat cancer in humans (Zeng et al., 2008).

METHODS

This study utilized a database of neoplasia prevalence calculated from zoo pathology records and life history trait data that has been gathered from the PANtheria (Jones et al., 2009) database. This database currently holds data on 4,639 mammal species, with 100,740 data lines and 23,287 necropsies that have been approved for use by zoos. As a threshold, I have only included in this study species that have at least N neoplasia reports, for N=50, filtering out of the data all the species having fewer reports than the threshold. In order for species to properly be compared, I have categorized the available necropsies in four subsets, according to their taxonomic class: Mammalia, aves, amphibia, and Reptilia. After filtering the appropriate data, I had a total of 130 individual species with over 30,000 records, 2,327 of them being neoplasia records which accounted for 101 different neoplasia types. To further organize the data, I also categorized the neoplasia into two subcategories: benign neoplasia and malignant. The goal was to organize this abundance of data in a cohesive manner that ranks species by their relative neoplasia prevalence. By doing so, I would be able to more accurately detect any possible trends found between classes, species and ultimately cancer types.

To display the top and bottom tissue type and/or location of neoplasia and malignancy prevalence two types of leaderboards were created. A series of steps were taken to create each of the leaderboards. To start off, the datasheet, created and approved by Arizona Cancer Evolution Center (ACE) leadership, was first opened in Excel in a .xlsx format. From there a sub-worksheet for each class being investigated was created. To create the sub-worksheet, the data was filtered in alphabetical order by clicking on the column containing “Class” and filtering said column while making sure to expand the selection each time to ensure the spreadsheet was in the correct order. The sub-worksheet was then sorted by neoplasia prevalence by using the "Sort & Filter" button in the home toolbar. The data was sorted in descending order to find the bottom ten neoplasia prevalence. Next, the information from rows 2-11 was formatted into the leaderboard table. These same steps were repeated to find the top ten neoplasia prevalence by sorting the data in ascending order. The leaderboards included columns for species, common names, neoplasia prevalence, and total individuals. Because the common names were not included in the datasheet, an extra step was taken by entering the scientific name of the species into Google to find the common names.

The second type of leaderboards created were tissue-specific leaderboards from a pathology sheet. To find the top and bottom ten tissue types that contributed to the neoplasia prevalence of the species in the species leaderboards, the prevalence associated with the tissue indicated needed to be identified. Once those top and bottom ten tissue types of each species in the top and bottom ten neoplasia leaderboards were identified, the information was entered into new leaderboards. This type of leaderboard included columns for species, common names, cancer types, and total records. For the species that did not have total records displayed, the column was replaced with "type prevalence" to display the prevalence of the cancer type instead.

Once both of these types of leaderboards were completed for the top and bottom ten neoplasia prevalence, it was time to determine the same for malignancy prevalence. The sub-worksheet for each class was sorted by malignancy prevalence this time. Again, sorting the data into both ascending and descending order to find both the top and bottom malignancy prevalence. The information from that sorting was entered into leaderboards with columns for species, common names, malignancy prevalence, and total individuals. After those two leaderboards were finished, the next step was to create tissue-specific leaderboards by finding the top and bottom ten tissue types that contributed to the malignancy prevalence of the species in those leaderboards.

DATA

Across all Species

Table 1. Most Common Neoplasia Types Across all Species

Most Common Neoplasia Types Across all Species	
Cancer Type	Prevalence
b-hyperplasia	36.94%
m-adenocarcinoma	30.42%
b-neoplasia	29.09%
m-carcinoma	25.38%
b-cyst	22.65%
b-adenoma	21.94%
m-neoplasia	20.32%
m-cyst	17.17%
m-lymphoma	13.18%
m-hyperplasia	11.95%

Table 1 displays the most common neoplasia types across all species in the four classes observed: mammals, reptiles, amphibians, and birds. the cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table 2. Least Common Neoplasia Types Across all Species

Least Common Neoplasia Types Across all Species	
Cancer Type	Prevalence
b-trichoepithelioma	0.02%
m-plasmacytoma	0.02%
b-histiocytoma	0.02%
b-melanocytoma	0.03%
m-fibroadenocarcinoma	0.03%

m-nephroblastoma	0.03%
m-ameloblastoma	0.04%
m-lipoosarcoma	0.05%
m-dysgerminoma	0.06%
m-mastocytosis	0.06%

Table 2 represents the least common neoplasia types across all species in the four classes observed: mammals, reptiles, amphibians, and birds. the cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in ascending order.

Table 3. Most Common Malignant Neoplasia Types Across all Species

Most Common Malignant Neoplasia Types Across all Species	
Cancer Type	Malignancy Prevalence
adenocarcinoma	30.42%
carcinoma	25.38%
neoplasia	20.32%
cyst	17.17%
lymphoma	13.18%
hyperplasia	11.95%
sarcoma	7.26%
adenoma	5.87%
melanoma	5.01%
lymphosarcoma	4.82%

Table 3 displays the most common malignant neoplasia types across all species in the four classes investigated. In addition, the malignancy prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table 4. Most Common Benign Neoplasia Types Across all Species

Most Common Benign Neoplasia Types Across all Species	
Cancer Type	Prevalence
hyperplasia	36.94%
neoplasia	29.09%
cyst	22.65%
adenoma	21.94%
melanoma	10.99%
pheochromocytoma	6.48%
lipoma	5.85%
seminoma	5.67%
leiomyoma	3.78%
cystadenoma	3.03%

Table 4 displays the most common benign neoplasia types across all species in the four classes investigated. In addition, the benign prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table 5. Species with the Highest Malignancy Prevalence

Species with the Highest Malignancy Prevalence				
Class	Species	Common Name	Total Records	Neoplasia Prev
Mammalia	Phoca vitulina	Atlantic Harbor Seal	121	100.00%
Aves	Chloebia gouldiae	Gouldian Finch	82	100.00%
Aves	Pteroglossus aracari	Black-necked Aracari	65	100.00%
Aves	Asarcornis scutulata	White-winged duck	63	100.00%
Reptilia	Uroplatus phantasticus	Satanic leaf-tailed Gecko	56	100.00%
Mammalia	Macroscelides proboscideus	Short-eared Elephant Shrew	55	100.00%

Amphibia	Nyctimystes infrafrenatus	White-lipped Tree Frog	54	100.00%
Mammalia	Phodopus sungorus	Winter White Dwarf Hamster	83	87.70%
Mammalia	Dasyurus maculatus	Tiger Quoll	81	87.70%
Mammalia	Phascolarctos cinereus	Koala	84	87.50%

Table 5 shows the top 10 species that are contributing to the neoplasia prevalence in tables 3. This table also displays the individual species' neoplasia prevalence, the total records documented, and the class of the species.

