A meadowful of meaning

When it comes to the biological world, we think we have a pretty good idea of how things work. But what if we need a bigger frame to fit around our current picture? What if it linked the workings of animals' cells with language and consciousness, all via unexplored webs of meaning? **Liz Else** discovers the strange new world of biosemiotics

EVERY so often, something shows up on the *New Scientist* radar that we just can't identify easily. Is it a bird? Is it a plane? Is it a brand new type of flying machine that we are going to have to study closely?

That was our reaction when we first heard about a small conference held in June at the philosophy department of the Portuguese Catholic University in Braga. There, a group of biologists, neuroscientists, philosophers, information technologists and other scholars from all over the world gathered to discuss some revolutionary ideas for developing the hitherto obscure field of biosemiotics.

Unlike most revolutionaries, it soon became clear that this group's goal was not to overturn the established order. They don't attack the current way of doing science – they see its value plainly – but they do believe that for biology to become a more fully explanatory science, it needs a more encompassing framework. This framework needs to be able to explain an under-studied aspect of all living organisms: the capacity to navigate their environments through the processing of signs.

Biology, of course, already concerns itself with information: cell signalling, the genetic code, pheromones and human language, for example. What biosemiotics aims to do is to weave these disparate strands into a single coherent theory of biological meaning.

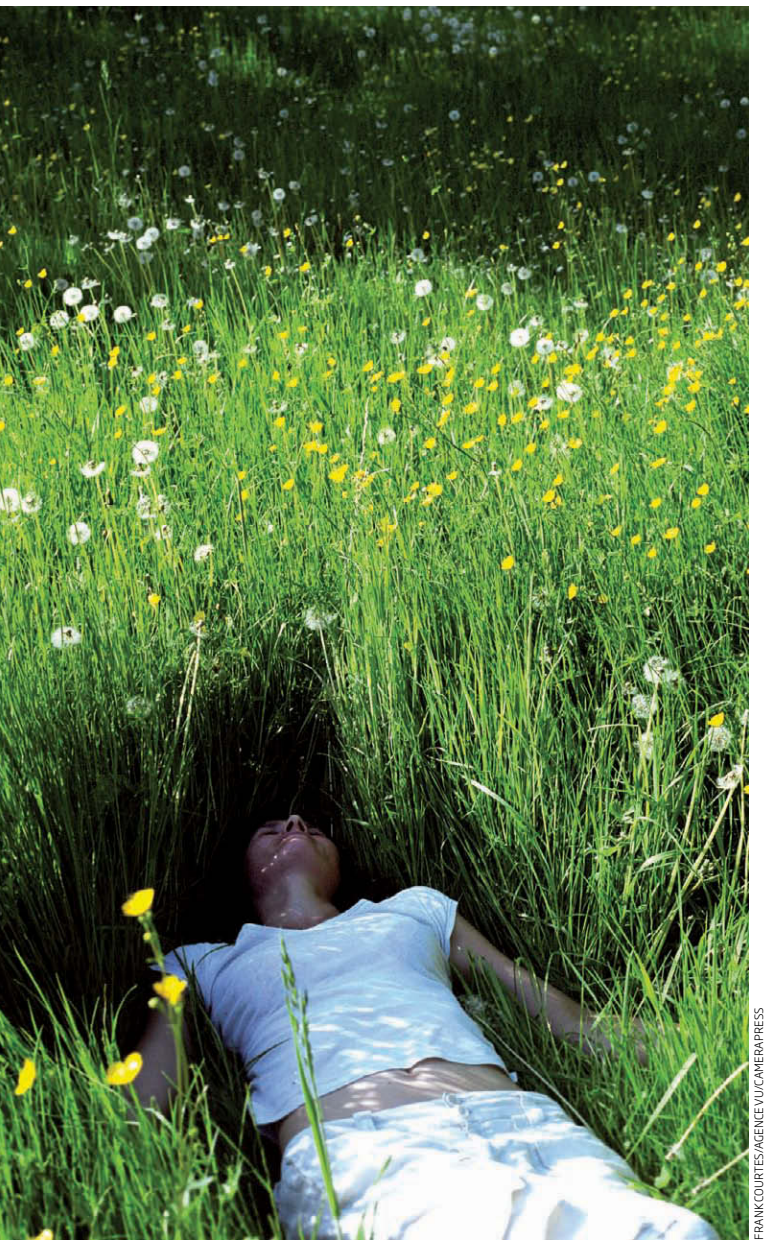
At first glance, the group seems to have chosen an unfortunate and incomprehensible name for its activity – semiotics is the study of signs and symbols that is most commonly associated with linguistic philosophers such as Ferdinand de Saussure. "Biosemiotics", then, might sound like the name of some arcane mix of biological science and linguistic philosophy. Luckily, though, the true message of biosemiotics is clear: we may do better to stop thinking about the biological world solely in terms of its physical and chemical properties, but see it also as a world made up of biological signs and "meanings".

