# The Platypus: an extraordinary animal for teaching

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## Abstract

In this paper, we intend to understand how the Platypus (*Ornithorhynchus anatinus*) is a paradoxical animal both for an epistemologist and for a science education researcher. First, we'll expose the historical identification process of this animal, from the beginning of the 19th Century till today. Second, we'll analyze the content of five storybooks about the Platypus that can be presented to primary school pupils (aged 8-11). The history of the Platypus is well known but it reflects many difficulties in anatomy and classification. Today, some paradoxical characters of the Platypus are investigated from a genetic, genomic or evolutionary viewpoint. But at primary school, we wonder if the Platypus, seen as a curiosity and an exception, is a good example to show some difficulties of description and classification in biology. Content analysis of the Platypus' storybooks focuses the different ways in which characters classify this animal and what kind of arguments they use. These fictional narratives underline the met failures when characters want to classify the Platypus: its similarities with mammals or birds constitute an obstacle to integration in a definite class.

**Keywords:** Platypus; classification; historical process; epistemological approach; storybooks; primary school.

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## Introduction

In this paper, the ways in which the Platypus is a paradoxical animal for researchers are explored by an epistemological approach combining historical investigation with didactic analysis.

The Platypus was discovered around 1798-1800 by English explorers on the Australian eastern coast. The history of the Platypus is well known because its discovery and its preliminary study by Europeans raised many difficulties in the sciences of morphology, anatomy and classification. It has been understood as a paradoxical animal between reptilians, birds and mammals. Its paradoxical characters are still under examination today from genetic, genomic and evolutionary perspectives.

These identified historical difficulties can become epistemological obstacles (Bachelard, 1938) to learning process. In children's storybooks, the Platypus usually appears as an out-of-place character. Are these stories good examples for exploring in primary school the principles of classification in biology and the difficulties that can be encountered? These difficulties Do we find the same difficulties in the historical process to identify this animal as in children's literature? We provide specific historical landmarks in order to interrogate, from a didactic perspective, some fictional storybooks that feature the Platypus as a central character.

## The historical discovery of the Platypus

### *English temptates to describe the animal*

The European settlers of New South Wales called Platypuses duckbills, watermoles or duckmoles in order to show they were composed animals: for example a synthesis of duck and mole or a mole swimming in water, or an animal with a duck's bill (Hall, 1999). They are found only in Australian freshwater lakes and streams. David Collins provided a first description in the second edition of *An Account of the English Colony in New South Wales*. He described the Platypus as "an amphibious animal, of the mole species, one of which has been lately found on the banks of a lake near the Hawkesbury. In size it was considerably larger than the land mole. The eyes were very small. The forelegs, which were shorter than the hind, were observed at the feet, to be provided with four claws, and a membrane, or web, that spread considerably beyond them, while the feet of the hind legs were furnished, not only with this membrane or web, but with four long and sharp claws, that projected as much beyond the web, as the web projected beyond the claws of the forefeet. The tail of this animal was thick, short, and very fat; but the most extraordinary circumstance observed in its structure was, having instead of the mouth of an animal [mammal], the upper and lower mandibles of a duck" (Collins, 1802). This early description is very interesting because the author gives us all the particularities creating an impossibility to classify this animal: similar to the land mole, it is much larger; its forelegs, shorter than the hind legs, are provided with four claws and a large membrane, which spreads all around the claws for the forefeet, as the claws project much beyond the membrane for the hind feet; and, of course, Collins doesn't forget the absence of a mammalian mouth and instead of its, the duckbill. These morphological characters suppose we have an animal similar to a mole but with curious feet (we think to the feet of a duck or goose, with a membrane) and with a duckbill. So, as soon as it was discovered, the Platypus was considered as a synthesis of a bird and a mammal. We are around the year 1800, but the discoverers and authors already note that these characters were adaptations to the environment: this animal was amphibious.