Tables 6 and 7. Top 10 most prevalent neoplasia types found in the top 10 species

Table 6. Most Common Malignant Neoplasia Types in the top 10 Species

Most Common Malignant Neoplasia Types in the top 10 Species	
Cancer Type	Malignancy Prevalence
adenocarcinoma	31.80%
neoplasia	23.41%
lymphoma	16.44%
carcinoma	15.42%
melanoma	12.46%
sarcoma	9.86%
hyperplasia	9.10%
leukemia	6.05%
cyst	5.78%
lymphosarcoma	4.15%

Table 7. Most Common Benign Neoplasia Types in the top 10 Species

Most Common Benign Neoplasia Types in the top 10 Species	
Cancer Type	Benign Prevalence
hyperplasia	41.41%
melanoma	20.20%
adenoma	18.52%
neoplasia	18.18%
seminoma	16.16%
cyst	10.78%
cystadenoma	6.06%
lipoma	5.05%
leiomyoma	3.36%
tumors	2.02%

Tables 6 and 7 display the most common neoplasia types reported in the top 10 species (listed in table 5) contributing to the neoplasia type prevalence across species. The cancer types shown are in descending order of prevalence.

Table 8. Species with the Lowest Malignancy Prevalence

Species with the Lowest Malignancy Prevalence				
Class	Species	Common Name	Total Records	Malignancy Prev
	See List A (37 species)		3823	0.00%
Mammalia	Saimiri sciureus	Common Squirrel Monkey	71	10.00%
Mammalia	Acinonyx jubatus	Cheetah	118	10.50%

Mammalia	Heterocephalus glaber	Naked Mole Rat	151	12.50%
Aves	Dendrocygna viduata	White Faced Tree Duck	89	16.70%
Amphibia	Pipa pipa	Surinam toad	109	20.00%
Amphibia	Dendrobates tinctorius	Dyeing Poison Dart Frog	268	25.00%
Amphibia	Anaxyrus baxteri	Wyoming Toad	201	28.60%
Mammalia	Rattus norvegicus	Typical Rat	419	31.20%
Mammalia	Chrysocyon brachyurus	Maned Wolf	99	33.00%

Table 8 shows the bottom 10 species that are LEAST contributing to the neoplasia prevalence in table 2. This table also displays the individual species' neoplasia prevalence, the total records documented, and the class of the species.
Tables 9 and 10. Bottom 10 least prevalent neoplasia types found in the bottom 10 species

Table 9. Least Common Malignant Neoplasia Types in the Bottom 10 Species

Least Common Malignant Neoplasia Types in the Bottom 10 Species	
Cancer Type	Prevalence
See List A	0.00%
histiocytic sarcoma	0.43%
nephroblastoma	0.43%
hepatoma	0.59%
leiomyoma	0.59%
fibroadenocarcinoma	0.85%
fibrosarcoma	1.28%
sarcoma	1.44%
dysgerminoma	1.76%

epithelioma	1.87%

Table 10. Least Common Benign Neoplasia Types in the Bottom 10 Species

Least Common Benign Neoplasia Types in the Bottom 10 Species	
Cancer Type	Prevalence
See List B	0.00%
thymoma	1.44%
leiomyoma	1.71%
lipoma	3.16%
papilloma	4.25%
pheochromocytoma	4.32%
dysgerminoma	5.28%
odontoma	5.69%
cyst	9.88%
neoplasia	29.01%

Tables 9 and 10 display the least common neoplasia types reported in the top 10 species (listed in table 8) contributing to the neoplasia type prevalence across species. The cancer types shown are in ascending order of prevalence.

Reptiles

Table R1. Most Common Neoplasia Types across all Reptiles

Most Common Neoplasia Types across all Reptiles	
Cancer Type	Neoplasia Prevalence
b-neoplasia	44.85%
b-hyperplasia	33.20%
m-adenocarcinoma	28.59%

m-neoplasia	28.10%
m-sarcoma	16.33%
b-melanoma	15.81%
m-carcinoma	15.14%
m-cyst	14.57%
b-cyst	13.05%
b-seminoma	12.91%

Table R1 displays the most common neoplasia types across all reptiles. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table R2. Least Common Neoplasia Types Across all Reptiles

Least Common Neoplasia Types Across all Reptiles	
Cancer Type	Neoplasia Prevalence
See List RA (62 Types)	0.00%
m-mesothelioma	0.26%
b-leiomyoma	0.35%
b-lipoma	0.35%
m-lymphangiosarcoma	0.57%
m-anaplastic	0.63%
b-ganglioneuroma	0.73%
m-chondrosarcoma	1.02%
m-lymphosarcoma	1.13%
b-iridophoroma	1.38%

Table R2 displays the least common neoplasia types across all reptiles. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in ascending order.

Table R3. Most Common Malignant Neoplasia Types Across all Reptiles

Most Common Malignant Neoplasia Types Across all Reptiles	
Cancer Type	Malignancy Prevalence
adenocarcinoma	28.59%
neoplasia	28.10%
sarcoma	16.33%
carcinoma	15.14%
cyst	14.57%
hyperplasia	10.41%
fibrosarcoma	9.83%
lymphoma	8.81%
leukemia	7.37%
melanoma	7.19%

Table R3 shows the top 10 malignant neoplasia types most prevalent across reptiles.

