and genes are always connected at some level.

Second, with respect to female copying, in very few species have females actually been shown to copy one another in their choice of mates, and one of the best-studied cases — Dugatkin's own work on Trinidadian guppies — is being questioned because two independent attempts to replicate the basic study have yielded negative results.

Third, in non-human species, natural selection acts as a very tight filter through which all observable traits must pass. Animals can be trained to do many things in the lab — for example, learn inefficient or maladaptive traits and culturally transmit them to others. But in the wild, natural selection quickly eliminates most maladaptive traits, however they are passed on.

Finally, it is important to remember that the vast majority of animal species are either not sufficiently complex for the evolution of culture to be relevant, or are solitary in nature, so that individuals seldom experience the conditions necessary for imitative behaviour to occur — as is the case, in fact, for most mammals.

Imitation clearly plays an important role in cultural evolution and, in limited cases, biological evolution. Nevertheless, it usually acts in concert with natural selection, its scope is limited, and the fact that cultural evolution is important in animal societies is hardly new. This book will provide a lay reader with some interesting anecdotes about animals, but I doubt that it will give them a better understanding of evolution. ■

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# Evolutionary celebrities

**The Cichlid Fishes: Nature's Grand Experiment in Evolution**
by George W. Barlow
*Perseus: 2000. 335 pp. $28*

**Axel Meyer**

David Star Jordan, the eminent ichthyologist, anti-darwinist and first president of Stanford University, is said to have justified his refusal to memorize students' names with the excuse that, for every student's name he was supposed to remember, he would forget the name of a fish species. That was in the days before student evaluations of professors.

Unfortunately for students, there are many fish names to remember. The 25,000 or so living species of teleost fishes are systematically arranged into more than 400 families. And, to paraphrase Thomas Huxley, God must have had a particular fondness for the Cichlidae family, as it contains perhaps up to 15% of all species of fishes.

The most ancestral cichlids are found in Madagascar and India, and hundreds of cichlid species live in Central and South America. But the centre of biodiversity is East Africa. In particular, Lakes Victoria, Malawi and Tanganyika each harbour species flocks of hundreds, possibly more than 1,000, endemic species. None of the many other families of fish living in these lakes comes even close to rivalling the cichlid's dominance in terms of species diversity.

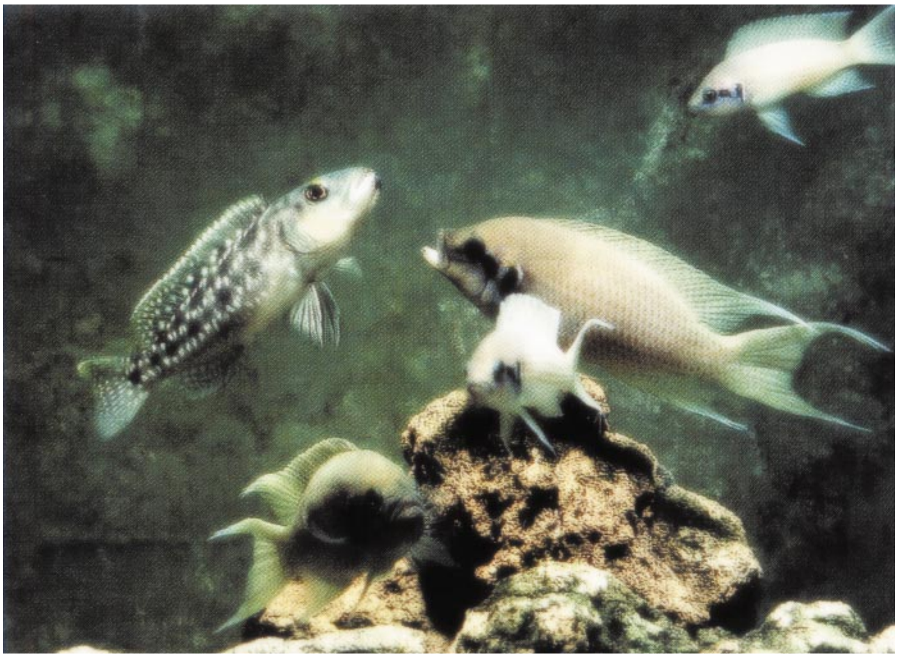
Only since the advent of molecular phylogenetic techniques, which can trace the evolutionary development of species at the molecular level, has it become known that all of these diversifications can be traced back to a single ancestral lineage — or at least a very small number — that colonized each of the lakes. One implication of this is that all the incredible ecological, morphological and behavioural specializations that are found in these three groups of cichlids arose independently of one another. This would make these species flocks one of the most spectacular examples of convergence in all of evolutionary biology.