One of the nascent field's leading lights, Donald Favareau of the National University of Singapore, provides a definition on the group's website. "Biosemiotics is the study of the myriad forms of communications… observable both within and between living systems. It is thus the study of representation, meaning, sense, and the biological significance of sign processes – from intracellular signalling processes to animal display behaviour to human… artefacts such as language and abstract symbolic thought."

To get a better sense of what this means, it is best to go back to the field's roots. Biosemiotics traces its earliest influences to the independent efforts of an Estonian-born biologist in the early 20th century and an American philosopher of the 19th century, who wrote much of his work hidden in an attic to avoid his creditors.

Estonian-born Jakob von Uexküll was an animal physiologist whose 1934 book *A Stroll Through the Worlds of Animals and Men: A picture book of invisible worlds* – and later works – inspired Konrad Lorenz and Niko Tinbergen, who then went on to win a Nobel prize in 1973 for their studies in animal behaviour, or ethology.

Von Uexküll wrote: "If we stand before a meadow covered with flowers, full of buzzing bees, fluttering butterflies, darting dragonflies, grasshoppers jumping over blades of grass, mice scurrying, and snails crawling about, we would be inclined to ask ourselves the unintended question: Does the



In her own world, yet enwrapped in myriad others

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meadow present the same view to the eyes of so many various animals as it does to ours?"

He thought that a naive person would intuitively answer that it is the same meadow to every eye. Physical scientists, he thought, would see all the animals in the meadow as "mere mechanisms, steered here and there by physical and chemical agents, the meadow consists of a confusion of light waves and air vibrations… which operate the various objects in it".

For von Uexküll, both views were wrong. Each creature in the meadow lived in "its own world filled with the perceptions which it alone knows", and it was in accordance with that experiential world – and not the entirety of the whole, unseen but physically existing world – that the creature had to coordinate its actions to eat, flee, mate and sustain itself.

For some animals, that subjective perceptual universe, or *Umwelt*, as von Uexküll called it, writing in German, is narrow. He describes the umwelt of a tick which sits "motionless on the tip of a branch until a mammal passes below it. The smell of the butyric acid awakens it and it lets itself fall. It lands on the coat of its prey, through which it burrows to reach and pierce the warm skin… The pursuit of this simple meaning rule constitutes almost the whole of the tick's life." By reacting only to the single odorant of sweat, the tick reduces the countless characteristics of the world of host animals to a simple common denominator in its own world.

So von Uexküll's meadow is alive with myriad perceptual worlds, with each one, for each species, evolving within, and functioning as, a different web of meaning. To understand why animals are organised the way they are, and why they act on the world as they do, he explained: "Meaning is the guiding star that biology must follow."

Von Uexküll's pioneering sensation-action "feedback-cycle" model for explaining the mechanics of biological meaning was revolutionary for its time. Indeed, it anticipated by many decades the science of cybernetics, which studies systems of control. But his

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model is now considered too mechanical and simplistic by most biosemioticians. To build what they hope might be a more scientifically fertile model, many of them base their understanding on the semiotic logic of the philosopher Charles Sanders Peirce.

