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WHY DO TAUNTAUNS HAVE TWO PAIRS OF NOSTRILS? ADAPTATION OF ORGANISMS TO EXTREME ENVIRONMENTS IN THE *STAR WARS* UNIVERSE

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ABSTRAKT

DLACZEGO TAUNTAUNY MAJĄ DWIE PARY NOZDRZY? ADAPTACJE ORGANIZMÓW DO ŻYCIA W EKSTREMALNYCH ŚRODOWISKACH W UNIWERSUM SAGI *GWIEZDNE WOJNY*

Jedną z ważniejszych cech organizmów jest zdolność adaptacji do otaczającego środowiska. Celem artykułu jest porównanie adaptacji do zróżnicowanych warunków występujących na pustyni, w ekstremalnie zimnych regionach i w środowisku wodnym u organizmów zamieszkujących Ziemię oraz stworzeń wymyślonych na potrzeby sagi Gwiezdne wojny. Omówione zostaną niektóre charakterystyczne dla sagi gatunki: sarlacc, banty, eopi, tauntauny, wampy, morski zabójca opee (ang. opee sea killer), ryba colo claw (ang. colo claw fish), morski potwór sando (ang. sando aqua monster) i aiwha. Występujące u fikcyjnych stworzeń przystosowania do środowiska zostaną porównane z adaptacjami wykształconymi przez wykazujące podobieństwo gatunki zamieszkujące Ziemię. Mechanizm tych przystosowań zostanie wyjaśniony na podstawie aktualnej wiedzy biologicznej.

SŁOWA KLUCZOWE:

adaptacja, ekofizjologia, środowiska ekstremalne, *Gwiezdne wojny*

INTRODUCTION

It is not the strongest of the species that survives, nor the most intelligent. It is the one that is most adaptable to changes

Charles Darwin

All organisms require specific conditions for living. The most appropriate parameters of the environment, which enable full activity including reproduction, are called optimal living conditions. Exceeding the boundaries of these conditions leads to stress, weakened performance and, in extreme cases, death. Although among other planets of our solar system Earth possess the most propitious environment for the development of life, it still shows a great diversity of physical parameters. The broad range of parameters, especially temperature and water availability, resulted in the formation of distinct biogeographic units characterized by specific environmental conditions and assembly of particular animal, plant and microorganism species. Such distinct units are called biogeographical realms, biomes or ecoregions. The recent list of ecoregions published by World Wildlife Fund (WFF) is shown in table 1[1].

Table 1. Ecoregions on Earth according to World Wildlife Fund (WFF)

TERRESTRIAL ECOREGIONS	FRESHWATER ECOREGIONS
Deserts and xeric shrublands	Large river ecosystems
Tropical and subtropical moist broadleaf forests	Large river headwater ecosystems
Tropical and subtropical dry broadleaf forests	Large river delta ecosystems
Tropical and subtropical coniferous forests	Small river ecosystems

1 M.C. Londoño-Murcia, O. Tellez-Valdés, V. Sánchez-Cordero, *Environmental Heterogeneity of World Wildlife Fund for Nature ecoregions and Implications for Conservation in Neotropical Biodiversity Hotspots*, "Environmental Conservation", 2010, 37, p. 116–127.

Temperate broadleaf and mixed forests	Large lake ecosystems
Temperate coniferous forest	Small lake ecosystems
Boreal forest / taiga	Xeric basin ecosystems
Tropical and subtropical grasslands, savannas and shrublands	
Temperate grasslands, savannas and shrublands	MARINE ECOREGIONS
Flooded grasslands and savannas	Polar ecoregions
Montane grasslands and shrublands	Temperate shelf and seas ecoregions
Tundra	Temperate upwelling
Mediterranean forests, woodlands, and scrubs	Tropical upwelling
Mangroves	Tropical coral

