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# Bioecology of Electric Fish (Actinopterygii: Gymnotiformes)

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**Abstract:** The poraquê has an elongated and cylindrical body, with just one anal fin, which extends across almost the entire abdomen it resembles the shape of an eel. Its head is flat and its mouth is equipped with a row of sharp, conical teeth. The color of this animal is always very dark, but the ventral part of the body is yellowish and they have poor vision. This group of fish is known for their ability to generate and detect electrical fields in the environment in which they occur, and these characteristics are used in communication, prey detection, defense, reproduction and even to help these animals move in the absence of light. This manuscript aims to describe the biology, ecology, morphology, geographic distribution, life cycle, habitat, and therapeutic use of electric fish (Chordata: Actinopterygii: Gymnotiformes). Concerned with establishing a public profile of quality research in the area, we sought to answer these questions based on a literature review in the main journals (national and international) classified by the Coordination for the Improvement of Higher Education Personnel (CAPES). Complement this analysis with other documents such as books, theses, dissertations, scientific journals, documents, and digital platforms.

**Keywords:** Atmospheric Air, Bioelectrogenesis, Electrical Organ, Electrocytes, Poraquê, Prey.

**RESEARCH PAPER**

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## 1. INTRODUCTION

The name poraquê, *Electrophorus electricus* (Linnaeus, 1766) (Chordata: Actinopterygii: Gymnotiformes: Gymnotidae) in the Tupi language, means "what puts you to sleep". This fish couldn't have a better name. Thanks to the presence of specialized muscle cells, your body can produce energy electrogenesis and capture it (electroreception). These cells, called electrolytes, are found in the animal's tail - which corresponds to 90% of the *E. electricus* body. An adult electric fish can have around ten thousand myoelectroplates, which are sets of electrolytes (Figure 1) (Albert, 2001; Albert *et al*., 2008; Luisa, 2019; Lima, 2021; Aprile, 2023; Amazon Portal, 2024).

**Figure 1: Electric Eel**
**Sources:** aqua.org and https://discover.hubpages.com/education/Electric-Eel-The-Most-Powerful-Electric-Fish

**1.1. Morfology**

The poraquê *E. electricus* has an elongated and cylindrical body, with just one anal fin, which extends across almost the entire abdomen it resembles the shape of an eel. Its head is flat and its mouth is equipped with a row of sharp, conical teeth. The color of this animal is always very dark, but the ventral part of the body is yellowish and they have poor vision. This group of fish is known for their ability to generate and detect electrical fields in the environment in which they occur, and these characteristics are used in communication, prey detection, defense, reproduction and even to help these animals move in the absence of light (Figure 2) (Barriga, 1991; Luisa, 2019; Lima, 2021; Aprile, 2023; Amazon Portal, 2024).

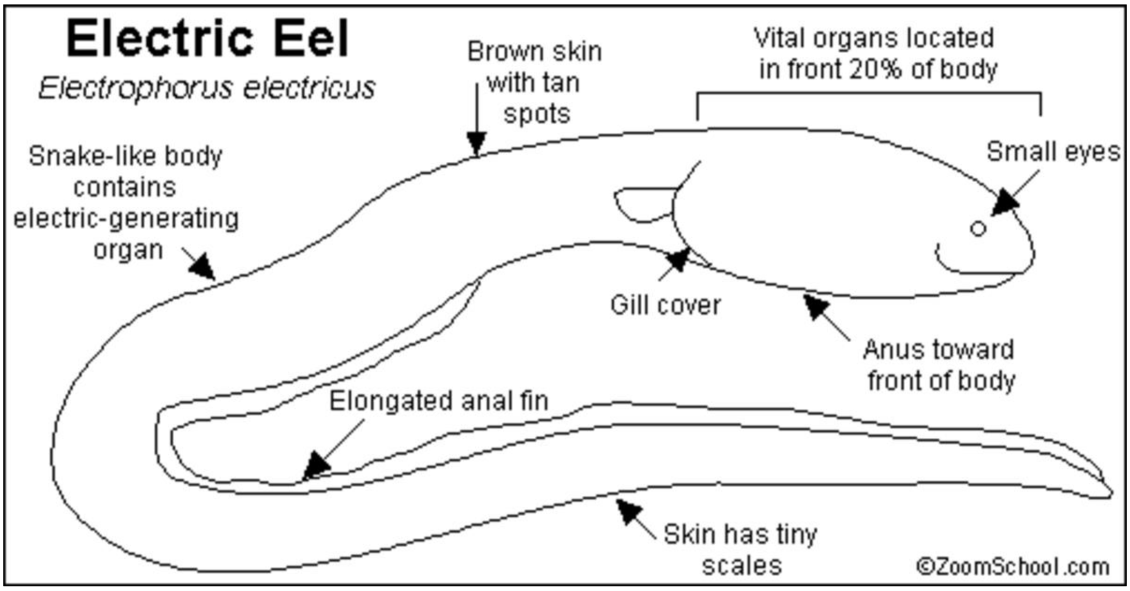


**Figure 2: Electric Eel**

**Sources:** aqua.org and https://discover.hubpages.com/education/Electric-Eel-The-Most-Powerful-Electric-Fish

**1.2. Gas Exchange**

Electric fish need atmospheric air as much as land animals to obtain oxygen. This species has gills, but it captures atmospheric air through the surfaces and buccal pharyngeal chambers the roof of the mouth is full of highly vascularized recesses, forming a large area of gas absorption exchange. As a rule, many species of fish of tropical freshwaters have obligatory or facultative air respiration, as they evolved in places with a lot of decomposing organic matter and high temperatures, therefore poor in oxygen, and any large, well-vascularized surface carries out gas exchange with a certain efficiency (Albert, 2001; Albert *et al*., 2008; Luisa, 2019; Lima, 2021; Aprile, 2023; Amazon Portal, 2024).