Peirce was born in 1839 in Cambridge, Massachusetts. His father was a professor of mathematics and astronomy at Harvard University. Peirce junior was a brilliant but rebellious student, who suffered from both neuralgia and depression. Known today as the father of the philosophical school of pragmatism, as a student Peirce made the serious mistake of angering his chemistry professor, who went on to become president of Harvard. During a life-long feud, he ensured that Peirce never gained a permanent post at any university.

For the 55 years after he graduated, Peirce wrote scientific and philosophic dictionary and encyclopaedia entries to support himself and his ongoing studies, which included producing the world's first photometric star catalogue at Harvard Astronomical Observatory and working as a geodesist for the US Coastal Service. It was a difficult life: he was often without heat and food, and was kept alive thanks to the kindness of his brother, neighbours and benefactors, including his closest friend and admirer, the psychologist William James.

Peirce's work in logic, mathematics and ›

philosophy ran to an astonishing 60,000 pages. Much of this has been discovered and re-examined only recently, giving rise to the vigorous field of Peircean studies. He saw logic as a formal doctrine of signs, and his theory of signs is important in modern biosemiotics.

Most of us naively conceive of a "sign" as standing for something concrete: a red traffic light for most of us simply means "stop". In other words, the two things – a sign and its meaning – are directly connected in a sign

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relationship. Peirce, however, saw a sign as representing a relation between three things.

Take the everyday example given by Jesper Hoffmeyer, a biochemist at the University of Copenhagen, Denmark, and a leader in biosemiotics, in his book *Signs of Meaning in the Universe*. Suppose a child breaks out in a rash of red spots and is taken to the doctor by his mother. For the mother, the spots are a sign that her child is sick. The doctor knows they mean that the child has measles. As Peirce put it in its most general form: "a sign is something which stands to someone, for something, in some respect". The red spots are not automatically something which is a sign of measles to anyone, but only to "someone", in this case the doctor.

Piece saw all signs as involving a triadic relation: the sign "vehicle" (the red spots); the "object" to which the sign-bearer refers (measles); and the "interpretant", the system that allows the realisation of the sign-object relation to take place (the doctor's thinking) and that acts accordingly upon that relation.

He wanted to investigate and uncover the complex logic by which "in every scientific intelligence, one sign gives birth to another, and especially one thought brings forth another". His insight was to see that even the simplest sign must be considered as a triadic relation, in which the sign vehicle, object and interpreting system all play ineliminable parts – an insight biosemioticians believe science would do well to explore more fully.

This realisation led Peirce away from devising linear chains of logic that relied on just two factors, to the construction of a "sign" logic that is an endlessly branching, multidimensional network. Although Peirce's work is theoretical, there are clear parallels between von Uexküll's model of the meadow, filled with different meanings, interpreted by the different biological systems of different creatures, and Peirce's model of the sign as ultimately a kind of relation that living agents adopt towards things for the accomplishment of various ends and actions.

When Peirce wrote, he was thinking primarily of signs as relations that enable human thought to effectively understand the world. Accordingly, his logic has recently been applied in efforts to understand the origins of human language that reject the idea that language appeared either as a lucky accident that endowed humans with a universal grammar – as posited by the linguist and philosopher Noam Chomsky – or as a by-product of an enlarged brain.

Instead, researchers such as Terrence Deacon, a biological anthropologist at the University of California, Berkeley, have used Peirce's sign logic to explain how language may have arisen as an evolutionary consequence of pre-linguistic symbolic activity.

But biosemiotics applies the idea of signs and signalling much more widely than just the analysis of human language. Take these sentences from a recent "Perspectives" article in *Science* magazine: "Living cells are complex systems that are constantly making decisions in response to internal or external signals. Among the most notable carriers of information are… enzymes that receive inputs from cell surface or internal receptors and determine what actions should be taken in response…" (*Science*, vol 328, p 983).