In London, when a conserved exemplar of a dead individual arrived to the British Museum, some zoologists suspected that it was a hoax: the bill of a duck attached to the body of a mole. The first person to study precisely the Platypus in England was George Shaw who gave the name *Platypus anatinus* (flat-foot duck) in 1799 (Hall, 1999, p. 211). In order to show his astonishment in front of this strange animal, Shaw evocated a "beak of a Duck engrafted on the head of a quadruped" (Shaw, 1799, p. 384). All the naturalists understood that this Ornithorhynchus was paradoxical, so it was named *paradoxus*. The anatomist Home reported that the males had internal testes - like reptiles - and that their urinary, defecatory and reproductive systems all open into a single duct, called the *cloaca*, which is a reptilian characteristic (Home, 1802). So, as soon as the year 1802, naturalists and anatomists had understood that platypus had not only birds and mammals characters but also some reptilian characteristics. It was a "monster", but at the common board of three great animal groups; it was also an animal irreducible to others, as said Thomas Bewick in 1805 "an animal *sui generis*" (Bewick, 1805). In 1803, Blumenbach named it *Ornithorhynchus paradoxus* and so, the first name Platypus had to be abandoned; but at the same time, the *genus* name *Ornithorhynchus* meant that the scientific community considered the character of bird bill in place of a mammal mouth was the main character to define this animal, however recognized as a mammal.

### *French temptates to classify the animal*

Now, it is interesting to show that, as English zoologists have described the Platypus, French anatomists discussed its zoological nature and wondered how to classify it. Home placed it in a new family of mammals, but Cuvier and Geoffroy Saint-Hilaire had to confirm and to improve these first observations and conclusions. In the *Journal de physique, de chimie, d'histoire naturelle et des arts*, Saint-Hilaire begins his description of platypuses

summing up the anatomical observations of Home (Geoffroy St-Hilaire, 1803). So, at the beginning, the French scientists didn't observe platypuses themselves but they commented English scientists' discoveries and they began a classification. According to Geoffroy Saint-Hilaire, there was a kind of kinship between the Echidnae and the duck-billed Platypus: so he looked at them as being of the same family, as belonging to the same order. But we notice some differences in the organs of locomotion, taste and gulp, so he thought, "we have to keep the Echidnae *genus* established by Cuvier and continuing to distinguish it from this one of duck-billed Platypus. Indeed, the Platypus has a wide, very compressed snout, a type of beak similar to that of the duck, indented also on its edges and surrounded at its base of a membranous crest. (…) All its body is covered with hairs, whereas the Echidnae, the body of which is decorated with spines as big and as resistant as those of the porcupines, has the head ended with a cylindrical snout" (Geoffroy St-Hilaire, 1803, pp. 232-234). These different characters give to each of them very different habits. Geoffroy Saint-Hilaire concludes he has to conserve a genus for platypuses, established by Blumenbach, and another for Echidnae, established by Cuvier. So he criticizes Home's assertions because Home set the two animals in the same *genus*.

Jean-Baptiste Delaméthérie (1804) also underlines the difficulty to distinguish correctly the diverse species discovered in New Holland and to classify them. He carries on a description of Echidnae and he proposes a comparison between Platypus and Echidnae. The characters of Echidnae remind Geoffroy that this animal postpones from the duck-billed Platypus; so it is necessary conserving the Echidnae genus kind established by Cuvier. A first problem is their common opening, which will be the basis of their classification in the Monotremata. At the beginning, the scientists didn't understand if the common cloaca is really present both in Echidnae and Platypus, they attributed a common opening to Echidnae but they seemed give another description of platypuses. A second problem is the definition of Echidnae and platypuses as oviparous or viviparous. This question will remain up to the end of the 19th Century. Delaméthérie (1804) explained that platypuses constituted an intermediary species between nearby groups. Some French anatomists will have a clearer viewpoint on platypuses, but it will need many times and the rational morphologists or anatomist of the first quarter of the 19th Century will work on these subjects and progressively bring some strong elements of classification. In 1805, Cuvier describes some organs of platypuses and from an anatomical viewpoint he sets these animals as an intermediary group between mammals and birds in his classification (Duvernoy, 1805).

