survive to generate more such organisms, again with their own subtle variations. In the development of an organism the stochastic nature of gene activation and protein interactions permits a vast array of possible developmental outcomes. Darwinian selection, Kupiec argues, constrains development so as to consistently form a particular organism. The local environment of the cell is the selecting agent, choosing which cells survive, differentiate, divide or die. He demonstrates his concept through computer simulations that generate simple patterns of two cell types. Each cell reacts with some probability to its local conditions to determine its next state.

In setting up local environment and metabolic interactions, cells must, however, use signalling protocols or programs that specify how the cells react — even if they involve probabilities. Yet Kupiec claims that because of stochastic protein interactions such programs cannot exist. But even if we allow simple reactive protocols to control any cell's reaction to its local environment, such strategies can produce only simple patterns. They cannot achieve the complex structures and functions generated in many multicellular organisms. Such reactive strategies can, at best, pass on information to determine the cell's next state.

Thus, in Kupiec's proposal, the local environment must host the constraining information necessary to form an organism. But it is not clear how this information could be stored and conveyed. In his view, the environment functions like a complex, external 'homunculus', magically controlling embryonic development at every step. Kupiec also fails to explain why differentiated cells remain stable if gene activation is stochastic, or why cellular control strategies and protocols exist at all.

Kupiec's version of a Darwinian-like cell-selection process needs to be robust and invariant. It must be more restrictive than typical Darwinian selection, which permits the formation of a diverse array of organisms and species to form. It must explain why a particular embryo forms, not just any embryo. It must account for the similarity of identical twins; the precision with which the left side mirrors the right in bilaterally symmetrical organisms; and why a mouse differs from a horse or a potato. A further issue is that even if there is local molecular randomness, it need not be passed on to the cell or to the developmental control architecture of the organism. Organisms consistently pass through the same stages during development, irrespective of minor variations in their local and maternal environments.

By treating the genome only as a generator of proteins, Kupiec adopts an implicitly reductionist view of development. But organisms of many species have virtually identical protein structures, yet their control architecture is vastly different, just as a house and a skyscraper can be made of the same parts. Every complex structure needs specific control information to develop, and the only reasonable source of that information is the genome, not some blind local evolutionary selection process. The genome and cell cooperate by means of an epigenetic interpretation system by which control information in the genome is interpreted and executed by the cell. Thus the genome encodes more than protein building-blocks — it contains a hidden control code. Such a feature could explain the vast non-coding regions in the genome; Kupiec prefers to think of these regions as mere space fillers determining gene-activation probabilities.

Kupiec's model also fails to account for global and temporal relationships. Local information is not powerful enough to generate global relationships in an organism — all the more so if it is probabilistic. Because the growth process of an embryo is ordered in time, directives from the genome must be linked to form control networks. The architecture of an organism is complex both spatially and temporally.

Kupiec is a very successful writer, deservedly so. I enthusiastically recommend this courageous book with its iconoclastic viewpoint. *The Origin of Individuals* is a pleasure to read, presenting complex ideas clearly and effectively. Whether one agrees with him or not, Kupiec's is an inspiring work, a thought-provoking rollercoaster ride through the history of ideas about the origins of ontogeny. ■

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Stuffed spectacular

Extreme Mammals: The Biggest, Smallest, and Most Amazing Mammals of All Time
American Museum of Natural History, New York City
Until 3 January 2010

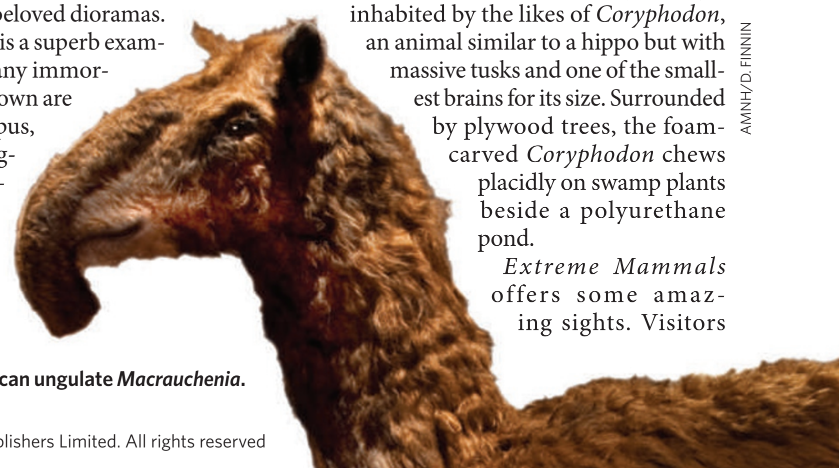
Roll up, roll up! See the giant *Indricotherium*, a plant-eating mammal from Mongolia that weighed as much as four adult African elephants! Gaze at the tiny bumblebee bat, which can hover in place like a hummingbird! Marvel at the wide-eyed sugar gliders, sailing nimbly through the branches! All can be seen in *Extreme Mammals*, the latest exhibition at the American Museum of Natural History that showcases the largest, smallest, toothiest, brainiest, prickliest, slowest, fastest and lustiest mammals on the planet.

Although its title suggests a circus, the show lacks the pizzazz of a real one. Except for the sugar gliders and the human visitors, none of the mammals in the exhibition is moving or breathing: all are models, skeletons or stuffed.

