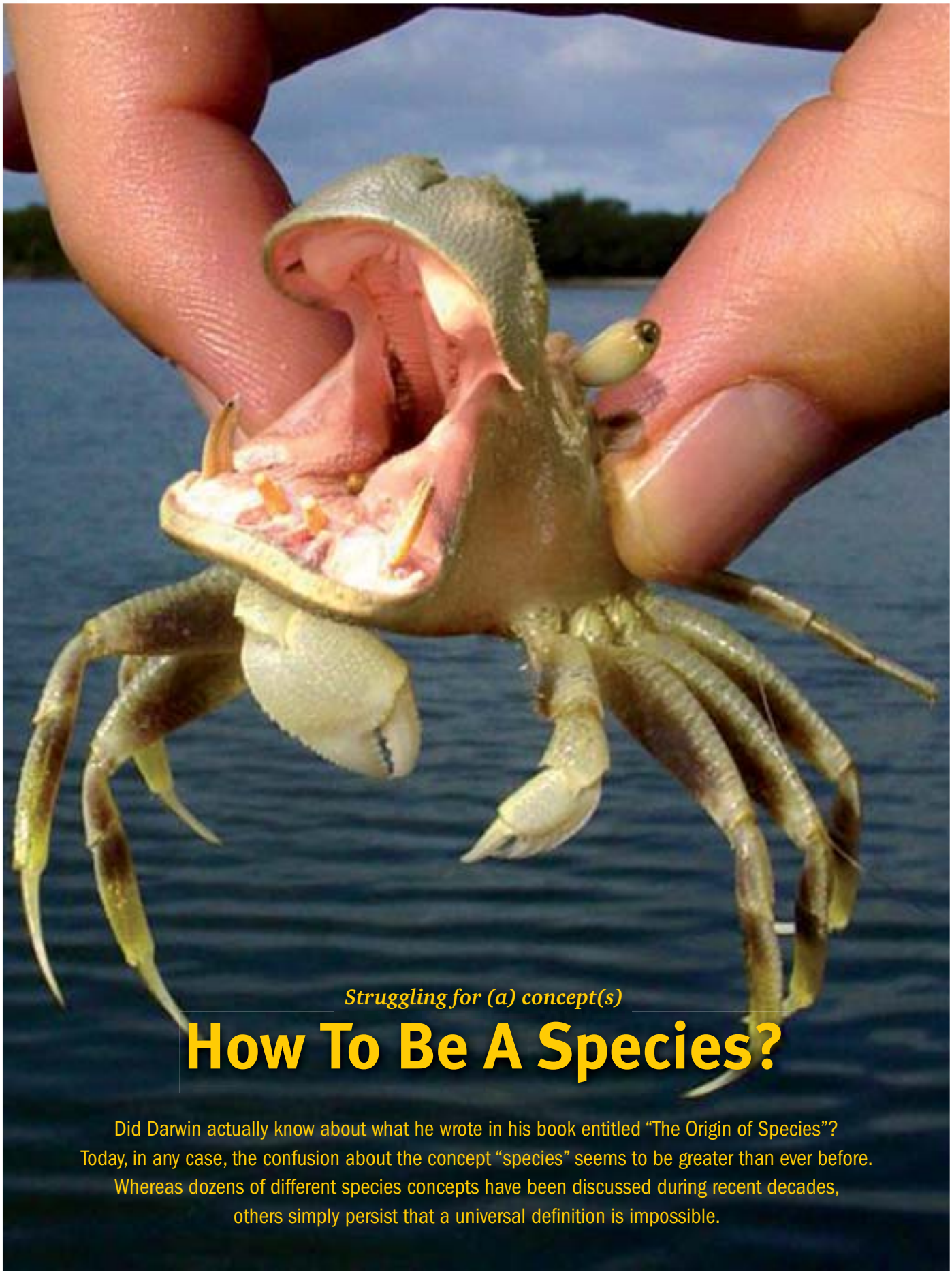

Struggling for (a) concept(s)

How To Be A Species?