**1.3. Distribution Geographic**

There are several species of electric fish, that live in both freshwater and saltwater. Among them are the African electric catfish, which can be found in the Nile River, in Africa, and several types of electric rays present in oceans worldwide. Poraquês live in Amazonian waters and rivers in Mato Grosso. The species is the only one that produces strong electrical discharges, used for hunting and defense. They can be found from the Salado River La Plata in Argentina to the San Nicolas River, in southern Mexico, but it is in Brazil, in the Amazon region, that 80% of the diversity of electric fish species is found (Finger, 2010; Catania, 2016; Catania, 2017; Ministério do Turismo, 2019; Chaves *et al*., 2021; Prefeitura de Belém, 2024).

**1.4. Objective**

This manuscript aims to describe the biology, ecology, morphology, geographic distribution, life cycle, habitat, and therapeutic use of electric fish (Chordata: Actinopterygii: Gymnotiformes).

## 2.0. METHODS

Concerned with establishing a public profile of quality research in the area, we sought to answer these questions based on a literature review in the main journals (national and international) classified by the Coordination for the Improvement of Higher Education Personnel (CAPES). To complement this analysis with other types of documents such as books, theses, dissertations, scientific journals, documents, and digital platforms.

**3.0. SELECTED MANUSCRIPTS**

**3.1. Life Cycle**

As for how they find their partners, it's quite simple. They communicate through their electrical current and have the power to discover the sex of nearby eels and their compatibility. Keeping in mind that each electric fish has its unique electrical wave, this communication is vital to finding a compatible mating partner. During the dry season, male electric fish create a nest from their saliva and then female electric fish lay their eggs in these nests. It is known for its unusual reproductive behavior. In the dry season, the male makes a nest with his saliva, where the female lays 3,000 to 17,000 eggs (Oviparous), with no parental care (Figure 3) (Ortega and Vari, 1986; Albert *et al*., 2008; Gervais, 2017; Garcia and Zuanon, 2019; Chaves *et al*., 2021; Sousa and Brunat, 2021).

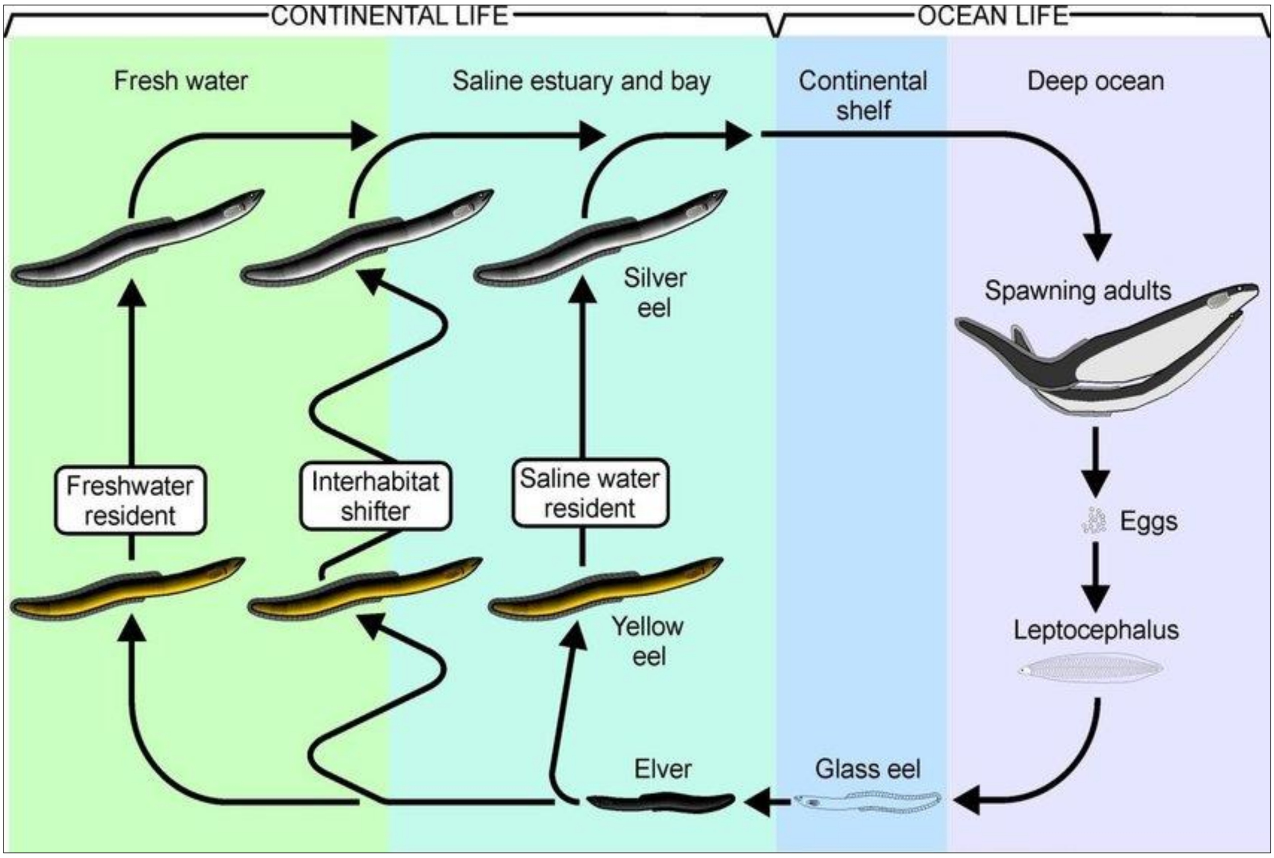


**Figure 3: Schematic diagram of the American Eel life cycle, showing alternative life history patterns during continental life**