The diversity of species found in particular ecoregions is a result of evolution leading to the development of various adaptations to the surrounding conditions. Therefore, it can be stated that the diversity of environmental conditions found on Earth results in biological diversity of organisms. However, Earth is still only one planet. How would life evolve in a universe with a number of planets differing in conditions but still capable of supporting life? Would the biodiversity be even greater and the adaptations more sophisticated? Human imagination has already created such universe in a world-famous series of movies, books, and comics – *Star Wars*. This article is an attempt to compare real organisms living on Earth and imaginary creatures from the *Star Wars* universe. How similar are their adaptations to distinct environmental conditions? To what extent are the *Star Wars* creatures based on real organisms? Do they possess some features that cannot be found on our planet?

Considering that it would be impossible to take into account all organisms found in the extremely extensive *Star Wars* Universe, the article is focused on the most characteristic species found in the deserts, in frigid regions, and in the water.

LIFE ON THE DESERTS

Deserts in the Star Wars Universe

It appears that deserts were one of the most favorite environments of the *Star Wars* authors. Probably, the most important planet of the whole saga is Tatooine: the home of Anakine and Luke Skywalker, hideaway of Obi-Wan Kenobi, and the territory of the Hutt clan with Jabba as the leader. The planet was located in the Outer Rim and was orbiting between two suns. Lack of surface water and high temperatures made it a difficult place to live. It was inhabited mainly by moisture farmers who obtained water from the atmosphere, as well as Jawa and Tusken Raider near-human species. Other important desert planet included Geonosis and Jakku. Geonosis was the first capital of the Confederacy of Independent Systems led by Sith Lord Dooku. In turn, Jakku was one of the main sites in *Star Wars Episode VII: The Force Awakens*.

Between plant and animals – the sarlacc

The available sources do not contain extensive data about the vegetation on the mentioned desert planets. Probably the best-described species is sarlacc, although it is unknown whether it is a carnivorous plant or a sedentary animal. It was a large organism, located mainly under the ground, armed with large jaws and long tentacles, which facilitated capture of its prey. The prey was thereafter slowly digested in one of the numerous stomachs. As Jabba the Hutt told Luke Skywalker, who has been sentenced to death by being thrown into sarlacc mouth: "In his belly you will find a new definition of pain and suffering as you are slowly digested over… a thousand years"[2]. The creature seems to be well adjusted to the desert environment and specific lifestyle. Most of its body was hidden away from the sunlight underneath the earth surface, where the temperature is lower and the humidity higher. A similar adaptation is often observed in the case of animals living on Earth. Their main defense mechanism against high temperature is hiding from the sunlight in the shade, behind rocks or under the ground. Many of desert species are active only during the night. Sarlacc additionally possessed moisture gathering roots, which penetrated the desert sand in search for water. Taken into account the considerable size of the adult creature, it can be assumed that it was characterized by attenuated metabolism enabling decreased requirement for energy (food) and water but also associated with low activity. The adult forms of

2 Wookieepedia. The Star Wars Wiki [online], [access: 7 August 2017]. Accessible in World Wide Web at: http://starwars.wikia.com/wiki/Main_Page.

this species led a sedentary lifestyle. Most of the time they waited passively for their prey to slip on loose desert sand[3].

Desert Reptiles

The deserts found in the *Star Wars* Universe were, similarly to Earth's desert, inhabited by various reptile species. This group of animals is well adapted to the harsh environment. The body of desert reptiles, such as lizards, snakes, and turtles, is covered with hard and dry scales and scutes, which form a tight isolation layer and reduce water loss through evaporation. It has been shown that the speed of body evaporation is over 20 times higher in the case of cayman inhabiting water environment in comparison to desert turtle. Additionally, reptiles excrete nitrogenous waste in uric acid and not urea. This form of excretion requires a smaller amount of water[4]. Interestingly, in contrast to Earth, some of the reptiles found on *Star Wars* planets were characterized by considerable body size. This could be observed on the example of rontos and dewbacks, which were used for riding and transports of loads. Another interesting example of a domesticated reptile were dogs resembling mastiffs used for guarding. In contrast to other reptiles, these animals were swift fast and agile.