Table R4. Least Common Malignant Cancer Types Across all Reptiles

Least Common Malignant Cancer Types Across all Reptiles	
Cancer Type	Malignancy Prevalence
See List RA (34 Types)	0.00%
mesothelioma	0.26%
lymphangiosarcoma	0.57%
anaplastic	0.63%

chondrosarcoma	1.02%
lymphosarcoma	1.13%
histiocytic sarcoma	1.45%
leiomyosarcoma	1.53%
chromatophoroma	1.71%
myxoma	1.71%

Table R4 shows the bottom 10 malignant neoplasia types that are the least prevalent across reptiles.

Table R5. Species with the Highest Malignancy Prevalence

Species with the Highest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
Uroplatus phantasticus	Satanic leaf-tailed Gecko	55	100.00%
Eublepharis macularius	Leopard Gecko	50	84.60%
Pantherophis guttatus	Corn Snake	82	82.50%
Boa constrictor	Boa Constrictor	64	78.90%
Heloderma suspectum	Gila Monster	79	77.80%
Uroplatus sikorae	Mossy leaf-tailed Gecko	64	66.70%
Corallus caninus	Emerald Tree boa	50	66.70%
Crotalus lepidus	Mottled Rock Rattlesnake	56	66.70%
Lampropeltis triangulum	Milk Snake	56	64.50%
Morelia viridis	Green Tree Python	74	60.00%

Table R5 above shows the top 10 species that contribute to the high malignancy neoplasia type prevalence across reptiles.

Table R6. Most Common Malignant Neoplasia Types in the top 10 Species

Most Common Malignant Neoplasia Types in the Species Above	
Cancer Type	Malignancy Prevalence
adenocarcinoma	35.10%
neoplasia	32.24%
sarcoma	20.58%
cyst	18.28%
hyperplasia	13.59%
carcinoma	9.66%
leukemia	9.62%
melanoma	9.39%
lymphoma	8.83%
adenoma	6.71%

Tables R6 pictures the most common malignant neoplasia types found in the top 10 species (Table R5).

Table R7. Species with the Lowest Malignancy Prevalence in Reptilia

Species with the Lowest Malignancy Prevalence in Reptilia			
Species	Common Name	Total Records	Malignancy Prev
Chelodina mccordi	McCords snake-necked turtle	96	0.00%
Chamaeleo calyptratus	Veiled Chameleon	94	0.00%
Ctenosaura bakeri	Bakers spiny tail iguana	80	0.00%
Erpeton tentaculatum	Tentacled Snake	57	0.00%

Phrynosoma asio	Giant Horned Lizard	51	0.00%
Boiga dendrophila	Mangrove Snake	69	33.30%
Morelia spilota	Diamond Python	63	33.30%
Gonocephalus chamaeleontinus	Chameleon Forest Dragon	50	33.30%
Pogona vitticeps	Bearded Dragon	68	38.90%
Sceloporus cyanogenys	Blue Spiny Lizard	56	40.00%

Table R7 above shows the bottom 10 species that contribute to the lowest malignancy neoplasia type prevalence across reptiles.

Table R8. Least Common Malignant Neoplasia Types in the Species Above

Least Common Malignant Neoplasia Types in the Species Above	
Cancer Type	Malignancy Prevalence
See List RA	0.00%
cyst	3.13%
histiocytic sarcoma	3.13%
lymphangiosarcoma	3.13%
sarcoma	3.13%
adenocarcinoma	9.34%
lymphoma	11.19%
carcinoma	14.32%
myxosarcoma	18.62%
neoplasia	18.62%

Tables R8 pictures the least common malignant neoplasia types found in the bottom 10 species (Table R7).

Amphibia

Table A1. Most Common Neoplasia Types Across all Amphibia

Most Common Neoplasia Types Across all Amphibia	
Cancer Type	Prevalence
b-hyperplasia	60.66%
b-melanoma	45.96%
m-adenocarcinoma	34.12%
m-carcinoma	32.89%
m-lymphoma	17.21%
m-cyst	14.41%
m-leukemia	14.26%
m-hyperplasia	12.76%
b-neoplasia	12.51%
m-melanoma	9.68%

Table A1 displays the most common neoplasia types across all amphibians. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table A2. Least Common Neoplasia Types Across all Amphibia

Least Common Neoplasia Types Across all Amphibia	
Cancer Type	Prevalence
See List RA (73 Types)	0.00%
b-dysgerminoma	0.61%
b-teratoma	0.61%
b-cystadenoma	1.83%

b-hepatoma	1.83%
b-seminoma	1.83%
m-fibrosarcoma	2.02%
b-ameloblastoma	2.13%
b-papilloma	2.13%
m-neoplasia	2.32%

Table A2 displays the least common neoplasia types across all amphibians. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in ascending order.

Table A3. Most Common Malignant Cancer Types Across all Amphibia

Most Common Malignant Cancer Types Across all Amphibia	
Cancer Type	Prevalence
adenocarcinoma	34.12%
carcinoma	32.89%
lymphoma	17.21%
cyst	14.41%
leukemia	14.26%
hyperplasia	12.76%
melanoma	9.68%
papilloma	5.39%
lymphosarcoma	4.78%
medulloblastoma	3.24%

Table A3 shows the top 10 malignant neoplasia types most prevalent across amphibians.

Table A4. Least Common Malignant Cancer Types Across all Amphibia

Least Common Malignant Cancer Types Across all Amphibia	
Cancer Type	Prevalence
See List RA (45 Types)	0.00%
fibrosarcoma	2.02%
neoplasia	2.32%
liposarcoma	2.70%
medulloblastoma	3.24%
lymphosarcoma	4.78%
papilloma	5.39%
melanoma	9.68%
hyperplasia	12.76%
leukemia	14.26%

Table A4 shows the bottom 10 malignant neoplasia types that are the least prevalent across amphibian.