**Source:** https://www.researchgate.net/figure/1-Schematic-diagram-of-the-American-Eel-life-cycle-showing-alternative-life-history_fig1_265292212

Males are smaller than females; these are stockier than the males. After the eggs hatch and give birth to larvae, the males guard them closely. This is especially important because the young can serve food for other larger mammals, such as piranhas, or be dispersed by floods during the rainy season. The average lifespan of electric fish is about 15 years when living in the wild. When living in captivity under laboratory conditions, male electricians had a lifespan of 10 to 15 years. On the other hand, also under field observation, females had a life cycle of 12 to 22 years. In summary, electric fish are known to survive an average of 15 years in the wild, while they can live up to 12 years in captivity (Plumb, 2010; Markham, 2013; Raimundo *et al*., 2020; Verçoza *et al*., 2021; Rechi, 2024).

### 3.2. Specialized Organ

These fish have a specialized organ called an electrical organ which is made up of cells that differentiated from muscles during their evolution. *E. electricus* has three pairs of abdominal organs that produce electricity: the main organ. These organs occupy a large part of their body and give them the ability to generate two types of electrical organ discharges: low voltage and high voltage. These organs are made of electrocytes, aligned so that a current of ions can flow through them, and stacked so that each adds a potential difference. The three electrical organs are developed from muscle and exhibit diverse biochemical properties and morphological characteristics of the muscular sarcolemma; they are found symmetrically along both (Figure 4) (Zakon *et al*., 2008; Turkel, 2013; Traeger, 2017; Santana *et al*., 2019; Sousa and Bruna, 2021; Verçoza *et al*., 2021).

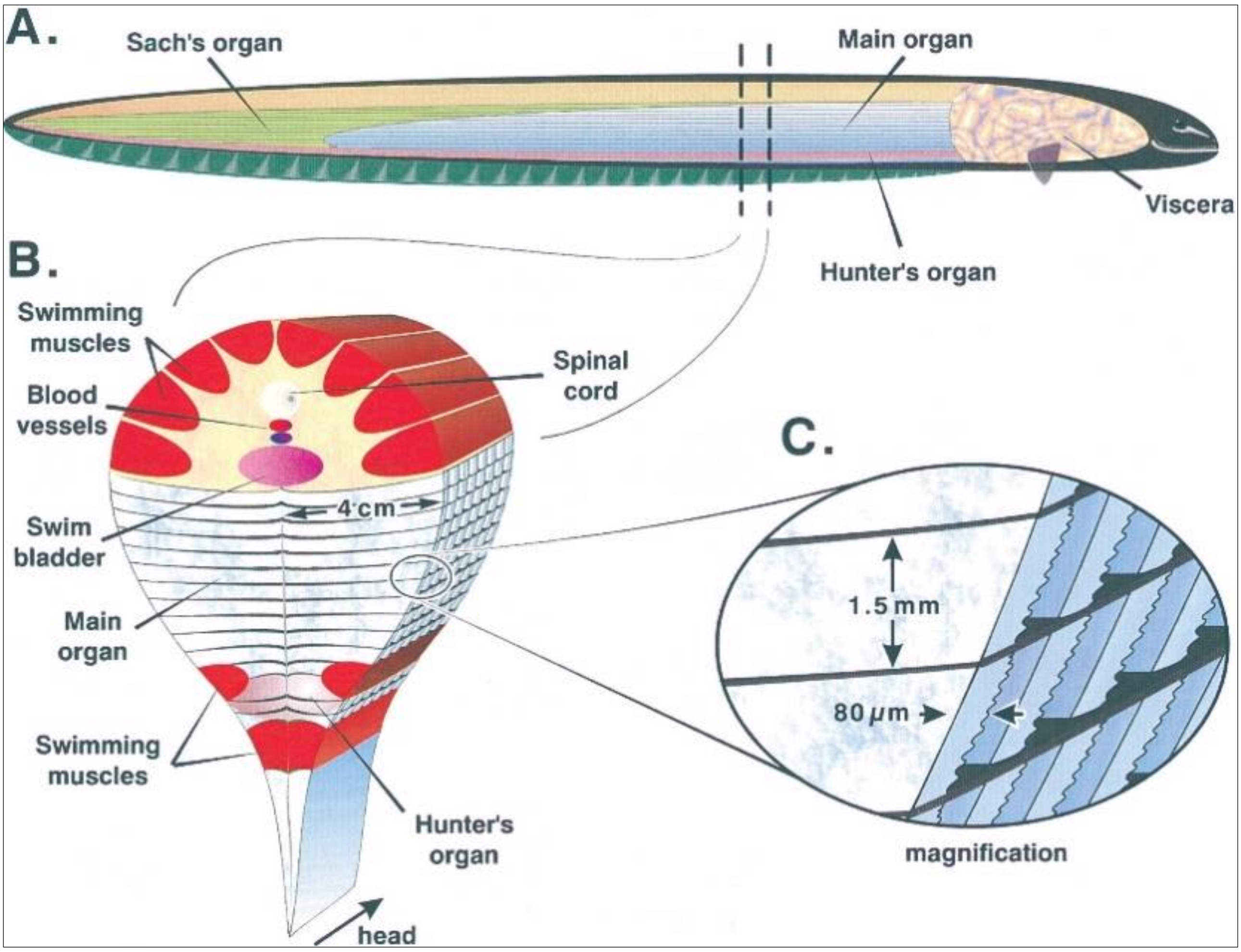


**Figure 4: The same basic scheme is used by Amazonian freshwater electric eels (technically they are air-breathing fishes rather than eels) to generate 2 ms pulses at 600 volts and up to 1 amp of current. While the electric eel is the voltage king, all kinds of other fish have managed to cobble together their version of the undersea cattle prod. Several species of catfish have even gone all electric. Most of these other guys only hit a couple hundred volts, but in their conductive salt-water environment, their biobattery generally doesn't need as much to do the job. The Greeks were particularly found of electric fish, and reportedly used the electric charms of rays or skates to numb patients for surgery and to treat any number of ailments**