From a taxonomic viewpoint, "Platypuses now reside in the Class Mammalia, Subclass Prototheria, Order Monotremata, and Family Ornithorhynchidae. However, in the years after their discovery, these animals were placed in an amazing range of existing *taxa* and had numerous *taxa* created especially for them" (Hall, 1999, p. 213). Henri de Blainville, a French anatomist, created a separate order for platypuses within the mammals: the Ornithodelphia, allied to marsupials (Blainville, 1816). The name *Ornithorhynchus* was given to platypus because Platypus had been used to design an insect, a coleopteran, by Johann Friedrich Herbst (1743-1807).

Etienne Geoffroy St Hilaire (1818) described half of the breastbone of platypuses as close to oviparous and the other half as close to viviparous animals (Geoffroy Saint-Hilaire, 1818, p. 125). Having described the breastbones of reptilians, he described the breastbone of platypuses as an intermediary between birds and reptilians. It was a very interesting study at the beginning of the 19th Century; he considers this breastbone as analogous to the breastbone of a saurian, the tupinambis. He writes: "Only while situating the duck-billed Platypus at a level after birds and in front of tupinambis, we succeeded in seizing the correspondences of the shoulder of the latter. Breastbones of those are going to help us, in their turn, to understand all the anomalies of the breastbone of duck-billed Platypus. It is obvious that what carries the foot of the fork is the analogous of the wide quadrangular plate of the tupinambis. (…) The wide plate is everywhere an odd bone, absolutely everywhere, excepted in duck-billed platypuses, where its division so becomes a strange, exclusive character. (...) If the breastbone of duck-billed platypuses is in this first half in touch with this of the oviparous animals, it is also linked with the breastbone of the viviparous animals by its second part" (Geoffroy Saint-Hilaire, 1818, p. 125). So, Geoffroy sets the Platypus in a separate vertebrate class he named Monotremata (because of the single opening for gut, urinary, and genital systems). He is more precise than Delaméthérie and maybe than Cuvier on this subject and he uses an analogical reasoning for the composition of the bones in order to compare platypuses to birds, but also to reptilians: the composition of the breastbone allows him to set platypuses between birds and reptilians. The *Encyclopaedia* of Cloquet (1819) synthesized informations about platypuses insisting on the mammalian characters. The works of Blainville and Geoffroy mainly inspire the article "Monotremes": the description of bones is systematic but there is no much compared anatomy description. A major characteristic of Monotremes is explained, the anus: "It forms a common opening to the generation organs, to excrements and urine" (Cloquet, 1819). In 1819, the main paradoxical characters of platypuses have been investigated, but the oviparous character was only confirmed by William Hay Caldwell in 1884 when he discovered some Platypus eggs in Australia (Caldwell, 1884). He sent a telegram to London and he announced "Monotremes oviparous,

ovum meroblastic", not holoblastic as in the other two mammalian groups (Caldwell, 1887). In 1887, the Platypus remained paradoxical.