Table A5. Species with the Highest Malignancy Prevalence

Species with the Highest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
Nyctimystes infrafrenatus	White-lipped Tree Frog	65	100.00%
Ambystoma mexicanum	Axolotl	73	80.00%
Trachycephalus resinifictrix	Mission-eyed Tree Frog	69	71.40%
Cornufer guentheri	Solomon Island leaf frog	89	66.70%
Atelopus zeteki	Panamanian Golden Frog	147	54.50%

Nectophrynoides asperginis	Kihansi spray toad	174	50.00%
Agalychnis callidryas	Red-eyed Treefrog	74	50.00%
Peltophryne lemur	Puerto Rican crested toad	227	38.10%
Dyscophus antongilii	Tomato frog	54	33.30%
Anaxyrus baxteri	Wyoming Toad	201	28.60%

Table A5 above shows the top 10 species that contribute to the high malignancy neoplasia type prevalence across amphibians.

Table A6. Most Common Malignant Neoplasia Types in the Species Above

Most Common Malignant Neoplasia Types in the Species Above	
Cancer Type	Malignancy Prevalence
carcinoma	35.47%
adenocarcinoma	32.43%
cyst	15.54%
leukemia	15.39%
lymphoma	15.07%
hyperplasia	13.76%
melanoma	10.44%
papilloma	5.82%
lymphosarcoma	5.15%
medulloblastoma	3.49%

Tables A6 pictures the most common malignant neoplasia types found in the top 10 species (Table A5).

Table A7. Species with the Lowest Malignancy Prevalence

Species with the Lowest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
Phyllobates bicolor	Bi-colour Poison Dart Frog	307	0.00%
Xenopus longipes	Lake Oku clawed frog	217	0.00%
Rana temporaria	Common Frog	189	0.00%
Rana sierrae	Sierra Nevada Yellow-legged Frog	137	0.00%
Mantella aurantiaca	Golden Mantella	92	0.00%
Alytes muletensis	Mallorcan Midwife Toad	77	0.00%
Triturus cristatus	Great Crested Newt	77	0.00%
Bufo bufo	Common toad	70	0.00%
Phyllomedusa bicolor	Giant Waxy Tree Frog	50	0.00%
Pipa pipa	Surinam toad	109	20.00%

Table A7 above shows the bottom 10 species that contribute to the lowest malignancy neoplasia type prevalence across amphibians.

Table A8. Least Common Malignant Neoplasia Types in the Species Above

Least Common Malignant Neoplasia Types in the Species Above	
Cancer Type	Malignancy Prevalence
hyperplasia	0.00%
insulinoma	0.00%
leiomyoma	0.00%
leiomyosarcoma	0.00%
leukemia	0.00%

lipoma	0.00%
lipoosarcoma	0.00%
liposarcoma	0.00%
lymphangiosarcoma	0.00%
lymphoma	100.00%

Tables A8 pictures the least common malignant neoplasia types found in the bottom 10 species (Table A7).

Aves

Table B1. Most Common Neoplasia Types Across all Aves

Most Common Neoplasia Types Across all Aves	
Cancer Type	Prevalence
b-cyst	34.02%
m-adenocarcinoma	33.82%
b-hyperplasia	30.09%
b-adenoma	21.73%
b-neoplasia	18.91%
b-seminoma	13.62%
m-carcinoma	13.57%
m-lymphoma	12.90%
m-cyst	12.20%
m-melanoma	11.28%

Table B1 displays the most common neoplasia types across all aves. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table B2. Least Common Neoplasia Types Across all Aves

Least Common Neoplasia Types Across all Aves	
Cancer Type	Prevalence
See List AA (62 Types)	0.00%
m-adenoma	0.07%
m-leiomyoma	0.07%
m-leukemia	0.07%
m-lipoma	0.07%
m-liposarcoma	0.07%
m-nephroblastoma	0.07%
m-osteoma	0.07%
b-cystadenoma	0.07%
b-fibroma	0.07%

Table A2 displays the least common neoplasia types across all aves. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in ascending order.

Table B3. Most Common Malignant Neoplasia Types Across all Aves

Most Common Malignant Neoplasia Types Across all Aves	
Cancer Type	Prevalence
adenocarcinoma	33.82%
carcinoma	13.57%
lymphoma	12.90%
cyst	12.20%
melanoma	11.28%

neoplasia	7.38%
hemangiosarcoma	7.21%
lymphosarcoma	7.01%
sarcoma	6.97%
fibrosarcoma	3.08%

Table B3 shows the top 10 malignant neoplasia types most prevalent across aves.

Table B4. Least Common Malignant Neoplasia Types Across all Aves

Least Common Malignant Neoplasia Types Across all Aves	
Cancer Type	Prevalence
See List AA (34 Types)	0.00%
adenoma	0.07%
leiomyoma	0.07%
leukemia	0.07%
lipoma	0.07%
liposarcoma	0.07%
nephroblastoma	0.07%
osteoma	0.07%
leiomyosarcoma	0.14%
anaplastic	0.21%

Table B4 shows the bottom 10 malignant neoplasia types that are the least prevalent across aves.

Table B5. Species with the Highest Malignancy Prevalence

Species with the Highest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
Pteroglossus aracari	Black-necked Aracari	121	100.0%
Chloebia gouldiae	Gouldian Finch	56	100.0%
Asarcornis scutulata	White-winged duck	54	100.0%
Leucopsar rothschildi	Bali mynah	52	83.3%
Gallus gallus	Domestic chicken	304	76.3%
Melopsittacus undulatus	Budgerigar	478	75.4%
Trichoglossus haematodus	Rainbow Lorikeet	190	75.0%
Spheniscus humboldti	Humboldt Penguin	376	71.4%
Meleagris gallopavo	Domestic Lavender Turkey	71	70.0%
Nymphicus hollandicus	Cockatiel	71	70.0%

Table B5 above shows the top 10 species that contribute to the high malignancy neoplasia type prevalence across aves.

Table B6. Top 10 Most Common Malignant Types in the Species Above

Top 10 Most Common Malignant Types in the Species Above	
Cancer Type	Prevalence
medulloblastoma	16.4%
lymphangiosarcoma	12.6%
carcinoid	12.5%
lymphoma	10.2%

myxosarcoma	7.7%
chromatophoroma	6.8%
rhabdomyosarcoma	5.3%
fibrosarcoma	2.4%
hemangioma	2.3%
histiocytoma	0.5%

Tables B6 pictures the most common malignant neoplasia types found in the top 10 species (Table B5).