**Source:** https://www.extremetech.com/extreme/185518-eel-muscles-could-be-the-first-step-towards-human-generated-electricity

Scientists thought that *E. electricus* was the only species of porcupine that existed. But now, 250 years after its discovery, it has been found that there are three different types of poraques. And one of them can produce an electrical discharge of 860 volts, a voltage 8 times greater than common 110V sockets. After scientists noticed physical differences between the shape of some individuals' skulls, a genetic analysis concluded that there are three different species of fish (Figures 5 and 6) (Von der Emde, 1999; Vermelstein *et al.*, 2000; Xu and Lavan, 2008; Zakon, 2008; Turkel, 2013; Verçoza *et al.*, 2021).

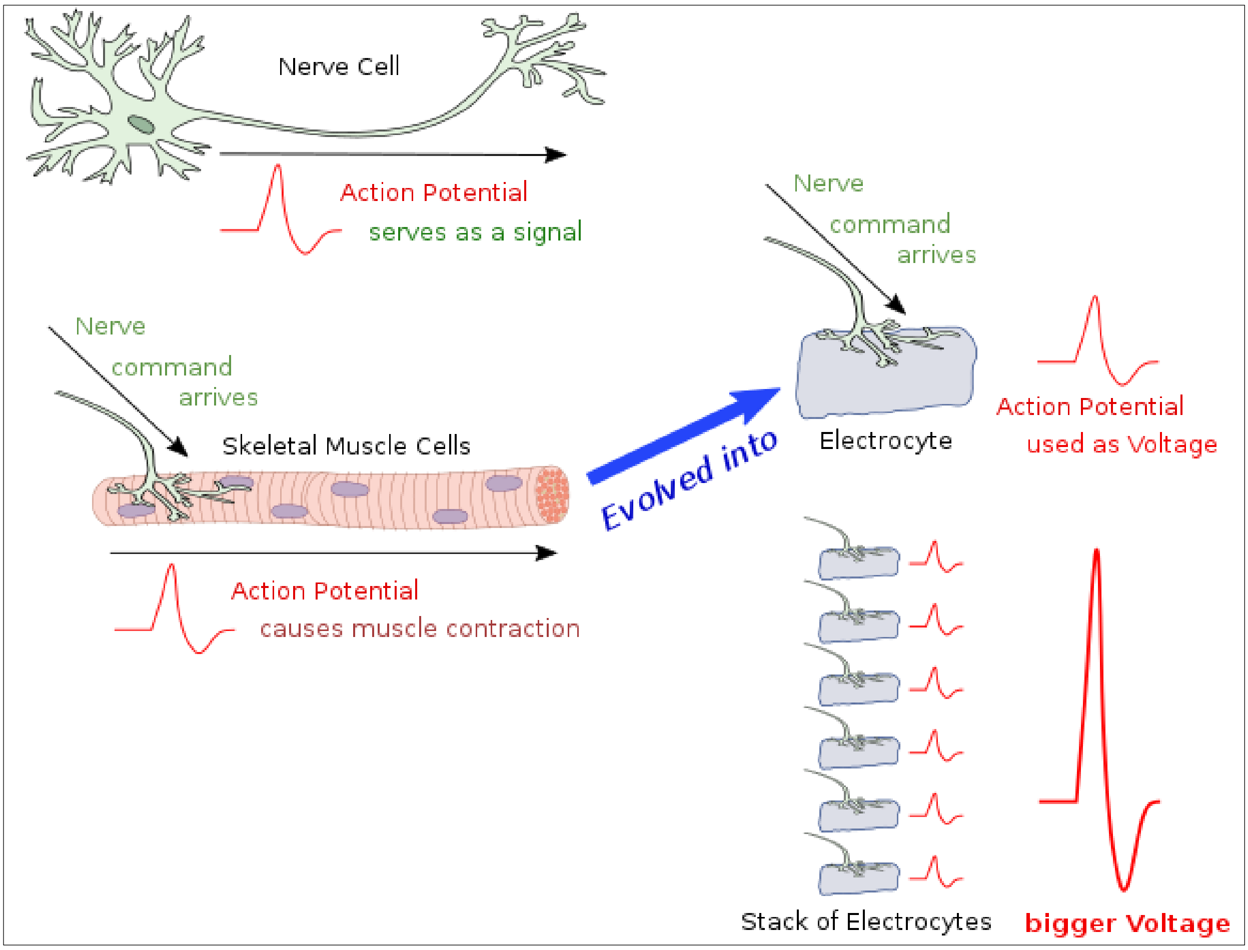


**Figure 5: Electrocytes evolved from an existing excitable tissue, skeletal muscle. Electrocytes are assembled into stacks to create larger voltages and into multiple stacks to create larger currents, not shown. Electric fish may have diphasic discharges (as shown), or discharges of other kinds**