Fig. 1. The sketch of massif

Desert mammals

In the case of mammals, the two most well-known species were eopies and banthas[5]. Eopies resembled Earth's camels and also possessed similar adaptations. One of the most characteristic features of both species is the possession of a hump, which serves as a reservoir of fat used in the case of long periods of limited access to food. Another similarity are long legs and wide feet, which facilitated movement on the sand. At the first sight it might seem strange that both animal species possessed thick fur. However, it has been proved that fur can serve as isolation layer limiting water loss. Camels, which have been shaved, showed 50% higher water loss than normally haired animals. It can be

3 Ibidem.
4 K. Schmidt-Nielsen, *Fizjologia roślin: adaptacje do środowiska*, tłum. M. Caputa, E. Święcka, Warszawa 1997.
5 Wookieepedia, op. cit.

hypothetized that eopies also possessed other physiological adaptations observed in camels including concentrated urine and exceptional resistance to the dehydration. Camels can survive 6-8 days without drinking. After encountering the source of water they can drink as much as one-third of their body weight. Another common feature of both species is their domestication and use as mount animals[6].

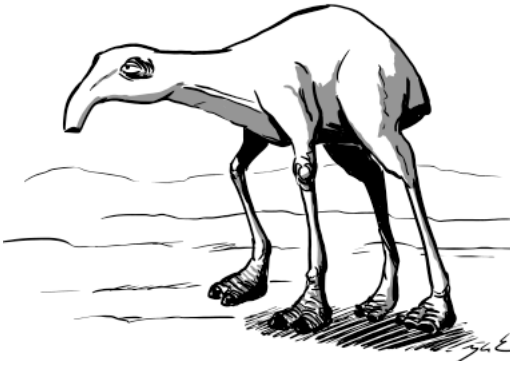

Fig. 2. The sketch of eopie

Also the second most well-known desert mammal species, banthas, were domesticated. They had a special bond with Tusken Riders. Usually, the small animal of 7 years was presented to its future Tusken Rider keeper of the same age. They grew up together and at the appropriate time, the keepers learnt to ride their companion. After getting married, the male and female banthas belonging to the husband and wife also mated and gave birth to the child at the same time as their keepers. Banthas were useful not only as riding animals. They also provided blue-colored milk used for drinking, as well as for preparation of yoghurts, ice cream, and butter, their hide found application in clothing and furniture, their meat served as food and their dung was used by Tusken Riders as cooking fuel. Apparently, they were well adapted to various environments. Distinct varieties of banthas were found in forests, mountains and in the deserts. They must have possessed exquisite adaptation mechanisms to various conditions. However, there is a lack of appropriate literature concerning the topic. It is known that banthas were herbivores feeding on shrubs and grass, which they collected with the use of long tongue with gripping knobs. Their thick fur might have protected them from extreme temperatures, both cold, and heat. Additionally, banthas' strong legs and broad feet might have helped in walking on loose desert sand as well as on slippery rocky surface in the mountains[7].

6 K. Schmidt-Nielsen, op. cit.; F. Ashcroft, *Życie w warunkach ekstremalnych*, tłum. P. Lewiński, Warszawa 2002.
7 Wookieepedia, op. cit.

What about plants?

