The scientific practice of identifying and naming species

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Four species of Strepsirrhine primates. Credit: Wikimedia Commons, CC BY-SA

How many kinds of plants and animals are there in the world? Where do humans fit within the vast fabric of life? Indeed, how did life, including humans, evolve?

At the centre of questions like these is the scientific practice of identifying and naming species, or taxonomy.

And, the basic unit of taxonomy – 'the species' – remains an elusive and controversial concept despite its fundamental importance to science.

Yet, few people outside of biology and philosophy realise that 'the species' has been at the centre of a major controversy in science for much of the last 50 years.

A cardinal science

Taxonomy is a fundamental or 'enabling' science that underpins all of biology and its many related fields including medical research.

How could we, for example, develop a vaccine or pharmaceuticals to fight deadly diseases like Ebola without knowing their status as a virus or bacterium?

It's also central to major global projects like the 'Open Tree of Life' which ambitiously seeks to reconstruct no less than the evolutionary relationships of the Earth's 1.8 million named living species.

Yet, so far, biologists have recognised and named less than 20 percent of the planet's estimated 11 million living organisms, some of them going extinct quicker than they can be discovered.

Taxonomy is also at the core of fields like my own, palaeontology, concerned with the study of ancient worlds and extinct organisms.

By examining the diversity of life in the past we glean insights into alternative world's, helping us realise that the Earth hasn't always been as it is today, and informing us about where we could be headed with a planet beset by anthropogenic warming.

Moreover, with about 99 percent of all life that existed now extinct, some 20 billion species may have existed during the roughly 4.0 billion year history of life, leaving plenty of work for future generations of palaeontologists!

Taxonomy is also central to how we understand, enjoy and utilise nature in a sustainable way so that future generations might also share the Earth's astonishing bounty and beauty.

A great debate about species

The 'species' is the most fundamental level in taxonomy and is also the unit of evolution.

The species is the only 'real' category in the taxonomic system – and by real I mean it has an objective existence in nature, at least according to most taxonomists and philosophers of biology.

Ironically though, it has proven to be the most troublesome of all the taxonomic categories to work with, and one of the most difficult concepts to define in science.

At present, there are at least 26 species concepts in use in biology which adds enormous confusion to an already confusing area of science.

In fairness, though, most of them don't enjoy widespread support or use, with only a handful - a half dozen or so - being routinely applied by biologists.

For much of the second half of the 20th century, and spilling over into the present century, philosophers and biologists engaged in an intellectual war over the ontological status (or reality in nature and meaning), basic properties and practicalities of recognising species.

Just what is this thing that we call a species? What are its properties? Is it like the names we give to cities or to our children? Does it have its own unique qualities by virtue of being biological?

Interbreeding, surely?

But wasn't all this resolved a long time ago, I hear you ask?

I learned at school, or in first year university biology, that species are groups of organisms that interbreed with each other, I hear you say.

You old sentimentalist! Harking back to the mid-20th Century before the big species debate erupted. If only it were so simple.

The interbreeding idea was widely discussed by biologists even before Charles Darwin's time, but it was only formalised as a species 'concept' during the 20th Century, taking centre stage in the ideas of Theodosius Dobzhansky and Ernst Mayr.

By 'concept' here I mean the species as a rung on the Linnaean hierarchy, a description or definition of what the species, in a generic sense, actually is.

Interbreeding was formalised by Dhobzhansky and Mayr as the so-called 'biological species concept', although, this is a misnomer because all species concepts are biological by definition.

Dissatisfaction with this concept was there right from its inception though.

One of the other chief architects of the 'modern synthesis' of evolutionary biology, George Gaylard Simpson, proposed his own concept known as the 'evolutionary species'.

A modern human (left) and Neanderthal (right) cranium. The unique physical features of each group are used to define us as different species. Credit: Darren Curnoe.

But, from the early 1960s onwards dissatisfaction grew so strong that it became the catalyst for a big debate that would consume much of biology for the next few decades.

Hard questions

From this time, philosophers and biologists began to ask some rather difficult questions, like:

- How does the species category compare with other scientific groups or types of things like say the chemical elements?
- Does it play the same kind of role in science – conveying the same sorts of information and allowing us to make predictions about nature?
- What's the best, most objective, way to recognise a species?