## Platypuses in biological sciences today

Today, do the modern scientific discoveries confirm the difficulties to classify the Platypus? Evolutionary biology and genetics bring some lights about this animal. Firstly, researches on the Platypus' chromosomes showed that karyotypes of both sexes have several unpaired chromosomes. They form a multi-chromosomal chain at meiosis. Platypuses have five male-specific chromosomes (Y chromosomes) and five chromosomes present in one copy in males and two copies in females (X chromosomes). About the discovery of these unpaired chromosomes and of the meiotic complex, a study shows that the male has 21 pairs of homologous chromosomes and 10 unpaired chromosomes designated E1–E10. The X1Y1X2Y2X3Y3X4Y4X5Y5 sex chromosome constitution in the male platypus seems unique among mammals (Rens and *al*. 2004). If the functions of the complex sex chromosomes system remain unclear, what are the implications of this complexity? These findings have consequences for the postulated model of evolution > 210 million years of the platypus sex chromosome system. The probable sex-determining gene carried by the Z chromosome in birds, maps to chromosome E9 in platypus. A ZW pair would be an ancestor of chromosomes E9 and E10 and the starting point in the evolution of the Monotremes chromosomes complex. ZW characterizes the birds, so this ancestral pair of the system might be "an early stage in the evolution of sex-determination systems from birds to mammals".

Second, after the discovery of the Platypus' chromosomes complex, many geneticists achieved a genome project and published in 2008 the discovery of the Platypus genome with a paper entitled *Genome analysis of the Platypus reveals unique signatures of evolution* (Warren and *al*., 2008). The authors show the combination of characters between mammals and reptiles in platypus, but they do not insist on bird's features. In the abstract, they wrote: "Analysis of the first Monotremes genome aligned these features with genetic innovations. We find that reptile and platypus venom proteins have been co-opted independently from the same gene families; milk protein genes are conserved despite platypuses laying eggs…" Warren and *al*. (2008) demonstrate that genes that have remained as single copies in Platypus are also found in Eutheria (specifically, in dog, human and mouse), in opossum, a representative marsupial and in chicken. Such genes seem to contribute most to the specific biological functions that distinguish mammals. The result about the very little distance between echidna and Platypus "predicts that Platypus and echidna last shared a common ancestor 21.2 Myr ago". The mammalian genetic character of platypus and their proximity with birds were established. But ancestral reptilian traits of Monotremes were rooted in a set of genes lost from eutherian and marsupial lineages. The paradox of a mammalian animal with reptilian and bird's features seems resolved. Is it really?

Some other studies have been driven to elucidate the evolution and behaviour of the platypus genome. Studies on conservation of genes or loss of genes in platypus evolution are frequent and they allow a better differentiation of platypus, mammals and reptiles in evolution. In 2008, Patrick Babin published a research about a vitellogenin gene cluster in oviparous vertebrates in relationship with the platypus genome (Babin, 2008). Another research concerns the loss of genes implicated in gastric function (Ordoñez and *al*., 2008); this research provides new insights into the importance of gene loss events during mammalian evolution. Many publications also underline a convergent evolution (evolution to a similar goal) of some venom genes in platypus and reptiles. From an historical viewpoint, it is sure that the recent genetic and evolutionary studies give a greater importance to the research for similar features of platypuses and reptiles: this knowledge was inaccessible during the 19th Century or at the beginning of the 20th. Camilla M. Whittington published a fundamental paper (Whittington and *al*. 2008) where she explains that the platypus is remarkable, not only because it lays eggs but also because it is venomous. Venom molecules have evolved independently but from antimicrobial peptides, in the Platypus and sauropsid reptiles, it is a convergent evolution.

All these results give evidence of the unity with mammals (genetic fund common to 82 %) but they also show the links with birds and reptiles (origin of chromosomes in a pair ZW birds). Researchers may observe some losses of genes in the Platypus evolution and a convergent but independent evolution of platypus and reptile venom genes. Unlike the rational morphologists of the beginning of the 19$^{th}$ century, here, evolution makes understandable the paradox. What importance of all this for the class? Can we use the Platypus to underline the complexity of evolution, which is not managed but tries diverse solutions to solve similar problems? It is impossible at primary school where evolution is not taught. But in upper classes, we have also to show that all these combined characters give evidence of an independent origin of other mammals, which goes back up very high in evolution (166 Myr).