Did Darwin actually know about what he wrote in his book entitled “The Origin of Species”? Today, in any case, the confusion about the concept “species” seems to be greater than ever before. Whereas dozens of different species concepts have been discussed during recent decades, others simply persist that a universal definition is impossible.

Ever since man has existed, so too have species concepts – whether we are aware of them or not. By pure intuition, we classify the organisms of our surrounding nature into discrete groups. It has been a matter of sheer survival because in this way, for example, we know that not only *one* large animal with stripes and sharp teeth would devour us but *all others* that look alike would do so too – hence, we should stay away from tigers! Similarly, we know equally well that it is safe to bite into *all* those small red fruits and not drop dead because cherries are not poisonous, as opposed to all those white spotted red mushrooms.

Thus, we intuitively apply species concepts in everyday life, in order to predict behaviour and properties of organisms and adjust our own behaviour to them, accordingly. Or simply by telling one another of them. Hence, species concepts are far from just being mere mind games of eccentric or bored scientists.

Therefore, it's all the more surprising that, to-date, it has proven so difficult to define what exactly constitutes a species. The dilemma began with the realisation that mere morphological similarity between two organisms can, in fact, lead one astray more often than originally thought. A so-called typological species concept, for example, didn't make plausible why all different dog breeds should belong to one species whereas each of the several thousand types of cichlids represent a separate species. The problem is that no alternative approach has since been able to fill the gap.

Significant hairsplitting

Today, biologists can only agree that a satisfying, all-encompassing definition doesn't exist. The result is obvious: the experts have separated into many camps, where heavy discussions take place simultaneously on several fronts. Well over thirty species concepts have been proposed and new ones are introduced, regularly. Depending on the focus, they are termed either "typological", "phylogenetic", "evolutionary", "genetic", "environmental" or "reproductive"; and according to purpose, they are purely theoretical or operational. So-called monists are searching for *the universal* species concept; pluralists, on the other hand, claim that each concept counts in its particular scope. Another group considers "species" merely as a kaleidoscope of human constructs bearing no relation to true biology, simply serving to arrange the diversity of nature into workable categories. Their opponents, of course, advocate the exact opposite and proclaim species instead as concrete phenomena of nature. A huge mess, apparently, to the outsider.

No wonder, therefore, that so much hair-splitting goes on in this debate. Quite often, however, important arguments emerge. What do you do, for example, with hybrids from two different species, as they frequently occur in plants? Or, how do concepts based on morphological similarity handle species, which run through different stages of development or show significant sexual dimorphism? After all, a caterpillar still belongs to a butterfly species, even if it resembles a worm or a centipede.

Typologically different but the same species: Peacock butterfly and its caterpillar.

Take the famous "biological species concept" by Theodosius Dobzhansky and Ernst Mayr, which, grossly simplified, defines concrete or potential reproductive communities as species. Strictly applying this concept, my own child would not belong to the same species *Homo sapiens* as me, just because it is not yet sexually mature. Moreover, how do we deal with obligatory self-fertilisers such as the case with many parasitic worms? According to Dobzhansky and Mayr, in these cases each individual would have to be regarded as an own species and any birth would be a speciation event. This is not just an odd side issue, since the majority of organisms on our planet do not actually reproduce sexually. When confronted with this problem in an interview five years ago, Ernst Mayr simply stated "Asexual organisms do not form species." It's for this reason that the biological species concept is often dismissed as a "zoologists' myth". And Mayr's critics rightly interject, "If the biological species concept qualifies most organisms as 'aberrant', then something is wrong with the way it specifies 'normal'".

What's so "fuzzy" about species

There are many similar examples regarding the shortcomings of one or the other species concept. But let's now shift focus and ask: why are there any species? Why the genetic variability of nature is quasi organised into discrete packages, which we call species? What's the sense of it? Or, in other words, which selective forces favour the formation and preservation of species through appropriate isolation mechanisms?

The answer is rather simple. Without isolation mechanisms to maintain the integrity of a given species, gene combinations, which are beneficial to the respective ways of life would outcross again and disappear rather rapidly. Only if such outcrossing is restricted, can the integrity of a gene pool, that has been established and balanced under certain conditions of selection, be protected. Each system offering this possibility must, therefore, be superior in evolution. One of these is the system "species".