In contrast to the animal kingdom, not so much attention has been paid to the plants of the Star Wars Universe. Plants on Earth have developed sometimes fascinating strategies to survive in the harsh desert environment. Firstly, they can avoid the most extreme drought and heat periods through completion of their life cycle during favorable conditions. Plant seeds might remain in the dormant state for many years waiting for appropriate time to germinate[8]. In the case of Atacama Desert, the blooming occurs during the more humid time, usually every 5-6 year. The desert blooming is a real spectacular phenomenon as shown on the photographs of Aguilar, Ruiz and Alamy (https://www.theguardian.com/environment/gallery/2015/oct/30/flowers-bloom-in-the-atacama-desert-in-pictures)[9]. To reduce the impact of high temperature and avoid water loss, plants fold or position their leaves parallel to the sun rays, develop small leaves covered with cuticle, hair or wax. Efficient water uptake is ensured by the extensive root system. Well-known succulents such as cactuses store water in their leaves or stems[10]. However, this protection mechanism exposes them to another danger - they become a tasty treat for desert animals, which also suffer from limited water availability. To scare off the herbivores, succulents are often covered with thorns, prickles, spines, and trichomes. If the first defense is broken they might still discourage pests through the development of razor-sharp crystals in their cells or synthesis of various bitter and poisonous compounds[11]. An interesting group of plants are resurrection plants, which can survive dehydration for months and "come back to life" after watering. This group consists mainly of mosses but includes also some "higher" plants such as *Camaegigas iterpidus*, *Myrothamnus flabellifolia*, *Talbotia elegans*, *Borya nitida* and *Anastatica hierochuntica* also called a rose of Jericho[12].

8 A. Kacperska, *Reakcje roślin na środowiskowe czynniki stresowe*, in: J. Kopcewicz, S. Lewak (red.). *Fizjologia Roślin*, Warszawa 2012, p. 634–707; J.P.M. Castillo, *Resistance to Drought in Crop*, in: N.S. Khan, S. Singh (eds), *Abiotic Stress and Plant Response*, New Delhi 2008, p. 197–204.

9 C. Aguilar, M. Ruiz, Alamy, *Flowers Bloom in the Atacama Desert – in Pictures*, "The Guardian", [online], 30 October 2015, [access: 27 January 2017]. Accessible in World Wide Web at: https://www.theguardian.com/environment/gallery/2015/oct/30/flowers-bloom-in-the-atacama-desert-in-pictures.

10 A. Kacperska, op. cit.; J.P.M. Castillo, op. cit.

11 R. Pallardy, *Botanical Barbarity: 9 Plant Defense Mechanisms*, *Encyclopaedia Britannica*, [online], [access: 10 August 2017]. Accessible in World Wide Web at: https://www.britannica.com/list/botanical-barbarity-9-plant-defense-mechanisms.

12 F. Ashcroft, op. cit.; A. Kacperska, op. cit.

THE FROZEN WORLD

The frigid Hoth

Planet Hoth stands in stark contrast to hot and arid Geonosis, Jakku and Tatooine. It was covered with snow and ice with temperatures dropping below -60˚C during the night. The life diversity on the planet was rather scarce. It was inhibited by 15 species of tauntauns and 2 wampas species. Additionally, the non-canon sources mention icetrompers, rayboos, ice-scrabblers and hoth hogs. Tauntauns, ice-scrabllers and hoth hogs fed mainly on fungus and lichens growing under the ice or in icy caves. Ice-scrabblers possessed very sensitive smell as well as hard beaks that enabled them excavating lichens hidden underneath deep layers of ice.

Adaptations to cold on the example of tauntauns

Tauntauns were big warm-blooded lizards well adapted to the frigid Hoth climate. They were covered with thick white-to-grey fur, which kept them warm and helped them stay unnoticed in the snow. The primary mechanism of defense against frigid conditions on Earth is also the development of isolation layers such as thick fur or deposits of fat under the skin and around main organs[13]. Interestingly, fat can be divided into two types: white and brown. The first type serves as an isolation layer and a reservoir of energy. In turn cells of brown fat convert energy to heat and help to keep the body temperature stable. In the case of humans, brown fat occurs only in newborn babies. In adult organisms, this kind of fat can be found in small mammals including chipmunks, hedgehogs, marmots, and bats.