**Source:** Markham, M. R. (2013). Journal of Experimental Biology 216 (13): 2451–2458

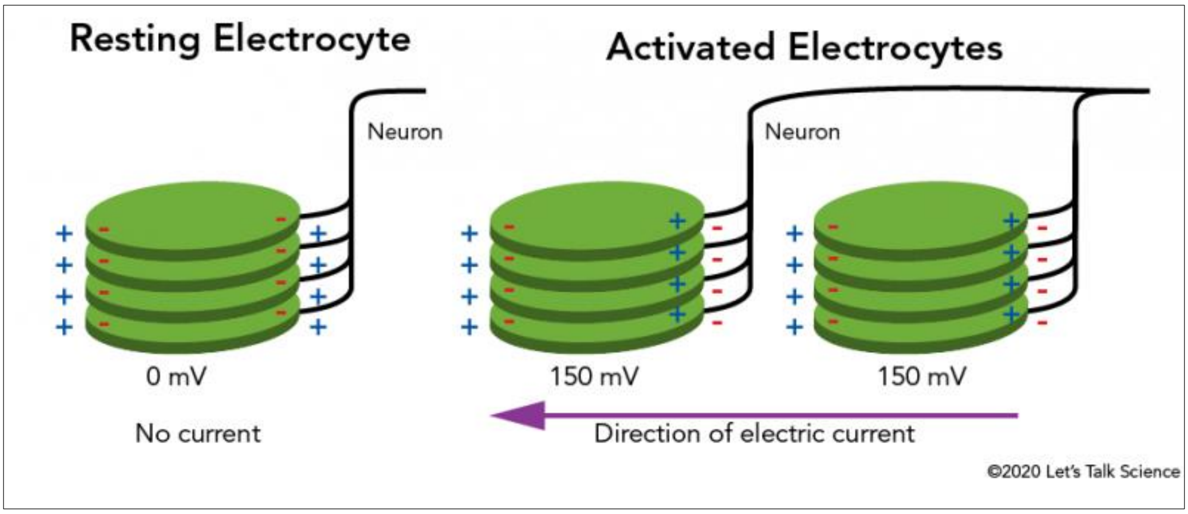


**Figure 6: The fish's electric organ is filled with disc-shaped cells. These are called electrocytes. Electrocytes are positively charged on the outside. They are negatively charged on the inside. But sometimes the fish sends a message from its brain. This signal travels through its nervous system to its electric organ. There, it changes the pattern of electrical charges in the cells. One side of each stack becomes positive. The other side becomes negative. Resting and activated electrocytes show the location of charges and voltages**

**Sources:** (©2020 Let's Talk Science) and https://letstalkscience.ca/educational-resources/backgrounders/generating-electricity-electric-animals

**3.3. Electric Fish Species**

The already known *E. electricus* lives in the extreme north of the Amazon, in the northern states of Brazil and countries such as Guyana and Suriname. One of the new species, called *Electrophorus varii* sp. nov. (Gymnotiformes: Gymnotidae) is found in the lower rivers of the Amazon basin. The star of the study, the poraquê that produces discharges of 860 volts, was named *Electrophorus voltai* sp. nov. (Gymnotiformes: Gymnotidae), and is present at the source of the Amazon River, in high areas of waterfalls and rapids. *Electrophorus voltai.* It is considered less dangerous for humans than the electrical network present in homes, as it has low amperage and lasts only a few seconds. Since most of these animals emit low-voltage currents, shocks to humans are almost imperceptible. But the shock caused by species like *E. voltai* can cause damage if it reaches regions that affect muscles, nerves, or the heart (Figures 7-8) (Von der Emde, 1999; Albert and Crampton, 2006; Kramer, 2008; Macesic and Kajiura, 2009; Shifman and Lewis, 2018).

If an electric fish can generate electric fields, it is electrogenic if it can detect electric fields, it is an electroreceptor. Most electrogenic fish are also electroreceptive. Some electric fish live in the ocean and others live in freshwater rivers in South America and Africa (de Moller 1995) provides a summary of the geographic distribution of electric fish. The weakly electric South American fish. Related searches *Apteronotus* Lacepède, 1800, *Apteronotus albifrons* (Linnaeus, 1766), and *Apteronotus leptorhynchus* (Ellis, 1912) (Figures 7-8). These fish have wave-type electric organ discharge (EOD), with a high discharge frequency of around 1 kHz and a weak electric field (Bullock and Heiligenberg, 1986; Heiligenberg, 1991; Moller, 1995).