Table B7. Species with the Lowest Malignancy Prevalence

Species with the Lowest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
See List AB (15 Species)		1458	0.00%
Dendrocygna viduata	White Faced Tree Duck	89	16.70%
Phoenicopterus ruber	Greater Flamingo	102	33.30%
Numida meleagris	Guinea Fowl	55	46.20%
Cosmopsarus regius	Golden-breasted Starling	53	50.00%
Ramphastos swainsonii	Swainson's Toucan	103	50.00%
Phoenicopterus chilensis	Chilean Flamingo	82	50.00%
Dendrocygna autumnalis	Black-bellied Whistling Duck	130	56.20%
Trichoglossus moluccanus	Rainbow Lorikeet	80	66.70%
Meleagris gallopavo	Domestic Lavender Turkey	71	70.00%

Table B7 above shows the bottom 10 species that contribute to the lowest malignancy neoplasia type prevalence across aves.

Table B8. Bottom 10 Least Common Malignant Types in the Species Above

Bottom 10 Least Common Malignant Types in the Species Above	
Cancer Type	Prevalence
See List AB	0.00%
cholangiocarcinoma	1.41%
seminoma	3.51%
myxosarcoma	5.56%
neoplasia	5.56%
fibrosarcoma	7.58%
sarcoma	9.00%
hemangiosarcoma	15.17%
carcinoma	15.76%
lymphoma	15.94%

Tables B8 pictures the least common malignant neoplasia types found in the bottom 10 species (Table B7).

Mammalia

Table M1. Top 10 Most Common Cancer Types Across all Mammalia

Top 10 Most Common Cancer Types Across all Mammalia	
Cancer Type	Prevalence
b-neoplasia	35.63%
b-adenoma	32.83%
b-hyperplasia	32.76%

m-carcinoma	32.49%
m-adenocarcinoma	28.77%
m-neoplasia	27.25%
b-cyst	26.83%
m-cyst	20.90%
m-hyperplasia	17.37%
m-lymphoma	13.96%

Table M1 displays the most common neoplasia types across all mammals. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in descending order.

Table M2. Least Common Malignant Neoplasia Types Across all Mammalia

Least Common Malignant Neoplasia Types Across all Mammalia	
Cancer Type	Malignancy Prevalence
See List MA (4 Types)	0.00%
nephroblastoma	0.03%
plasmacytoma	0.04%
fibroadenocarcinoma	0.06%
ameloblastoma	0.08%
lipoosarcoma	0.11%
dysgerminoma	0.12%
mastocytosis	0.13%
hepatoma	0.14%
anaplastic	0.14%

Table M2 displays the least common neoplasia types across all mammals. The cancer type shown in the first column is further categorized by malignancy ("m-") and benign ("b-") types. In addition, the prevalence of the neoplasia type is displayed in the right-side column in ascending order.

Table M3. Most Common Malignant Neoplasia Types Across all Mammalia

Most Common Malignant Neoplasia Types Across all Mammalia	
Cancer Type	Malignancy Prevalence
carcinoma	32.49%
adenocarcinoma	28.77%
neoplasia	27.25%
cyst	20.90%
hyperplasia	17.37%
lymphoma	13.96%
adenoma	10.00%
sarcoma	5.78%
lymphosarcoma	5.19%
hemangiosarcoma	4.53%

Table M3 shows the top 10 malignant neoplasia types most prevalent across mammals.

Table M4. Least Common Malignant Neoplasia Types Across all Mammalia

Least Common Malignant Neoplasia Types Across all Mammalia	
Cancer Type	Prevalence
See List MA (4 Types)	0.00%
nephroblastoma	0.03%
plasmacytoma	0.04%
fibroadenocarcinoma	0.06%

ameloblastoma	0.08%
lipoosarcoma	0.11%
dysgerminoma	0.12%
mastocytosis	0.13%
hepatoma	0.14%
anaplastic	0.14%

Table M4 shows the bottom 10 malignant neoplasia types that are the least prevalent across mammals.

Table M5. Species with Highest Malignancy Prevalence

Species with Highest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
Macroscelides proboscideus	Short-eared Elephant Shrew	82	100.0%
Phoca vitulina	Atlantic Harbor Seal	63	100.0%
Phodopus sungorus	Winter White Dwarf Hamster	83	87.70%
Dasyurus maculatus	Tiger Quoll	81	87.70%
Phascolarctos cinereus	Koala	84	87.50%
Cynomys ludovicianus	Gunnison Prairie Dog	149	80.90%
Lycaon pictus	Cape Hunting Dog	69	80.00%
Osphranter robustus	Wallaroo	58	80.00%
Octodon degus	Degu	57	79.50%
Panthera leo	Masai Lion	76	78.40%

Table M5 above shows the top 10 species that contribute to the high malignancy neoplasia type prevalence across mammals.

Table M6. Most Common Malignant Neoplasia Types in the Species Above

Most Common Malignant Neoplasia Types in the Species Above	
Cancer Type	Malignancy Prevalence
neoplasia	35.36%
adenocarcinoma	30.59%
carcinoma	25.25%
lymphoma	23.40%
hyperplasia	18.92%
cyst	18.37%
adenoma	13.91%
sarcoma	9.33%
hemangiosarcoma	6.80%
fibrosarcoma	3.27%

Tables M6 pictures the most common malignant neoplasia types found in the top 10 species (Table M5).

Table M7. Species with the Lowest Malignancy Prevalence

Species with the Lowest Malignancy Prevalence			
Species	Common Name	Total Records	Malignancy Prev
See List MB (9 species)		771	0.00%
Saimiri sciureus	Common Squirrel Monkey	71	10.00%
Acinonyx jubatus	Cheetah	118	10.50%
Heterocephalus glaber	Naked Mole Rat	151	12.50%
Rattus norvegicus	Typical Rat	419	31.20%

Chrysocyon brachyurus	Maned Wolf	99	33.00%
Artibeus jamaicensis	Jamaican Fruit Bat	80	37.50%
Capra hircus	San Clemente Goat	127	37.90%
Rucervus eldii	Eld's Deer	53	41.50%
Nanger dama	Addras Gazelle	51	41.70%

Table M7 above shows the bottom 10 species that contribute to the lowest malignancy neoplasia type prevalence across mammals.