Tauntauns possessed strong legs and tail and broad feet with claws, which enabled fast running on the slippery snow and ice cover. In contrast, their arms and ears were relatively small. This is an adaptation frequently observed in real animals derived from the fact, that protruding body parts such as limbs, ears, noses, and tails are subjected to the frostbite the most. Additionally, the small size of these organs limits the surface through which animals loose the heat[14].

Similarly to some Earth animals, tauntaun were able to endure the coldest periods through hibernation. During the process, the body temperature and metabolism significantly decrease. The heart rate, blood flow and speed of respiration slow down. This limits the loss of heat and energy necessary for providing stable temperature and

13 K. Schmidt-Nielsen, op. cit.; B.J. Fuller, *Cryoprotectants: the Essential Antifreezes to Protect Life in the Frozen State*, "Cryo Letters" 2004, 25, p. 375–388.

14 K. Schmidt-Nielsen, op. cit.

higher activity. The "classical" hibernation is typical to small mammals such as hamsters and bats. Some bear species also spend winter time asleep limiting their activity and metabolism. However, the temperature of their body drops only by few °C[15].

An unusual tauntaun adaptation were two pairs of nostrils. In normal conditions, they breathed through smaller nostrils to avoid an excess of cold air. However, during higher activity, for example running, they used the larger pair of nostrils to inhale higher oxygen quantities. Two pairs of nostril enabled also better circulation of air[16].

Animals can adapt to low temperatures not only through adjustment of physiology but also through their behavior. For example, during incubation of eggs the males of Emperor penguin spend 65-75 days in one location without the possibility to search for food or shelter. At that time there are exposed to the temperature dropping below -30°C. The only possibility to endure these conditions is ...sticking together. The penguins form large colonies of hundreds or thousands of birds standing close to each other and keeping each other warm. Their position changes from time to time, so that the animals from the outskirts of the colony, which are subjected to the cold the most, can also warm themselves. A similar strategy, in a little bit less extreme conditions though, can be observed in the case of bees. In response to low temperatures, they keep close to each other forming a large swarm. While the temperature outside can drop to 2°C the temperature inside of the swarm might be as high as 30°C[17]. Tauntauns also formed a herd of animals. Another behavioral adaptation was hiding in the caves or burying in the snow during the coldest periods, especially in the night.

The Wampas

The main predators found on Hoth were wampas. These large animals resembled Earth's crypto-animal Yeti. Similarly to the Yeti's descriptions, they moved mainly on two feet, reached 3 m of height and 150 kg of weight and were covered with thick white fur. Wampas were well-fitted for predatory lifestyle. Their white fur served as a perfect camouflage and enabled sneaking to the potential prey. One hit with strong, long arms equipped with sharp claws could quickly overpower an unfortunate animal. Another adaptation to the predatory lifestyle was very sensitive smell enabling sensing the potential prey from the distance[18].

15 Ibidem; F. Ashcroft, op. cit.
16 Wookieepedia, op. cit.
17 K. Schmidt-Nielsen, op. cit.
18 Wookieepedia, op. cit.

The importance of blood circulation

Some of the adaptations can be concluded on the basis of animals morphology or behavior. However, cold endurance needs also physiological changes, which cannot be observed by the "naked" eye. To discover this adaptation we would need specialized equipment, which is obviously not possible to use in the imaginary *Star Wars* Universe. However, on the basis of biological knowledge, we can presume that the inhabitants of Hoth must have also adjusted their blood circulation to low temperatures. It is one of the most common protective mechanisms observed in many mammals, including humans. In response to a sudden drop of the temperature the small blood vessels under the skin shrink. This limits blood flow to the skin, redirecting it to the inner part of the body to secure proper temperature of main organs. This mechanism underlies human reaction to the rapid drop in temperature – our hands and faces become pale. However, prolonged ischemia has a very adverse effect on tissues. Therefore, after some time in the low temperatures, small vessels localized under the skin start alternately shrinking and relaxing making the uncovered parts of human body looking reddish[19].