Also, as intuitively appealing as the ability of organisms to interbreed is as a test of species membership it's been terribly difficult to apply in practice.

In fact, according to Lélia Lagache of the University of Bordeaux and co-workers, by 2013 it had only ever directly been applied once in a wild population!

So, it turns out we've all been cheated by the textbooks we read in high school or university.

Short-changed by our science teachers and biology lecturers.

A more honest reading of history shows that in fact most species – especially animals, the organisms I'm most familiar with – have been discovered and named on the basis of their physical appearance, or 'phenotype'.

And the winner is..?

One of the biggest insights about the 'species problem' came during the late 1990s from the Smithsonian-based biologist Kevin de Queiroz who recognised that most of the concepts in use were simply a catalogue of the features that species might possess.

An example will help to explain its importance: cars.

They have a real existence, separate from us: an objective status if you will.

They possess an engine, four wheels, doors, a radio, need fuel, carry people and parcels and groceries, move, and come in a range of shapes and colours.

But does any one of these properties define a car adequately? Are cars described well by their engines or seats? Or by the fact that they have wheels or require fuel?

Some of these characteristics may be essential for them to be cars, but they don't define what a car actually is.

Cars are, by definition, human controlled machines that move (propel in a controlled way) and carry people and other items from one place to another.

And so it is with species. Are species simply organisms that reproduce with each other? Or recognise each other's mating call? Or share an ecological role or niche?

Like cars, there is something much more fundamental about species that defines them regardless of the particulars of any one or other species.

Species are groups of organisms that may do all, or some, of these things, but these qualities don't define them.

It is much more productive to think of species as groups of organisms that share an evolutionary history.

They belong to their own branch on the tree of life; a branch with a beginning, a history, and eventually an end as well; an evolving lineage.

It's all about the diagnosis

Many insect species are recognised by the anatomy of their genitalia. Shown here is a pair of red mason bees. Credit: Wikimedia Commons

Focusing on the other fundamental issue here: if we don't use interbreeding as our criterion, what should we use to distinguish species?

In a word, their 'diagnosablity'.

That is, the evolutionary branches we call species, in sharing a common history, will share a set of physical features which aren't shared with other organisms.

They possess a set of unique features that makes them diagnosable or distinguishable from all other branches or species.

Think of living humans or *Homo sapiens*. We can recognise our kind as having a bubble-shaped brain case, faces tucked beneath the front part of our brains producing a steep forehead and jaws that sport a chin.

We are the only primate to have this set of features in our skeleton, and they define us as an evolutionary branch or species.

Still, not every taxonomist agrees that diagnosability offers the best way forward in recognising species.

But, today, most do, and for me, and many others interested in classifying life, especially extinct organisms, it makes a great deal of sense, because we normally have little else to go on but features of fossilised teeth and bones.

Written in the genes?

What I have neglected here of course is the role that DNA evidence is increasingly playing in taxonomy.

Genetics has come to be seen a central to the process of identifying living species and increasingly also extinct species following remarkable developments in the investigation of ancient DNA.

But, an ongoing issue continues to be whether DNA markers can be used to describe species in nature.

While each species must, by definition, be genetically unique, among animals at least, species descriptions are still fundamentally based on observable physical features, be they soft tissues, fur pattern or coloration, or features of the teeth and skeleton.

DNA compliments information about the phenotype and of course informs us about how physical features develop and evolve.

Yet, there are species which can't be distinguished easily with physical traits, but have been shown to be genetically highly distinct.

These are 'cryptic species': and I and others suspect they are much more common in nature than we realise.

Back to practicalities

While the species debate continues, much of the focus of current discussion is on how we should go about identifying them in nature.

Not everyone is satisfied with the criterion of diagnosability. In particular, one issue that causes unease is that different concepts can sometimes result in vastly different estimates of the number of species.

And, such issues will ensure that the species debate will continue for years to come.

But, we are closer than ever to resolving the question, reaching a consensus, over what has been one of the most hottly contested questions in the history of science, despite is remarkably low public prominence.

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