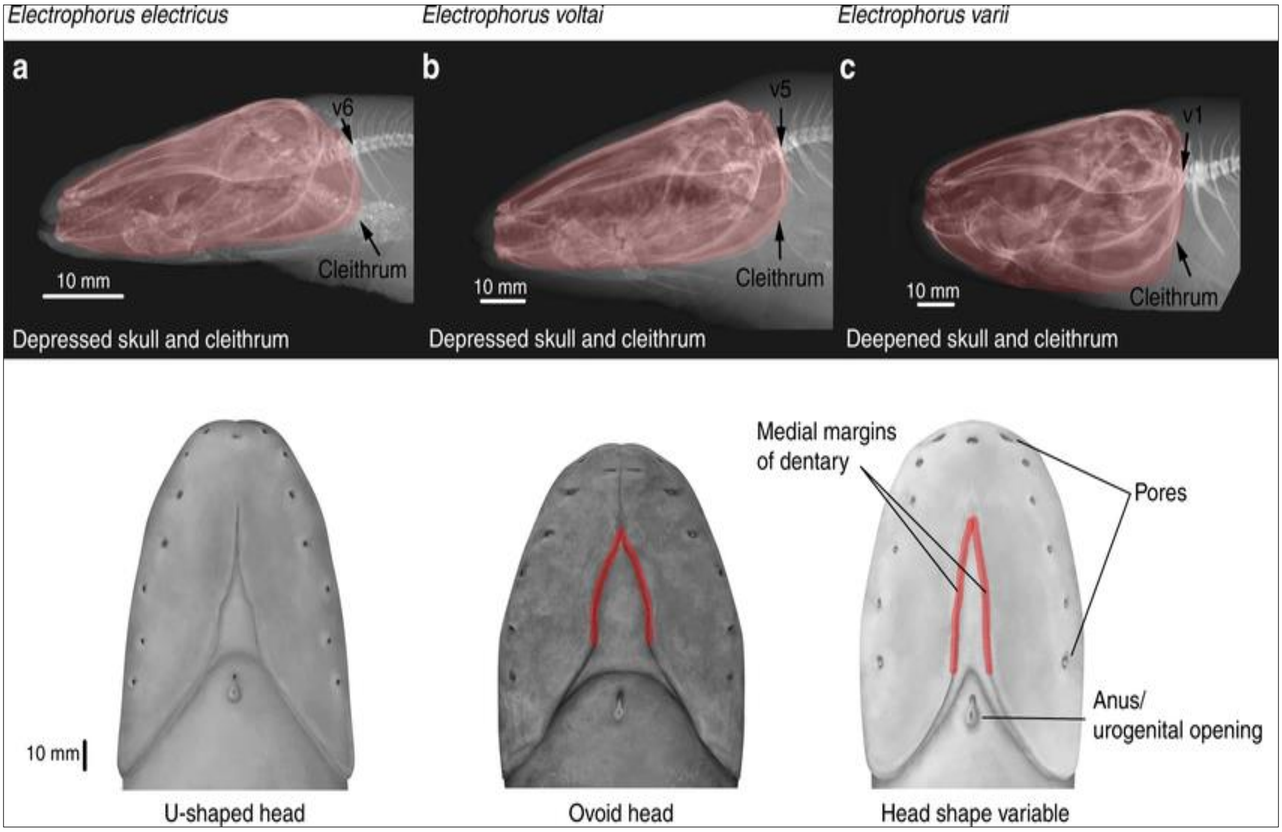


**Figure 7: Key morphological features to recognize the three species of *Electrophorus* Gill, 1864 (Gymnotiformes, Gymnotidae). Top, radiographs of lateral view of the anterior portion of the body (skull and pectoral girdle highlighted red). The cleithrum lies between the fifth and sixth vertebrae (v) in *Electrophorus electricus* (Linnaeus, 1766) (a) and *Electrophorus voltai* sp. nov. (b) versus first and second vertebrae in *Electrophorus varii* sp. nov. (c). Bottom, illustrations of ventral view of the head, showing key features listed in Diagnoses. a top: National Museum of Natural History, NMNH 403765, 300 mm TL, Cuyuni River, Guyana; bottom: NMNH 225576, 1000 mm TL, Corantijn River, Suriname. b top: Instituto Nacional de Pesquisas de Amazônia, INPA 39009, 450 mm TL, Teles Pires River, Brazil; bottom: Academy of Natural Sciences of Drexel University, ANSP 197583 (t3539), 1280 mm TL, Xingu River, Brazil. c top: NMNH 306677, 450 mm TL, Lago Janauari, Amazon River, Brazil; bottom: NMNH 196634, 1220 mm TL, Amazon River, Brazil**

**Source:** https://www.researchgate.net/figure/Key-morphological-features-to-recognize-the-three-species-of-Electrophorus-Top_fig3_335724172