Some animals possess special adaptation mechanism called countercurrent heat exchanger. The vessels that transmit warm blood from the inner parts of the body are tightly connected with blood vessels coming from the protruding parts such as legs and fins. This mechanism enables the exchange of the temperature between the countercurrent vessels. On the one hand, the blood from external body parts gets warmer. On the other hand, the blood transmitted from the inner of the body to the limbs lowers the temperature and, therefore, limits the loss of the body heat. The countercurrent heat exchanger can be found for example in the fins of dolphins and legs of water birds such as swans and ducks[20].

Adaptations to cold in food industry

Birds and mammals belong to *homeothermic* animals, which keep their body temperature relatively stable independently from the environmental conditions. However, most of the animals including invertebrates, fish, amphibian and reptiles assume the temperature of their surroundings. Their main problem is the danger of bodily fluids freezing leading to organ damage. These organisms have developed interesting defense mechanisms. Some bacteria strains and insect species can produce ice nucleating agents (INA) – substances that propagate formation of ice crystals in relatively safe body parts such as outer coat or haemolymph (insects analogue of blood). In turn, compatible solutes, such as glycerol and some sugars, for example,

19 F. Ashcroft, op. cit.
20 Ibidem; K. Schmidt-Nielsen, op. cit.

trehalose prevents the formation of ice crystals by increasing liquids viscosity. Other helpful compounds are anti-freeze proteins (AFP), which prevent small ice crystal from growing. So far AFPs have been discovered in plants, fungi, bacteria, insects, and fish[21]. Interestingly, some AFPs might be useful in the food industry for examples in the production of smooth ice-creams[22]. The rare arthropod species found in the Antarctic, beside the synthesis of osmoprotectants and ability of supercooling bodily fluids, also have increased levels of proteins engaged in repair processes such as Heat Shock Proteins (HSPs). Interestingly some of these species also struggle with dehydration – although there is a lot of water in their surroundings, it is in the unavailable, frozen state. These organisms show higher tolerance to desiccation or limit water loss by the development of hard and impermeable coating[23].

Water refuge

It is worth noting that in the coldest regions of Earth life is nearly always connected with water. The reason for this phenomenon is the fact that water forms a stable environment. Most of the water reservoirs surrounding Arctic and Antarctic has a relatively stable temperature of -1.8˚C (slightly below the water freezing point due to the dissolved salts). Although below 0˚C, it is still higher than the temperature on the surface dropping sometimes below -50˚C. More favorable living conditions in the seas and oceans resulted in the development of diverse life forms, including small animals, algae, bacteria and protozoa organisms forming plankton. Plankton, in turn, serves as food for larger animals such as fish and whales. Even land mammal species of Arctic and Antarctic, including polar bears, seals, and penguins spend some, if not most, of their time in the water.

DEEP UNDER THE WATER

Life in the water

Life in the aquatic environment also requires special adaptation. Even the ability to swim needs adjustments. If water organisms were too heavy they would have a tendency to fall to the bottom of the water reservoir. Therefore, many aquatic organisms have developed mechanisms which help them reduce their weight: high

21 B.J. Fuller, op. cit.

22 M. Griffith, K.V. Ewart, *Antifreeze Proteins. Antifreeze Proteins and Their Potential Use in Frozen Foods*, "Biotechnology Advances" 1995, 13, p. 375–402.

23 N.M. Teets, D.L. Denlinger, *Surviving in a Frozen Desert: Environmental Stress Physiology of Terrestrial Antarctic Arthropods*, "Journal of Experimental Biology" 2014, 217, p. 84–93.

concentration of oils and fat, which are lighter than water, compartments filled with gases, for examples plant air bladders or fish swim bladder, or decreased content of heavy salts and ions including calcium, phosphorus, sulfur, and magnesium. To facilitate movement in the water limbs of many aquatic animals evolved into flippers, finned limbs and fluke tails. Additionally, swimming in relatively dense water (when compared to the air) requires some adjustments preventing from fractioning forces, mainly streamline shape of the body and a mucus cover[24].