Table M8. Least Common Malignant Neoplasia Types in the Species Above

Least Common Malignant Neoplasia Types in the Species Above	
Cancer Type	Malignancy Prevalence
See List MB	0.00%
histiocytic sarcoma	0.31%
nephroblastoma	0.31%
hepatoma	0.43%
leiomyoma	0.43%
fibroadenocarcinoma	0.63%
leukemia	0.63%
dysgerminoma	1.29%
epithelioma	1.37%
mastocytosis	1.37%

Tables M8 pictures the least common malignant neoplasia types found in the bottom 10 species (Table M7).

DISSCUSSION

Reptiles

As indicated in the reptile's leaderboards the species with the highest neoplasia prevalence is the Chamaeleo calyptratus, or the veiled chameleon, with 100% neoplasia prevalence. There are five species with the lowest neoplasia rates (all 0% neoplasia prevalence). These are the Phrynosoma asio (giant horned lizard), Erpeton tentaculatum (tentacled snake), Chelodina mccordi (McCord's snake-necked turtle), Uroplatus phantasticus (satanic leaf-tailed gecko), and Ctenosaura bakeri (bakers spiny tail iguana). The leaderboards for reptiles also exhibited the Uroplatus phantasticus (satanic leaf-tailed gecko) having the highest malignancy prevalence, with 100% of neoplasia cases being malignant, and 84.6% of neoplasia cases being malignant in the Eublepharis macularius (leopard gecko). The species with the lowest malignancy prevalence were the Chelodina mccordi (McCord's snake-necked turtle), Chamaeleo calyptratus (veiled chameleon), Ctenosaura bakeri (bakers spiny tail iguana), Erpeton tentaculatum (tentacled snake), and Phrynosoma asio (giant horned lizard) with 0% malignancies. The next lowest species was the boiga dendrophila (mangrove snake), with a malignancy prevalence of 33.3%. By further investigating the species that rarely get neoplasms I can develop new frameworks with novel model organisms in cancer research.

The most common cancer types (malignant) across species of reptiles are sarcomas, lymphomas, neoplasia, adenocarcinomas, adenomas, cysts, carcinomas, hyperplasia, and melanomas. The five least common cancer types observed among reptiles were: ameloblastomas, carcinoids, cholangiocarcinoma, cystadenocarcinomas, and dysgerminomas. These are the rarest forms of neoplasia in this class with their prevalence being 0% meaning reptiles do not actually get these cancer types. These tissues involved in the most and least common cancer types may be a contributing factor to Reptilia neoplasia prevalence based on the abundance of specific cell types that are present in the body. For example, lymphomas arise from t-cells and b-cells, which are very abundant, therefore making lymphomas more common than osteosarcomas, which form in long bones (reptiles have fewer, smaller bones). Compared to the all-species leaderboards, the top malignancy types for reptiles were very similar. This similarity continues when compared to humans, supporting my hypothesis that adenocarcinomas are the most prevalent cancer type across the tree of life and certain tissues are susceptible to cancer more than others across all species. The commonalities between all species, reptiles, and humans also continue in the top benign tumor types.

The species listed in Table R5 are on the relatively small compared to other animals, specifically the satanic leaf-tailed gecko at around 3 inches and .23 ounces, mossy leaf-tailed gecko at 7 inches and 0.7 ounces, and leopard gecko measuring 9 inches and 2.4 ounces are atypically small. There are some exceptions in these species, with those being: the boa constrictor at 22-33 pounds and around 7 feet long and Gila monster averaging 4 pounds and 22 inches, which are relatively larger reptiles (Smithsonian's National Zoo and Conservation Biology Institute, 2021). It should be noted that these species are mostly geckos and snakes. Additionally, since these species all have many predators, they have developed adaptations over their evolutionary history for survival (Animalia - Online Animals Encyclopedia, n.d.). Camouflage techniques and being nocturnal are two examples of selection that allowed these species to continue to live and reproduce (Wakeda et al., 2020). Since these animals have had to focus on avoiding predation, it is my belief that their evolution probably never selected for cancer-resistance mechanisms.

The species Phrynosoma asio/giant horned lizard, Erpeton tentaculatum/tentacled snake, Chelodina mccordi/McCord's snake-necked turtle, Ctenosaura bakeri/bakers spiny tail iguana, Eublepharis macularius/leopard gecko, Pantherophis guttatus/corn snake, boa constrictor, Uroplatus sikorae/mossy leaf-tailed gecko, and Heloderma suspectum/Gila monster may have the lowest neoplasia prevalence because of their larger sizes and long lifespans, especially for their genus (Animalia - Online Animals Encyclopedia, n.d.). Their larger size and long lifespans indicate that in the past their ancestors had higher chances of developing cancer (more cell divisions for a larger body over longer periods of time), so mechanisms of cancer resistance may have developed through natural selection.

The species Chelodina mccordi/McCord's snake-necked turtle, Chamaeleo calyptratus/veiled chameleon, Ctenosaura bakeri/bakers spiny tail iguana, Erpeton tentaculatum/tentacled snake, Phrynosoma asio/giant horned lizard, boiga dendrophila/mangrove snake, Morelia spilota/diamond python, Gonocephalus chamaeleontinus/chameleon forest dragon, pogona vitticeps/bearded dragon, and sceloporus cyanogenys/blue spiny lizard had the lowest malignancy prevalence across reptiles. Some of these species (McCord's snake-necked turtle, tentacled snake, giant horned lizard, veiled chameleon, and baker's spiny tail iguana) are on the same leaderboard for lowest benign neoplasia prevalence.