Of course, a certain degree of variation is permitted among individuals within a species but only up to the level where not too many "species-deleterious" gene combinations occur. In fact, many consider even these variations among individuals to be a universal feature of the "species", as it is absolutely necessary for their ability to evolve.

This is also one of the reasons why many – not all – consider the "species" as the central unit of evolution. Natural selection constantly picks those individuals from the population that display traits best suited to the challenges of their environment and through this choice, natural selection gradually changes an entire species. This means that any species evolves independently, quasi forming a separate unit of evolutionary history, according to the proponents of this view.

Whoever takes up this position ought to accept, as an imperative prerequisite, that species really do exist. However, not everybody does that. A remarkably strong party instead considers "species" to be merely man-made abstract concepts, devoid of any biological reality and only existing to divide natural diversity into digestible bites. One of their main arguments is that species do

not constitute fixed constants but rather dynamically change in a steady evolutionary flow over time. Species can, therefore, only be snapshots at best, they say. Even Darwin himself acknowledged them merely a temporary existence. The second point is that it's often difficult to draw clear boundaries between closely related species, particularly in cases where the process of speciation hasn't yet been completed but is still at work. Consequently, species are blurred around the edges, a fact which prompted some biologists to introduce the term "fuzzy species".

Anything goes?

This fuzziness, however, could simply result from our own inability to recognise the appropriate boundaries, is the answer of those who, instead, consider species to be very real. After all, it's not really important whether we humans recognise the differences between two related species – the main thing is that the species themselves recognise them. And, without a doubt, they do. Think, for example, of prey and predator recognition; or think of parasites that are often able to accurately distinguish their favourite host from its closest relatives.

All this clearly speaks for the notion that species are not merely an abstract concept but do actually exist, claim the "realos" in the field. Ernst Mayr explicitly stated, "The term 'species' refers to a concrete phenomenon of nature. Just as the words 'moon' or 'planet' are technical terms for specific phenomena."

Some philosophy-oriented biologists or biology-oriented philosophers go even further. They include species in the philosophical category of real and historical individuals. One of their pioneers is the American, Michael Ghiselin, who considers a species as a specific individual. Accordingly, a species consists of a number of historically and genetically related organisms, each one of them in turn constituting an individual itself. Like any other individual, therefore, a species exists at a certain time in a particular place – it has a beginning, a causal history and unique characteristics; it is constantly changing and it has, when extinct, an end. Hence, a species does not show the characteristics of a "class", which, in contrast, is immutable and, moreover, exists without spatial and temporal limit. Take, for example, the chemical class "gold": gold was gold, is gold and will be gold – here, there and everywhere. This simple assumption actually has quite far-reaching consequences. One being that species cannot be defined; they can only be described – just like the individual, David Beckham.

Perhaps this is one of the reasons why the current trend is slightly shifting toward pluralism. In contrast to the so-called monists, the pluralists have surrendered the search for the "one and only" species concept. They proclaim that there are a whole range of legitimate species concepts in biology and very pragmatically conclude, "The respective specialists should take the concept that best meets their theoretical and methodological needs." The crux lies with the word "legitimate". Within such a pluralism it must be very clear, when a concept meets the "legitimacy criterion" and when not, otherwise the beauty of pluralism quickly degenerates to a meaningless "Anything goes".

These Hawaiian happy face spiders look different but, since they can interbreed, they are considered the same species: *Theridion grallator*

It is mainly the philosophers who are rankled by pluralism. Wherever pluralism lurks many of them scent conceptual promiscuity and epistemological anarchy – and feel particularly challenged! That's one reason why they have been meddling with verve in the discussion, searching for the universal species concept on which all others could be based.

To most biologists, on the other hand, pluralism concerning species concepts causes relatively mild headaches, as only they know what they are talking about. For many of them, definitions have no more status than useful educational tools, whereby even the exceptions can often be dealt with as "particularly interesting".