Another problem is the low content of oxygen. Fish breathe with oxygen dissolved in the water due to the development of gills. In turn, aquatic mammals such as dolphins and whales breathe with oxygen from the air. They can accumulate oxygen in myoglobin – a molecule similar to hemoglobin, which has high affinity to oxygen. Moreover, under limited oxygen supply, muscles of these animals maintain low metabolism[25].

The water in natural reservoirs such as oceans, seas, rivers or lakes is not absolutely pure. It is enriched by various elements, mainly sodium, chloride, magnesium, potassium, sulfur, and calcium. The problem occurs when the concentration of salts in the water differs significantly from the concentration of salts in body liquids of aquatic organisms. In the case of salt water of the oceans and seas, the difference in salt concentration leads to flow of water from the organism to the surrounding medium. The solution to this problem is increased water uptake accompanied by excretion of salts, which are toxic in high concentrations. Various organs are engaged in salt excretion: Malphigian tubules (invertebrates), gills (fish and some invertebrates) or salt glands (for examples some birds and mammals).

In turn in the freshwater reservoirs, such as lakes and rivers, the concentration of salts is usually higher in the aquatic animals than in their environment. In this case, the water from the environment has a tendency to penetrate into their body, which might lead to a burst of the cells. To avoid damage such organisms have evolved various defense mechanism including lower permeability to water and increased water excretion. The aquatic environment also forced new ways of sensing and communication including echolocation and sensing of water vibration, which gives information about the water flow or localization of potential prey[26].

24 K. Schmidt-Nielsen, op. cit.; J.S. Reidenberg, *Anatomical Adaptation of Aquatic Mammals*, "The Anatomical Record" 2007, 290, p. 507–513.

25 Ibidem.

26 K. Schmidt-Nielsen, op. cit.

The "monsters" of Naboo

In the *Star Wars* Universe, the greatest biodiversity of aquatic organisms was present on the planet Naboo. One of the characteristic species was opee sea killer, which looked very? alike to anglerfish (*Lophius piscatorius*) found in the Atlantic Ocean. Opee sea killer was a hybrid of crustaceous and fish, with hard armor, a pair of fins and three pairs of legs. It had a unique technique of swimming depending on swallowing of water and then propelling it through pores. Another characteristic feature was a pair of luminous stalks. Similar organ, called "esca", is found in the mentioned earlier anglerfish. It is a result of symbiosis with bioluminescence bacteria and serves as an attractor for prey[27].

Another interesting species found in the waters of Naboo is colo claw fish. It resembled Earth's eel, with an exception of crocodile-like-looking head. Colo claw fish was very well fit for the predatory lifestyle. It possessed two rows of bioluminescence nodules functioning as prey attractors, jaws which could unhinge to swallow bigger prey and ability to stun animals with strong, sonic screech.

However, as the Qui-Gon Jinn, one of the protagonists of the fictional universe, said: "There's always a bigger fish". The largest and most dangerous predator of Naboo's waters was sando aqua monster reaching 200 m of length. Little is known about the animal. It was heavily muscled, possessed finned claws and a long tail. The described features facilitated its movement in the water. Interestingly, sando aqua monster could not only swim but also walk on the bottom of the sea.

The aiwha

In the case of other planets, it is worth to mention aiwha native to Kamino. They were exceptional animals able to swim and fly[28]. Some of the adaptations to both ways of locomotion can be concluded on the basis of their body structure. They had streamline body shape, which enabled fast movement in the water and in the air. They also possessed large fins, which could serve as wings. Their movement would require powerful muscles and a rigid skeleton – features commonly observed in birds on Earth. Interestingly, on the one hand, the skeleton of birds is exceptionally rigid due to the fusion of some bones, on the other hand, it is very light as the bones are nearly hollow. Additionally, birds have air sacs which reduce their weight and at the same time enable efficient breathing. The effort of flying also requires fast blood circulation and

27 T.W. Pietsch, *Oceanic Anglerfishes: Extraordinary Diversity in the Deep Sea*, Berkeley, 2009, p. 3–22.
28 Wookieepedia, op. cit.

therefore rapid heart rate. Hearts of some small beards beat 1000 times per minute. In comparison, the average human heartbeat rate is 70 times per minute[29].