## Platypuses in storybooks for children

### *Conceptual framework, corpus analysed*

Platypus' paradoxical characters give to it a strange aspect. These characters are interesting for biology education for two reasons: first, it deals to talk about classification, and second, to allow to question problems linked to Platypus' classification with primary school pupils (Charles and Bruguière, 2016). Although it doesn't live in Europe, French

children know the Platypus because of its funny name ("*Ornithorynque*" in French) and its particular characters.

At Primary school, is the Platypus, seen as a curiosity and an exception, a good example to show some difficulties of description and classification in biology? In science education, exceptions are often excluded while the popular science puts. At Primary school, mediation is needed to explain classification to pupils and storybooks were chosen as this *media*. Therefore, it can be understood that this familiar animal is a good topic for authors in children literature, which often describe Platypus as « a bizarre animal ». In children's storybooks, the Platypus usually appears as an out-of-place character.

We selected 5 children's literature albums in English or French language that can be presented to Primary school pupils:

- 3 realistic fiction storybooks, in the sense that the stories are admittedly fictional but forced by scientific logic (Bruguière and Triquet, 2012): "Mais où est donc Ornicar" (Glasauer and Stehr, 2002), "Parker the Platypus" (Melillo and Melillo, 2009); "Drôle de nez" (Usatschow and Faust, 2012).
- A fictional album: "How the Platypus got his Shape" (Walmesley and Faundes, 2012). It depicts a fanciful Platypus, colored as a rainbow. The end of the story allows us to know the origin of its flat shape.
- A documentary album: "Platypus" (Whiting and Jackson, 2016) that contains two stories in parallel. The first is an informative text illuminating the second story following the life of a Platypus.

Content analysis of these storybooks focused on the different ways the characters of the story classify the Platypus. This analysis aims to know if these narratives are relevant *media* to show some difficulties of description and classification we already underlined on historical analysis.

**Exposure and confrontation of characters give reason for Platypus' exclusion**

As scientists' descriptions, storybooks' content underlines the surprising characters of the Platypus. All the storybooks highlight different characters of the Platypus (its birth out an egg, its venomous sting, etc.). The documentary is exhaustive with this set of characters playing its encyclopaedic role. "The Platypus" treats its lifestyle, which is shown by dark and greenish coloured images, signs of its night and marshy way of life. Its habitat, in a burrow, is represented in "Drôle de nez". The Australian geographical distribution of platypuses' populations appears clearly in "The Platypus", "Drôle de nez", and "How the Platypus got his Shape".

After exposure, these paradoxical characters are put in confrontation with those possessed by other animals: the Platypus faces mammals which laugh at its beak ("Drôle de nez"); Ornicar the Platypus, among mammals and birds, has got its beak placed in front of the duck ("Mais où est donc Ornicar?").

Whereas scientists tried to include the Platypus in other groups, children' storybooks expose stories where the characters of animals exclude the Platypus; social aspects domine scientific aspects. Exclusion is a reason chosen by the authors of realistic fiction books for developing the vicissitudes experienced by the Platypus, excluded because of its incompatible characters. The Platypus does not find its place among other animals in its school or in its world. It's always rejected during its quest for identity. Books' double pages show that the Platypus is staged with other animals sharing one of their characters (for example, the duckbilled or the flippers). But these animals don't accept the Platypus: the reason is that it has got an inconsistent character with their own group. "It drinks milk" but " it was born in an egg"… exclusion brings Ornicar to run away with sadness ("Mais où est donc Ornicar?); "It's got a nose" but "no wings and no feathers"... constrained the Platypus to go into exile in another country, Australia ("Drôle de nez"). This kind of narrative allows examining different Platypus' characters by a set of successive confrontations. This Platypus' isolation is reinforced by a particular image layout: Platypus doesn't belong to the same label as other animals ("Drôle de nez"); it's sidelined or in the middle of the double page ("Mais où est donc Ornicar?").