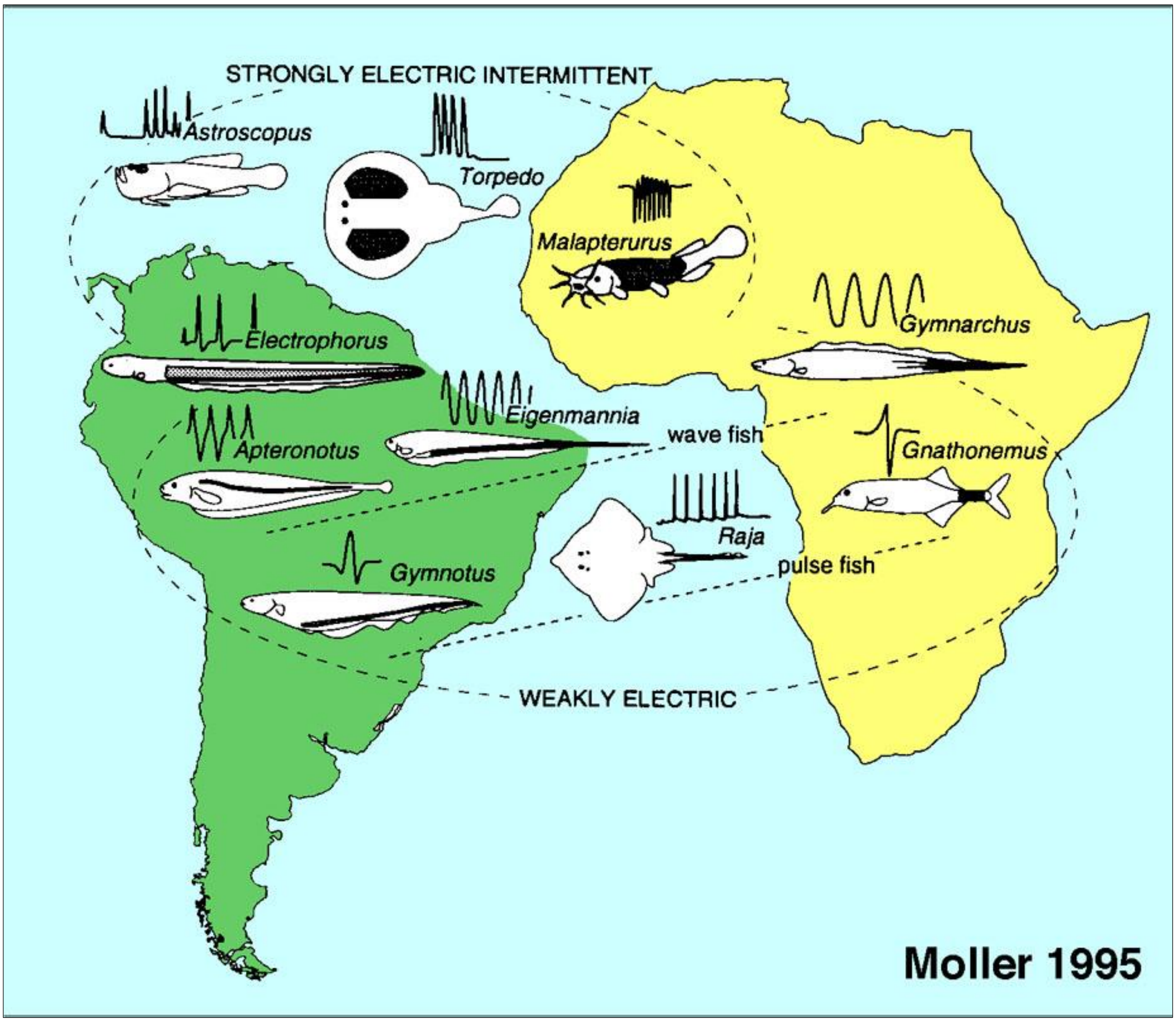


**Figure 8: The figure below (from Moller 1995) provides a summary of the geographical distribution of electric fishes (click on the image to see a larger version). The figure also shows the location of the electric organ in each fish and a sample of the waveform of the electric organ discharge**
**Source:** Moller, P. (1995). New York, Chapman & Hall

Preserved specimens of larvae, juveniles, and adults of the *E. varii* were examined to describe the spatial distribution of the canals and pores. Ontogenetic shifts of the cephalic lateral line formation were observed for each canal and support a hypothesis of non-synchronized development. The morphogenesis of cephalic canals in larvae and juveniles begins just before the onset of exogenous feeding. In adults, the cephalic sensory canals are formed separately from the skull and overlay cranial and mandibular bones and muscles (Peter, 1991; Boyer *et al.*, 2015; Pedraja *et al.*, 2020; Pedraja and Sawtell, 2024).

### 3.4. Therapeutic Possibility and Reality

#### 3.4.1. Treatment for Alzheimer's

According to the São Paulo State Research Support Foundation (Fapesp), there is several ongoing research carried out with poraquê, from studies involving electricity to the production of medicines. Some of this research analyzes enzymes produced in the fish's electrical organs and evaluates their applicability as components for the production of medicines that treat neurodegenerative diseases, such as Alzheimer's (Figure 9) (Amazon Portal, 2024; Prefeitura de Belém, 2024; Rechi, 2024).

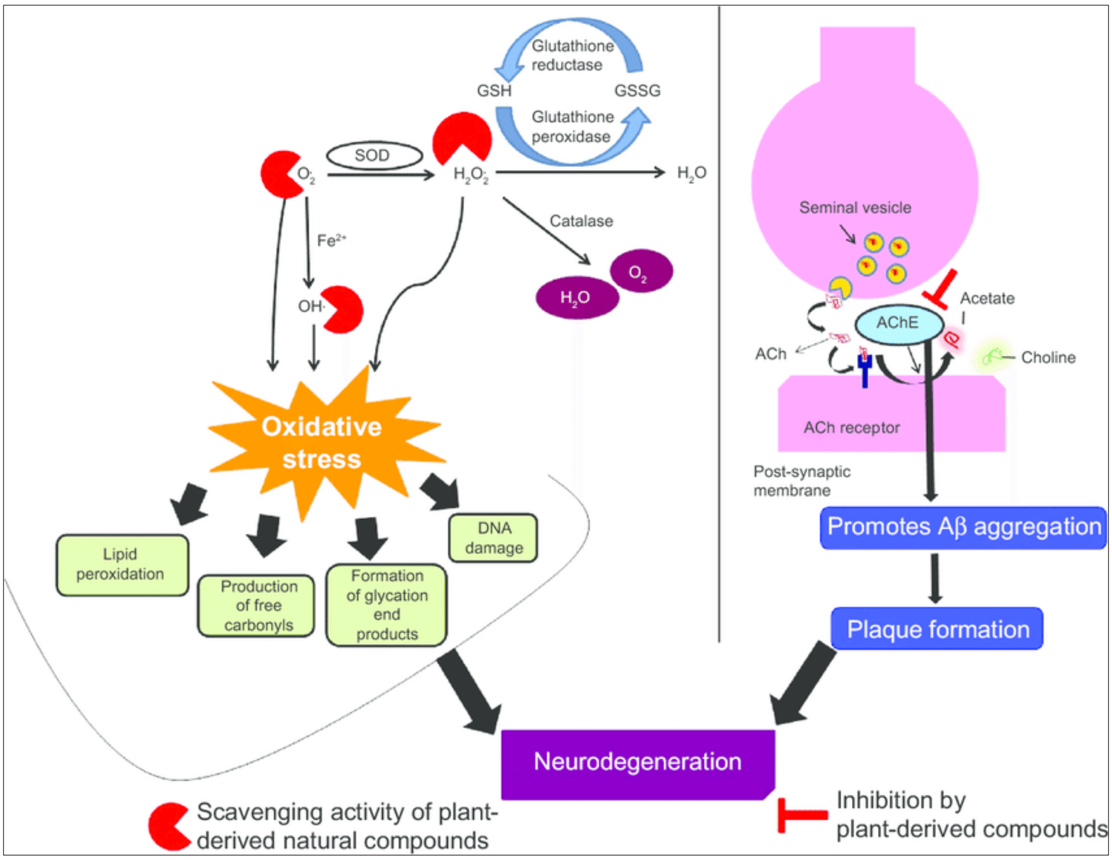


**Figure 9: Role of oxidative stress and acetylcholinesterase in neurodegeneration. Abbreviations: Aβ, amyloid beta; ACh, acetylcholine; AChE, acetylcholinesterase; GSH, glutathione; GSSG, glutathione disulfide; SOD, superoxide dismutase**