Cichlid taxonomists had assumed that if two species in different lakes showed very similar morphologies or behaviours, then they were closely related. Who could blame them? For it would have seemed preposterous to assume that evolution was so lazy or unimaginative as to reinvent such unbelievable diversity three times over. Moreover, molecular data also show that the speciation and diversification of cichlids took place in record time — in Lake Victoria around 500 species arose in probably less than 14,000 years. Cichlids are evolutionary celebrities indeed. In case you don't remember, Wanda — she was the piscine star in the movie *A Fish Called Wanda* — was a cichlid, a South American species called the angel fish.

Ecologically, cichlids seem to employ every possible trick. But if hundreds of often extremely closely related species coexist in one lake, they have to keep out of one another's way competitively. Some are specialized to feed only on the scales of other cichlids, some use the specialized second set of jaws — probably part of the explanation for the cichlids' evolutionary success — to crack open snail shells. Other species suck the young out of the mouths of brooding cichlid mothers, and still others tend the gardens of algae on which they feed and which they vigorously defend against other cichlids. Many of these astonishingly specialized adaptations are found repeated in the species flocks in all three lakes.

Cichlids are smart, and in terms of mating systems and parental care systems, they are more diverse than any other family of fish. They have been the white rats of fish behavioural research for more than 50 years. George Barlow, the author of *The Cichlid Fishes*, has dedicated his life's work to cichlids. He single-handedly made the University of California at Berkeley the premier centre of research in cichlid behaviour during the heydays of animal behaviour research in the 1970s and 1980s.

In this book, which is written in a colloquial and non-technical style, Barlow summarizes decades of his experience with cichlids. Fishy tales are often interwoven with human anecdotes. The focus is on many of the fundamental (and often still unsolved) questions in behaviour and sociobiology. Communication, aggression,



**Fishy business: the Cichlidae family at home in Lake Tanganyika.**

mating systems, parental care systems and parent–offspring conflict are all covered: the list seems all too human. Barlow has a behavioural view of the world, and draws on his impressive knowledge of the behaviour and natural history of many groups of fishes to make more general, important points about evolution and the ecological circumstances that shape the development of parental care and mating systems.

But Barlow has aimed this book at a wider, not strictly hard-core scientific, audience. There is a huge community of what he calls "cichlidiots" who keep and breed the typically beautifully coloured and 'brainy' cichlid fishes. They will enjoy the lucid writing and the plethora of general biology facts and aquarium behavioural observations. The book is also entertaining and fun to read because of (or in spite of, depending on your taste) headings in chapters such as "Beauty is only fin deep", or statements such as "gonads are in command".

*Cichlid Fishes* has a different focus from the grand ol' book of cichlid research, Geoffrey Fryer and T. D. Iles' 1972 text, *The Cichlid Fishes of the Great Lakes of Africa: Their Biology and Evolution* (Oliver & Boyd). The latter book focuses more on ecological and evolutionary questions, and, owing to very active research by many laboratories around the world, is quite outdated in places. An updated synthesis focusing specifically on the ecology and evolutionary biology of cichlids is still wanting. ■

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# Science in culture

## Architect reaches for the clouds

**How fractals may figure in our appreciation of a proposed new building.**

*Richard Taylor*

We're all familiar with the Manhattan skyline of New York, with its many skyscrapers reaching into the clouds. Imagine the effect if one of these skyscrapers were shaped like the clouds surrounding it. This is the plan of the Guggenheim Museum, which recently unveiled a design by the architect Frank Gehry for an $800 million building to house its modern art collection. The Guggenheim Museum is no stranger to controversial architecture. Its current collection is housed in the landmark white spiral structure designed by Frank Lloyd Wright. But with its swirling layers of curved surfaces spanning three piers, the proposed 45-storey, 'cloud-like' structure is expected to radically reshape New York's waterfront.

Traditional architecture is based on euclidean shapes, such as circles, squares and triangles. But clouds belong to fractal geometry, consisting of patterns that recur at increasingly fine magnifications. How, then, will people react to architecture designed to mimic one of nature's fractal patterns? The answer may lie, not in architectural concepts, but in recent perception studies of fractal patterns.