The museum has more than a million stuffed animals in its collection, and never misses an opportunity to haul them out for display, preferably in one of its beloved dioramas. *Extreme Mammals* is a superb example. Among the many immortalized creatures shown are a duck-billed platypus, a fluffy koala, a long-tailed howler monkey, a spectacled bear and a striped Tasmanian wolf or thylacine, which went extinct in 1936 when the last of its kind died in an Australian zoo.

One diorama depicts Ellesmere Island — now an expanse of frozen tundra some 1,000 kilometres from the North Pole — when it was a warm paradise 50 million years ago, inhabited by the likes of *Coryphodon*, an animal similar to a hippo but with massive tusks and one of the smallest brains for its size. Surrounded by plywood trees, the foam-carved *Coryphodon* chews placidly on swamp plants beside a polyurethane pond.

Extreme Mammals offers some amazing sights. Visitors


AMNH/D. FINNIN

Extinct: South American ungulate *Macrauchenia*.

Extant: the duck-billed platypus.

AMNH/R. MICKENS

enter the exhibition by walking under the belly of a model of a 34-million-year-old adult *Indricotherium* — at 18 tonnes, it is the largest land mammal ever found. They are then treated to a stupendous array of mammalian headgear, such as a cast of a 2.5-metre-long, bendable tusk of the narwhal; some 2-metre-wide moose antlers; the giant fossil jaw of the 14-million-year-old extinct *Platybelodon grangeri* — an elephant relative that may have used its platter-like teeth to scoop up swamp grasses; and the curved upper canines of the Indonesian male babirusa pig that stick upwards through its skull.

The exhibition includes plenty of basic biology: all mammals have three bones in the middle ear, some sort of hair, large brains for their body size and females that produce milk for their young. The show also offers a plethora of weird facts: the Shaw's jird, a small African desert rodent, can mate 224 times in 2 hours; the aardvark, or 'earth pig', can dig for and eat 40,000 termites in a night; the bony, armoured shell of a glyptodont — an extinct South American armadillo relative that grew up to 3 metres long — could weigh more than 500 kilograms. A model easily fits three children inside.

A quarter of all living mammal species are now threatened with extinction. Among those that are endangered are some species that have only recently been found, such as the shy saola, *Pseudoryx nghetinhensis*, a beautiful horned ox discovered in 1992 in the wet evergreen forests of Vietnam's Annamite Mountains that is now threatened by road construction and hunting.

And the striped rabbit, *Nesolagus timminsi*, was discovered in 1999 on sale at a food market near the border of Laos and Vietnam. A taxidermized specimen sits at the end of the exhibition and seems a fitting symbol of the fate of so many of its threatened mammal brethren. Unless we protect them, the only place we might be able to see these fascinating animals in future is in a museum, stuffed. ■

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Evolution's influence on art nouveau

Emile Gallé, Nature and Symbolism: Influences from Japan
Georges de La Tour Departmental Museum, Vic-sur-Seille, Moselle, France
Until 30 August 2009

Characterized by sinuous shapes and subtle colours, the glass vases, bowls and other objects made by the nineteenth-century French artist-designer Emile Gallé and his factory are still highly regarded. But his interest in botany and evolution is less well known. An exhibition this summer in Moselle, northeastern France, explores how Gallé's work was influenced by nature and by Japanese art and design. The show is co-curated by scientist François Le Tacon of the French National Institute for Agronomic Research in Nancy, France.

Gallé was one of the founders of art nouveau, an influential art and design movement. He learnt glass-making skills as an apprentice, but after taking over his father's factory in Nancy in 1875, he created designs that were made by its artisan employees. He exploited the sensual properties of glass, using acid etching to form opaque vessels with layered colours and shaped surfaces. His organic designs did not simply borrow from nature — they expressed contemporary thought and politics. Gallé was aware of Darwin's work by 1877 and owned a copy of Ernst Haeckel's *Art Forms in Nature* (1899–1904).

Plant, insect and animal motifs were derived from his careful observations, but also held deeper meanings. "Beetles symbolized industriousness; the thistle symbolized Nancy, Lorraine and separation from Germany; the rose symbolized France and the lover," note Jennifer Hawkins Opie in *Art Nouveau 1890–1914* (V&A Publications, 2000). Gallé was also inspired by aquatic flora and fauna, as shown in nine works incorporating themes such as undulating strands of seaweed and deep sea colours.

Emile Gallé vase with etched dragonfly.

FOND. MUS. KUNST PALAST, GLASMUS. HENTRICH, DUSSELDORF

Japanese artwork displayed in Europe at the end of the nineteenth century captivated many western artists and designers. Gallé himself owned woodblock prints by Hokusai and others, and he befriended the Japanese botanist Hokkaï Takashina after meeting him at a horticultural exhibition in Nancy in 1886. They were both interested in chrysanthemums, a potent symbol in Japan, which Gallé used as a decorative motif. The internally crackled and coloured glass used by Gallé and his artisans, although made in France, was inspired by Japanese watercolours and lacquerware, as well as carved rock crystal and jade from China.

From 1886 until his death in 1904, Gallé investigated evolutionary mechanisms in botany, an interest covered in the exhibition. Displayed, for example, are plates illustrating the orchid *Aceras hircina*, from a paper on polymorphisms in orchids local to Lorraine that Gallé presented at an international botanical congress in Paris in 1900. They underscore how Gallé's biological exactitude and interest in symbolism generated his incomparable designs. ■

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