**Sources:** Murohashi *et al.*, 2018 and https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecularbiology/bioelectrogenesis

### 3.5. Bioelectrogenesis

Properties of certain cells neurons and muscle cells generate and change the difference in electrical potential across the membrane. They have been widely used as a model in the study of bioelectrogenesis. The species is of interest to researchers, who make use of its acetylcholinesterase and ATP (Figure 9) (Zimmermann and Denston, 1976, Lavoué, 2012).

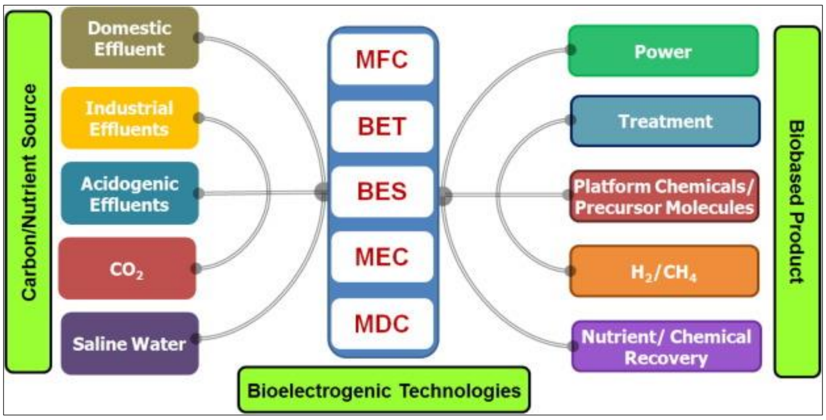


**Figure 9: Bioelectrogenic model depicting various microbial electrochemical systems for multi-faceted applications. These bioelectrochemical systems are capable of producing electrical power and fermented by-products through bioelectrochemical redox reactions. These systems can be used to power biosensors and serve as distributed power systems for local uses in underdeveloped regions of the world as in the case of eco-villages where renewable power sources can be used**

**Source:** Murohashi *et al*., 2018 and https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/bioelectrogenesis

### 3.6. Hydration for the bod

**Contains in its composition**:

**A.** Menthol: when applied to the skin, it produces vasodilation, providing a feeling of freshness followed by an analgesic effect.

**B.** Arnica Extract: has stimulating, anti-inflammatory, antiseptic, and analgesic actions. It is used to treat bruises of any nature, sprains, muscle strains, arthritis, and phlebitis, and to stimulate blood circulation.

**C.** Electric Fish Oil: It is great for improving the condition of dry skin, making it shiny and vibrant. It is useful in treating various skin problems such as eczema, psoriasis, itching, skin redness, skin lesions, and rashes.

**D.** Mastruz extract is used to treat muscle pain, and also for its anti-rheumatic properties.

**E.** Andiroba Oil: It has a healing and anti-inflammatory action, which is enhanced when massaged, relaxing the muscles and relieving muscle pain and inflammation.

**F.** Copaíba Oil: It has healing, regenerating, and nourishing properties, it is a powerful antibiotic, known as a forest antibiotic and anti-inflammatory (Vermelstein *et al*., 2000; Xu and Lavan, 2008; Zakon, 2008; Turkel, 2013; Garcia and Zuanon, 2019, Sousa and Brunat; 2021; Verçoza *et al*., 2021; Aprile, 2023; Amazon Portal, 2024; Pure Flora, 2024; Rechi, 2024).

### 3.7. Legitimate Amazon Electric Fish Lard

The Amazon electric fish ointment has been used for many years with excellent results in all related cases and mainly as an aid in the treatment of Rheumatism, Joints, Muscles, Neuralgia, Contusions, Torticollis, cramps, and Pain in General (Verçoza, G *et al.*, 2021; Aprile, 2023).

### 3.8. Infections and Inflammations in General

The Amazon electric fish ointment has been used for many years with excellent results in all related cases and mainly as an aid in the treatment of rheumatism, joints, muscles, neuralgia, contusions, torticollis, cramps, and pain in general (Pure Flora, 2024).

Pimples (Acne), eczema, impinges, ringworms, uric acid dermatoses, chilblains, scabies, urticaria, diaper rash, sunburn, heat rash, skin eruptions, abscesses, boils, nails, inflammation of the lips, breasts, nose, ears, fissures in the anus, skin accidents, bruises, abrasions, insect bites, burns in general, irritations, infections produced by the razor blade and infections in general (Pure Flora, 2024).

### 3.9. Pyrethroid Insecticide

Deltamethrin is a pyrethroid insecticide widely used to control pests in Brazilian agriculture. The intensive and disordered use of this pesticide in the Amazon can carry it to aquatic ecosystems in several ways, but mainly through runoff and leaching, it was found in tissues of the electric fish *Microsternarchus bilineatus* Fernández-Yépez, 1968 (Gymnotiformes: Hypopomidae) (Chaves *et al*., 2021).

## 4. CONCLUSION

Electric fish are a group of ichthyofauna fish fauna belonging to the Order Gymnotiformes. This group of fish is known for their ability to generate and detect electrical fields in the environment in which they occur, and these characteristics are used in communication, prey detection, defense, reproduction and even to help these animals move in the absence of light.

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