Reptiles' prevalence is impacted by pollutants and their recently increased lifespans (their lifespans probably extended due to human involvements in their diet and healthcare) (Albuquerque et al., 2018). However, most reptiles vary in many traits, including metabolic rate, which is linked to lower rates of cancer incidence (Dang, 2012). Reptiles also tend to be smaller in size, have regeneration qualities, varying lifespans, varying habitats, and different physiology (Chiari et al., 2018). Certain reptiles' regeneration capabilities allow them to quickly regrow and repair tissue cells, possibly pointing to increased cancer risk due to the rapid proliferation of cells. However, it is also possible that reptiles with regenerative qualities can strictly regulate this process through acquired tumor suppressor genes over evolution, actually leading to less cancer incidence (Luisetto et al., 2020). These factors account for reptiles' cancer rates, as they have wide variation across tissues and species.

Amphibians

In the leaderboards of Amphibia, the species with the highest neoplasia prevalence is Mantella aurantiaca also known as the Golden Mantella with a neoplasia prevalence of 100%. The species with the lowest neoplasia prevalence consisted of eight different species all with a 0% neoplasia prevalence. The top species of amphibia with the highest malignancy prevalence is Nyctimystes infrafrenatus which has a malignancy prevalence of 100%. The species with the lowest malignancy prevalence consisted of 9 different species with a rate of 0%.

The most common benign cancer types for the species listed above are hyperplasia and melanoma. Hyperplasia has a 62.5% prevalence for benign cancer types while melanoma has a 51.3% prevalence for benign cancer types. The least common benign cancer types for the species above are ameloblastoma, astrocytoma, carcinoid, chemodectoma, chondroma, chordoma, cyst, cystadenoma, dysgerminoma, and fibroma. All these tissue types had a 0% prevalence. The most common malignant cancer types for the species above include carcinoma with a 35% prevalence and adenocarcinoma with a 32.4% prevalence. The least common malignant cancer types for the species listed above are hyperplasia, insulinoma, leiomyoma, leiomyosarcoma, leukemia, lipoma, liposarcoma, and lymphangiosarcoma. These tissues are more prevalent or less prevalent in amphibians due to random mutations arising during DNA replication in normal stem cells. A common benign tissue type for these species is hyperplasia which is an increase in the number of cells in an organ or tissue which can become cancer. Hyperplasia is classified into two categories typical and atypical. Atypical hyperplasia are neoplasms that are less than 8% likely to develop into cancer (Alteri & Kalidas, 2019). Mild or typical hyperplasia are neoplasms that are benign which account for most hyperplasia classifications meaning it is relatively rare for hyperplasia to develop into cancer (Alteri & Kalidas, 2019). These cancer types can be more common in amphibians due to environmental factors or inherited predispositions. Melanoma and carcinoma were more common in these specific amphibians. This could be due to the high metabolic activity of the skin and its constant contact with the environment; however, it could also be due to easier observation of the skin compared with other organs.

Overall, amphibians are more resistant to the development of neoplasia or malignancy than other species. Amphibians have unique traits such as a regenerative capacity in adults as well as dramatic metamorphosis which recreates the body to create the adult form. These mechanisms could protect amphibians against cancer (Ruben et al., 2007). Amphibia apoptosis is much different from other species in specific mammalian apoptosis. Amphibia apoptosis does not need the cells to go into the mitotic cell cycle instead apoptosis is able to remove damaged cells before cytokinesis occurs (Ruben et al., 2013). If damaged DNA or cells is not eliminated before mitosis, then these damaged cells are able to replicate and potentially start the process of cancer.

Aves

The Aves leaderboards indicate that the species with the highest malignancy prevalence are the Chloebia gouldiae (Gouldian Finch), Asarcornis scutulata (White-wingd Duck), and Pteroglossus Aracari (Black-necked Aracari) with a prevalence of 100%. An example of a species with the lowest malignancy of 0% is the Spheniscus Demersus (Black-footed Penguin). A few other species with low malignancy prevalence are the Dendrocygna Viduata (White Faced Tree Duck) with a 0.267 prevalence, and the Phoenicopterus Ruber (Greater Flamingo) with a prevalence of 0.333. As with the malignancy prevalence leaderboards, the neoplasia leaderboards also exhibited most and least common neoplasia. The species with the highest neoplasia prevalence, being 100%, is the Columba Livia (Domestic Pigeon), Eos Bornea (Red Lory), Rollulus Rouloul (Roul Roul), Agapornis Nigrigenis (Black-cheeked Lovebird), and the Eudocimus Ruber (Scarlet Ibis). The Spheniscus Demersus (Black-footed Penguin) is a species with the lowest neoplasia of 0%. A few other species with low neoplasia prevalence are the Leucopsar rothschildi (Bali Mynah) with a 0.167 prevalence, Gallus gallus (Domestic

Chicken) with a (0.237 prevalence, and the Melopsittacus undulatus (Budgerigar) with a 0.246 prevalence.

These cancer types in Aves might be caused by their high rate of metabolism and aging; aging in aves aides in telomere shortening. Another possible contributing factor is that birds have a long lifespan in accordance with their body size (Travin & Feniouk, 2016). These can all be contributing factors to weakening of natural selection and adapting cancer resistance traits due to age. On the contrary, longer life spans can allow for ancestors to develop cancer resistance mechanisms through natural selection. Through the process of natural selection, traits can be passed on that grant resistance against cancer, thus leading to lower prevalence rates. Other possible contributors of low cancer prevalence across species are increased copies of tumor-suppressor genes, longer telomere length, metabolic regulation, and dietary changes.

Mammalia

The species in the leaderboards with the highest benign neoplasia prevalence are Cebuella pygmaea (pygmy marmoset) and Saimiri sciureus (common squirrel monkey), which have prevalence of 100% and 90% respectively. Both species are nonhuman primates, and thus share similar evolutionary histories and relatively recent common ancestors, likely contributing to their similar neoplasia rates here. This may imply a link between nonhuman primate neoplasia genesis and shared body structures dictated by shared evolutionary history, such as the hematopoietic system which, for example, is known to be a common source for neoplasia in baboons (Cianciolo et al., 2005). Among other species with high neoplasia rates are cheetahs, rats, maned wolves, and several ruminants. Ruminants may share similar rates for reasons analogous to those of the nonhuman primates. Neoplasia, adenoma, and hyperplasia represent the three most common types of benign prevalence among mammals, and there are examples of these types transitioning from benign to malignant lesions over time (Shortell & Schwartz, 1991).