Recipes but concepts

What usually interests biologists much more than defining species, is *identifying* species. Here, theoretical concepts hardly help. Whoever wants to classify species first needs operational, diagnostic concepts. Although commonly called "concepts", they in fact just constitute *recipes* for the determination of demarcations between individual species. Therefore, it's no surprise that such operational concepts/recipes particularly thrive, where many species are still to be discovered, for example, within prokaryotes, protozoa and fungi.

Frequently fooled by genetics

However, this is not as easy. Even Darwin said that there is no certain minimum number of differences separating one species from the other. Phenotypes or, accordingly, the degree of morphological, physiological, ecological or other differences can fool you, terribly. Actually, it has already happened quite frequently. Over the last decades a plethora of examples have accumulated revealing how a group of organisms, which had originally been included in one and the same species, actually turned out to be split into two or even more. Take elephants, for example. Everybody thought, until recently, that there were only two species: the African and the Indian elephant. After obtaining new data, researchers are now discussing whether in fact there are three different species living in Africa alone. Or, the Californian salamander *Batrachoseps attenuatus*: within only a few years, experts found that this supposed "species" actually forms more than twenty separate ones.

These new insights are, of course, primarily owed to methodological advances enabling us to further dissolve additional differences between groups of organisms to a much finer degree. The key term here is: sequence comparisons. In the last two to three decades genetic or, more recently, genomic distances have developed into a new, strong criterion for the discrimination of species. Particularly in cases where the existing criteria hardly worked, comparative genetics and genomics have since opened up entirely new possibilities for species identification: prokaryotes, protozoa, fungi, etc ...

However, sequence comparison is certainly no magic bullet either, even though many had high hopes at first. Although rules of thumb for such molecular species differentiation have already been established, the classification of species solely by the amount of base differences can also be awfully misleading. An impressive example is, again, the aforementioned famous species flocks of the East African cichlids: on Lake Victoria alone there are more than five hundred morphologically considerably different cichlid species, yet genetically they differ even less from each other than individuals among human popula-

tions. Or take the many breeds of the species "dog", where phenotypic intra-species variation has probably been driven the furthest due to the unnatural man-made breeding conditions. Nevertheless, their genetic intra-species variation has remained lower than that of humans, mice or rats.

Thus, whatever criterion is taken, the core issue apparently still remains the same: what degree of difference is enough for two organisms to be assigned to two different types? And, vice versa, to what degree do we only have variation between two populations of the same species? Questions that we will probably never be able to answer universally.

Many speciation mechanisms

This brings us back round to the theoretical species concept. As long as species are not classified on the basis of the mechanisms or properties by which they become and remain species, the resulting groupings must be artificial. In the first instance, this categorically speaks against morphological/typological concepts, which are based on the evaluation of pure similarities. Furthermore, assuming that species are indeed real, they would even have to be defined on the basis of mechanistic aspects.

Of particular concern are certainly the mechanisms of speciation and isolation. And, thus, we have finally arrived at the core problem: the mechanisms are numerous. There is not only one class of mechanisms by which species emerge and remain stable and for this very reason, there can hardly be only one universal mechanistic species concept.

Just take the mechanisms of how species isolate: they differ widely in the various domains of organisms. The consequence being that the term "species" does not consistently describe the same type of evolutionary phenomenon across bacteria, protozoa, lichen, birds, fungi, parasites and grasses. On the contrary, the corresponding "species modes" differ from each other and obviously constitute specific inherent properties of different evolutionary lineages. Put another way, the properties and mechanisms that causally make groups of organisms different from others, have themselves developed evolutionarily and, in fact, many of them independently. Accordingly, Mayr's 'biospecies' is also an evolutionary-derived feature, which developed in parallel with the emergence of sexual reproduction about 600-1,000 million years ago. In the end, reproductive barriers just emerged as another class of species isolation mechanisms, in addition to those already in existence.

The conclusion is that one universal mode of being a species doesn't, and cannot, exist. Instead, there will be as many mechanistic species concepts for as many causal pathways there are to be a species. We will probably have to live with the fact that a fungi species is something very different to a bacteria species; and a frog species is something else yet again.

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ONE FINE DAY IN THE LAB...

BY LEONID SCHNEIDER