THE ORIGIN OF *STAR WARS* CREATURES

There is one crucial difference between animals inhabiting Earth and *Star Wars* planets: the first ones are real, while the others are a product of human imagination. Are the similarities in their adaptations to the harsh environments just a coincidence? The well-known quote says: "Behind every fairy tale there is a hint of truth". The images of fantastic creatures are always, at least partially, based on some existing organisms. The unicorns and Pegasus resemble a horse, the Kraken is alike a giant octopus, while dragons look similar to lizards. In fact, one of the biggest lizards on Earth is called Komodo Dragon. Thus, it would be difficult to believe that the organisms found in the *Star Wars* Universe were not based on any living organism. Indeed the designers admit that at least some of the creatures have their earthly model. For example, the anatomy of wampas was based on crypto animal Yeti, while eopies resemble camels.

Many of the animals in the *Star Wars* Universe were designed by one of the most famous creature designers – Terryl Whitlatch. Her success in the field stems from her broad knowledge concerning animal anatomy and biology. The artist studied zoology and is a paleo reconstructionist and Senior Consultant for Wildlife Art and Animal Anatomy at World Wildlife Fund. In one of the interviews, she admits that during her work on the *Star Wars* animals she was looking for inspiration in the real organisms, such as salamanders, caterpillar or already extinct sabertooth cats. She also points out to the importance of taking into the account the life environment of imaginary animals in their designing: "I usually have a story and place/environment that the creature exists in – this determines to a great deal what types of behaviors and functional lifestyles, and what type of anatomy it needs to survive successfully"[30]. In another interview she highlights that in order to design a convincing imaginary creature the artist should "be familiar with the biology of living animals – their place in nature, how they behave within their environment, what they eat, how they catch their food, are they carnivorous, herbivorous, omnivorous, etc. how does their anatomy enable them to exist?"[31].

29 K. Schmidt-Nielsen, op. cit.

30 Artist interview with Terryl Whitlatch on Copic [online], [access: 29 January 2017]. Accessible in World Wide Web at: https://imaginationinternationalinc.com/copic/inspire/showcase/concept-illustrator-terryl-whitlatch/.

31 Interview with Terryl Whitlatch on The Gnomon Workshop [online], 10 October 2008, [access: 29 January 2017]. Accessible in World Wide Web at: thegnomonworkshop.com/blog/interview-with-terryl-whitlatch.

Although designed with consideration of scientific rules and biological concepts the creatures of *Star Wars* have one great advantage – their biodiversity is limited mainly by the authors imagination. There is no way in which we could unfailingly evidence that they would survive in their environment and withstand the competition. The evolution of life on Earth was a long process dependent on dramatic event leading to massive extinctions such as rapid increase in oxygen level, sudden cooling, volcanic eruptions or meteorite strikes. It is impossible to predict with full confidence how would the life evolve on other planets with distinct history and environmental conditions. However, the example of *Star Wars* universe show that we can use biological knowledge to create such fantastic universes in our imagination.

SUMMARY AND CONCLUSIONS

On one hand, the creatures in *Star Wars* Universe are unique and possess fantastic features. On the other hand, their anatomy, physiology, and behavior are well thought, often based on real animals and a broad biological knowledge, which makes them very convincing. Most of their adaptations to desert, cold and water environments can be observed in real animals inhabiting Earth. However, some creatures, such as sarlacc or aiwha, possess absolutely unique adjustments. Undoubtedly the mixture of the realism and fantasticality of the *Star Wars* creatures contributes to the authenticity of the universe and to the worldwide phenomenon of the saga.

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