***The Platypus remains unclassifiable scientifically but finds socially a place at the end of the story***

After paradoxical characters' confrontations, classification attempts are conducted in storybooks. Documentary approaches and scientific observation are presented. If the problem of Platypus' classification is central for French scientists in the 19th Century, it's also the purposes of these storybooks but stories stick scientifically to the discovery of the various characters. They are exposed, confronted but never discussed. Platypus remains still until its arrival in Australia. The Platypus indicates it belongs to Mammals but without explaining the reason why: existence of hairs is not mentioned ("Drôle de nez").

Documentary and observation approaches testify to the care of a certain scientific approach, done in the story by a character or the narrator: the teacher reads books to better understand the Platypus ("Mais où est donc Ornicar?"). In "Parker the Platypus", scientific drawings (observational labeled drawings) are made. Last, in "Drôle de nez", all attributes of scientific observation process are present: drawing, measuring meter, magnifying glass and microscope to investigate the problem of Platypus' classification.

But no real scientific answer is provided about its classification, even if the Platypus always finds its place among other animals at the end the stories. Platypus' exclusion is solved socially by its

inclusion (not its scientific classification) in a group or a geographical territory: Ornicar is integrated in its class when the character of the teacher makes groups with artistic or sporting skills ("Mais où est donc Ornicar?"); the Platypus is well hosted in Australia by the other animals ("Drôle de nez"); Parker is accepted by other animals when it saves them from a predator with its poisonous sting ("Parker the Platypus"). The last pages of the realistic fiction storybooks offer a vision of an integrated Platypus.

Despite these different social inclusions and "happy endings", the problem of Platypus' classification is not scientifically solved and stays a problem as the 19th Century scientist met.

## Discussion and conclusion

The first part of our epistemological approach, historical analysis, highlight problems linked to the description of Platypus' characters. These paradoxical characters made controversies about its classification. Recent studies show that the Platypus reveals a particular problem in the animal kingdom. Selection of common characters across different zoological groups associated with adaptation to a specific environment tied to an evolutionary pattern endemic to Australia. This tells us something about the evolution of the Platypus and its divergence from other zoological groups. It also underlines the limits of any classification. Only evolution can explain paradoxical characters that can only be understood with a phylogenetic perspective: "Nothing in biology today makes senses except in the light of evolution" (Dobzhansky, 1973).

The second part of our epistemological approach, didactic storybooks' analysis shows that they are relevant *media* for exploring the principles of classification in biology and the difficulties that can be encountered. Same difficulties are found in the historical process of the identification of this animal as in children's literature. So, storybooks highlight tensions met by 19th Century scientists, follow their approach (description, confrontation and comparison) and develop social outcomes without scientific solution.

These narratives underline the met failures when characters want to classify the Platypus: its similarities with mammals or birds constitute an obstacle to integration within a definite class. Based on these problems, it is interesting to discuss the relevance of the *criteria* chosen for such classification in the classroom. But it is also important to become aware of why certain classifications are possible or impossible: scientific thought is clear when "the device of reasons is set up" and imposes a break with everyday thinking (Bachelard, 1938). It can be explained to pupils that this animal is a mammal but that biological studies of its characters reveal a unique signature in evolution. A reason remains adaptation to the environment and it can be explained by using storybooks in the classroom.

So, the didactic potential of these storybooks are perceived. They engage reader in a questioning of the classification. Although the Platypus is an exception, it is absent from textbooks because it's often considered too complex to treat it. On the contrary, we think that Platypus is relevant to treat of the classification's problem.

Although these storybooks make science attractive for pupils and encourage their questioning, it needs to resort to other scientific resources, to confront reasoning of the scientists and the storybooks' characters: teachers have to imagine learning situations associating epistemological reading and scientific classification. We suppose that these situations will engage children to struggle epistemological obstacles (Bachelard, 1938) we identified about classification, such as "primitive experience" which consider immediate criteria rather than innovative criteria.

Therefore, he Platypus represent for storybooks' authors a privileged animal to deal with issues as universal as those of exclusion or difference.

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