The study of human aesthetic judgement of fractal patterns constitutes a relatively new research field of perception psychology. Only recently have researchers started to quantify people's visual preferences for (or against) fractal content. The visual appearance of a fractal object is influenced by a parameter called the fractal dimension, *D*. This quantifies the fractal scaling relationship between structure observed at different magnifications. Its value lies between 1 and 2 and moves closer to 2 as the complexity and richness of the repeating structure increase.

In 1995, Cliff Pickover at the IBM Thomas J. Watson Research Center in New York used a computer to generate fractal patterns with different values of *D* (ref. 1). He found that people expressed a preference for fractal patterns with a value of 1.8. A subsequent survey by Deborah Aks and Julien Sprott at the University of Wisconsin also used a computer, but with a different mathematical method for generating the fractals[2]. This survey reported much lower preferred values of 1.3. The discrepancy between the two surveys seemed to suggest that there is no universally preferred *D* value, but that the aesthetic qualities of fractals instead depend specifically on how the fractals are generated.

To determine whether there are any 'universal' aesthetic qualities of fractals, I collaborated with psychologists Branka Spehar at the University of New South Wales, Colin Clifford at Macquarie University in Sydney and Ben Newell at University College London. We performed perception studies incorporating the three fundamental categories of fractals — 'natural' fractals (scenery such as trees, mountains and clouds), 'mathematical' fractals (computer simulations) and 'human' fractals (cropped sections of Jackson Pollock's dripped paintings, which I have shown to be fractal[3]). Participants in the perception study consistently expressed a preference for fractals with *D* values in the range 1.3 to 1.5, irrespective of the pattern's origin. Significantly, many of the fractal patterns surrounding us in nature have *D* values in this range. Clouds have a value of 1.3.

Although Gehry's proposal for the Guggenheim Museum is designed to mimic the general form of clouds, it is clear that the completed building will not be strictly fractal. To build a structure described by a *D* value of 1.3 would require many layers of repeating patterns. Although this is no great challenge for nature, such complexity is beyond current building techniques. In fact, both Gehry and New York's mayor, Rudolph Giuliani, readily admit that no shovel will be turned for at least five years and that the plans will have to evolve during that time. It will be fascinating to see if people's fundamental appreciation of fractal clouds will inspire New Yorkers to embrace this revolutionary building design. ■

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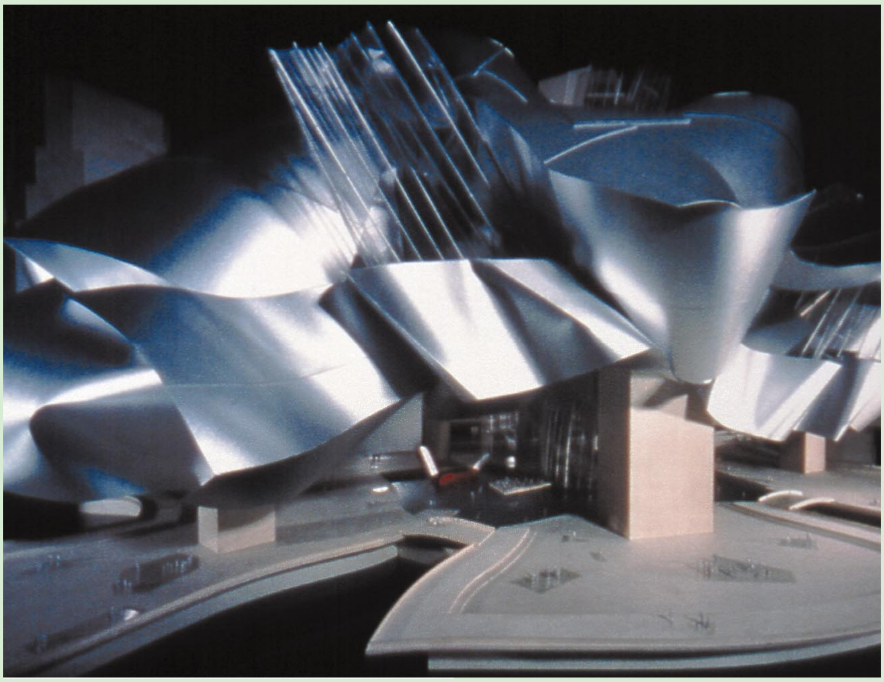

DAVID HEALD

**Fractal future: a model of the proposed new Guggenheim Museum in New York.**