The broadest scope

Words like "signals", "information" and "inputs" litter the biology literature. But all of these usages are metaphorical. What biosemioticians really want is an analysis which goes further, says Charbel El-Hani, a biologist at the Federal University of Bahia in Brazil. "The importance of going beyond metaphor and really building a theory of information is underlined by the reiterated claim that biology is a science of information," El-Hani told *New Scientist*.

The scope envisioned for the new field is therefore truly broad: a viewpoint which connects everything from biomolecular networks sending signals that control cell behaviour to animal behaviour and human language. That is the agreed goal, but the scientists and philosophers involved each bring their own uniquely interdisciplinary perspective, and so do not always agree on the best way forward. It is safe to say that this new science is very much in ferment.

To get a feel for this, *New Scientist* asked a range of thinkers attending the Braga conference to explain how they saw the field. More than 20 responded. The wildly different roads they have travelled to reach biosemiotics, and the different areas to which they wanted to apply it, were evident in their responses.

Favareau came to biosemiotics as a result of "growing discontent with the inability of cognitive neuroscience to explain the reality of experiential 'meaning' at the same level that it was so successful in, and manifestly committed to, explaining the mechanics of

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Imagine your entire world was flowers and how to kiss them

the electrochemical transmission events by which such meanings are asserted (without explanation) to be produced".

For Gerard Battail, an information theorist at Télécom ParisTech in France, it is the fact that mainstream biology, while loosely using a vocabulary borrowed from communication theory – "pathways", "codes" and the like – "remains basically concerned with the flow of matter and energy into and between living entities, failing to recognise [that] the information flow is at least as important".

Frederik Stjernfelt of Aarhus University in Denmark echoes El-Hani: "Notions such as 'information', 'message', 'representation', 'code', 'signal', 'cue', 'communication' and 'sign' crop up all over biology," he says. He points out, however, that while the use of such terms is apparently unavoidable in explaining the workings of living systems, rarely, if ever, are such concepts explicitly defined as technical terms. His version of biosemiotics sees this as an explanatory blind spot that should be taken seriously.

"If not, the danger is that biology is trapped in a dualism where all organic communication, from cells to apes, are claimed to be describable as simple physiochemical causes only – while, on the other hand, full intentional meaning is a specifically human privilege. How could such a thing have developed phylogenetically, if not from simpler semiotic processes in biology?" asks Stjernfelt.

Kalevi Kull at the University of Tartu in Estonia stays closer to von Uexküll. "Biology has studied how organisms and living communities are built. But it is no less important to understand what such living systems know, in a broad sense; that is, what they remember (what agent-object sign relations are biologically preserved), what they recognise (what distinctions they are capable and not capable of), what signs they explore (how they communicate, make meanings and use signs) and so on. These questions are all about how different living systems perceive the world, how they model the world, what experience motivates what actions, based on those perceptions."

"The exploration of the scientifically new continent of 'meaning' has just begun"

These answers and many more are just a taste of how biosemiotics is shaping up. As Favareau explains, we must remember that it is still a "proto-science – closer to a very lively debate between scientists about what such a future science will have to explain about biological meaning, and how it will do so, than it is to a fully realised science with a common terminology and a settled methodology".

The founders are open to new ideas. "If one truly recognises the need for something like biosemiotics, then one owes it to science to apply one's best thought and effort to the task," writes Favareau in the introduction to a recently released anthology *Essential Readings in Biosemiotics* (Springer, 2009).

Marcello Barbieri, a molecular biologist at the University of Ferrara in Italy, another key figure, echoes Favareau. He brings yet another perspective to the field – a "code model" that he has applied to the genetic code, splicing and other cellular codes. "Nothing is settled yet in biosemiotics," he says. "Everything is on the move, and the exploration of the scientifically new continent of 'meaning' has just begun." Watch this space. ■

To learn more about biosemiotics and its history, download a free pdf of the first chapter of Donald Favareau's *Essential Readings in Biosemiotics* at www.bit.ly/axHqMO, courtesy of Springer Science publishers and Donald Favareau