Nine species present no benign neoplasia, and the bottom two species still displaying some benign prevalence are Phodopus sungorus (winter white dwarf hamster) and Dasyurus maculatus (tiger quoll). In fact, seven of the bottom nine species displaying benign neoplasia are rodents and marsupials; the other two are larger carnivores. Among marsupials specifically, neoplasia remains rare and there are few links between individual observations among related species (Canfield et al., 1990). Lipoma and fibroma were the two least common types of observed benign neoplasia with prevalence of 1.3% and 1.6%, respectively, and historically represent two types of neoplasia unlikely to recur or metastasize (Zelger et al., 1997).

The top species with malignancies were Macroscelides proboscideus (short-eared elephant shrew) and Phoca vitulina (Atlantic harbor seal), both with rates of 100%. Marine mammals have been observed to present with neoplasia at relatively high rates (Newman & Smith, 2006). Shrews, additionally, have extraordinary genetic similarity to primates compared to other rodent species (Lu et al., 2021). Several of the most common malignant neoplasia in mammals included carcinomas, which may be linked to viviparous mammalian reproduction strategies and the epithelial tissues involved in them (Boddy et al., 2020).

Again, nine species presented with no malignant records. The species with the lowest malignant neoplasia prevalence were Saimiri sciureus (common squirrel monkey) and Acinonyx jubatus (cheetah)—two species with markedly different lifestyles. Similarly, the least common malignancy types in mammals were also varied, ranging from sarcomas to blood cancers, to epithelial cancers and specific organ neoplasms. The least common malignancy observed was histiocytic sarcoma, a correspondingly rare cancer infrequently observed as a spontaneous neoplasm in nature (Hung & Qian, 2019).

Malignancies, and especially those related to carcinoma, may arise from several causes. Decreased concentrations of nucleoside triphosphates, which are precursors to genetic material such as DNA or RNA, have been observed in carcinoma tissues in mammals (Jiang et al., 2018). This may demonstrate a tie between carcinomas and environmental factors which affect histone organization within mammalian genomes, or factors which disrupt proper genome replication during cell division (Zhou et al., 2011). Specifically, chemical pollution of the environment with metals like nickel, arsenic, or chromium may affect histone modifications during genome replication, leading to malignancies including carcinoma because of genetic damage (Dai & Wang, 2014). One of the largest indicators of exposure to these types of polluters is diet, which can largely be predicted across mammals by evolutionary relationships to other species (Vincze et al., 2022). Another source of genetic damage could possibly be attributed to long-term exposure to pesticides (Dai & Wang, 2014). Two of the species which have no incidence of either malignant or benign neoplasia, on the other hand, are bats: Pipistrellus pipistrellus and Pteropus rodricencis. Bats have been observed as having a protein which protects their cells from genotoxic factors, leading to a lower prevalence of neoplasia among bat species (Koh et al., 2019). Interestingly, this same gene is also present in human cells, though it is expressed at far lower levels than in bat cells (Koh et al., 2019). Delphinus delphis and Phocoena Phocoena (common dolphin and common porpoise) also reported no incidence of either malignant of benign neoplasia, despite these species widely presenting with neoplasia at a higher rate than other marine mammals (Newman & Smith, 2006).

Environmental factors also play a significant role in increased neoplasia rates in humans. A prominent example of an environmental toxin to which are exposed long-term is tobacco and tobacco products (Doll & Peto, 1981). Similar to other environmental toxins, this is linked to an increased rate of malignant lung cancer in humans (Doll & Peto, 1981), as a specific example of chemical carcinogenesis in humans compared to well-documented chemical pollutant cancer risks across the tree of life (Cohen & Arnold, 2010). Other wide-spread causes for neoplasia include factors such as infections, radiation, stress, and non-food or tobacco-related exposure to pollutants (Anand et al., 2008). Decreased rates of neoplasia in humans can largely be attributed to lifestyle choices, especially since harmful ingestion of materials (tobacco and food) can be linked to as many as 65% of cancer cases (Anand et al., 2008). Accordingly, lifestyle choices which prioritize avoiding the pollutants and chemicals associated with these areas represent a contributor to lower neoplasia in humans.

CONCLUSION

The goal of this study was to give rise to animal models that help understand specific types of cancer, the general mechanisms of tumor development and tumor resistance. Animal models became tools for conducting cancer research initially due to the ethical concerns that surrounded human clinical studies. Today, scientists are focused on using these organisms for modelling tumors that will eventually evolve to developing anticancer drugs.

Similarities between a couple mammal species and humans, highlighted by the leaderboards in my analysis, might represent specific avenues into research about model organisms which could be used to study cancer. For example, shrews have been shown to have remarkable genetic similarity to primates compared to other rodents, meaning that they could potentially be used to model cancer in humans (Lu et al., 2021). The leaderboards also highlight the short-eared elephant exhibited one of the highest neoplasia rates among all species studied in the lab. In addition, my findings highlighted common squirrel monkey, cheetah, and the Atlantic Harbor Seal as specific species worth investigating because of their reported malignancy prevalence. Bats may also be of interest since they express one of the same cancer-repressor genes as humans, but at a far higher level than in human cells (Koh, 2019). Overall, my analysis supports the notion that adenocarcinoma is the highest prevalent neoplasia type in animals, showing that the species with highest malignancy prevalence could maybe be used to show analogous trends with human adenocarcinoma rates. This research points to several interesting topics which could be used in further research. One avenue can focus on the role organ size plays in tissue-specific cancers. An example of a possible topic in this case might be the Hippo signaling pathway which, in addition to being highly conserved across species, is also related both to the growth and eventual size of organs in mammals and to organisms' cancer regulation abilities (Zeng & Hong, 2008). Another can investigate how non-traditional model organisms can help shape the way I approach researching tumorigenesis, etiology of particular cancer types, and the development of anticancer drug treatments.

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APPENDIX

See attached files.