Weismann sought to illuminate the links between them.

Churchill shows how Weismann's experimental observations of chromosome movements during cell division reinforced his germ-plasm theory. Weismann adapted ideas from leading cytologists and experimental embryologists such as Theodor Boveri and Wilhelm Roux, to link heredity and development through what Churchill calls his "architectonic view". Instead of a holistic or vitalistic understanding of the organism, Weismann developed a more structural view in which the system depends on integration of the material parts, with guidance from the germ-plasm and its determinants. Development then constructs the organism out of cells, with reproduction providing a source of variation on which natural selection acts, enabling evolution.

Weismann was confident and sometimes controversial. Churchill shows how disagreements helped Weismann to work out his own ideas. He sparred, for example, with physician and biologist Rudolf Virchow over issues of acquired characteristics and the role of external factors in shaping variation. And Weismann clashed with zoologist Theodor Eimer about the apparent randomness of evolution. Dozens of leading scientists influenced or interacted with Weismann because of his central role in biology. The zoologist and illustrator Ernst Haeckel, for example, was a close friend, but his views diverged from Weismann's in ways that influenced both men, and affected public perceptions of biology. We also see the impact on Weismann of technically brilliant figures such as Boveri and theoreticians including Darwin. Weismann in turn influenced his contemporaries and subsequent generations of Darwinians.

Even as his contemporaries began to specialize and to give up the study of connections between heredity, development and evolution in favour of specialized study of the parts or selected processes, Weismann worked hard to develop a comprehensive understanding of life. Churchill has mirrored that determination in developing a compelling and comprehensive understanding of Weismann, his ideas, work, life, contemporaries and context. ■

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The hybrid dinosaur *Indominus rex* runs rampant in *Jurassic World*.

Q&A Jack Horner

The dinosaur doctor

Montana palaeontologist Jack Horner has served as scientific adviser on the Jurassic Park *films from the start. With the latest,* Jurassic World*, soon to be released, he talks about a shark-devouring* Mosasaurus*, breeding chickens back into dinosaurs and the influence of the film franchise on his own field.*

How did you get involved in the series?
In the early 1990s, a colleague called me and said, "You're in a book about cloning dinosaurs" — Michael Crichton's *Jurassic Park* (Alfred A. Knopf, 1990). I said, "I hope my character doesn't get eaten." I never bothered to pick it up; I am dyslexic and have trouble enough keeping up with my own science. Then director Steven Spielberg called and asked whether I wanted to work on the film. I thought growing a dinosaur was an intriguing idea, and I still do. It is a little far-fetched now, but I think one day we will be able to do it, not using amber-trapped DNA, but through genetic modification of dinosaurs' closest living relatives, birds.

What did work on *Jurassic Park* (1993) entail?
My job was to find things that were obviously wrong. In one scene, the puppeteers were having trouble getting an animatronic *Tyrannosaurus rex* leg to move properly. So I stepped in to control the joystick, making the foot land on its toes in a bird-like position, rather than heel-first like a mammal. In a kitchen scene, the puppeteers had velociraptors sticking out forked tongues, which dinosaurs did not have. Instead, we had the raptors snort to fog up the window, revealing that they had warm blood.

What are the innovations in *Jurassic World*?
The science has got ahead of the films, but we cannot really change the way the dinosaurs look. If suddenly the raptors had feathers, it would destroy consistency. But I did help to render new creatures. You can see a mosasaur, a giant swimming reptile, shoot up from a tank to eat a great white shark. From my research, I helped to ensure that the juvenile triceratops, with its backward-curving horns, looked distinct from the adult, whose horns curve forward. But my biggest job was helping to create the 'genetically modified' *Indominus rex*, a combination of several dinosaurs and other animals, which turns against its makers.

How plausible is such a dino-hybrid?
Jurassic World is set in the future. If you can clone a dinosaur, you can modify its DNA and combine it with that of other animals. We

TOP: UNIVERSAL PICTURES/AMBLIN ENTERTAINMENT; LEFT: MUS. OF THE ROCKIES

Jurassic World
DIRECTOR: COLIN TREVORROW
Universal: 2015.

already have lots of tools for modifying an animal. We have been breeding them for centuries. Now we are getting to the point where we can take genes out of one organism and put them into another, for example taking fluorescent genes out of jellyfish and putting them into the embryos of other animals to make them glow in the dark. The challenge is finding ways of changing a creature without killing it. And I think we will.

Are you trying to breed birds back into dinosaurs?
In the Dino-Chicken Project at Montana State University in Bozeman, we are looking for the genetic pathways that provided the transformation from dinosaurs into birds, with the hope that some of those pathways can be reversed. Part of it is genetic engineering to see if we can get a long tail back on a chicken (D. J. Rashid *et al*. *EvoDevo* **5,** 25; 2014). My postdoc Dana Rashid has screened mouse genes, looking for pathways that cause mice to lose their tails. If she can find one that causes a similar reaction in a reptile, it might be possible to reverse the process and grow a tail on a chicken.

Do the films do justice to the science?
Each film explains a bit of the science, for example through the dancing DNA cartoon in the first movie. If people are wondering about whether the science in *Jurassic World* is real, that is great for science. *Jurassic Park* brought out all sorts of students who wanted to switch careers into palaeontology. It channelled a flood of graduate students to my lab, including some of the best scientists I have trained.

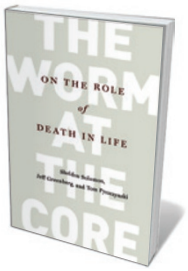
How have digital effects changed your work?
For the first film, I would sit with Steven Spielberg and advise him on the motions of the dinosaur puppets. But *Jurassic World* had only one puppet on set — an injured sauropod. For the rest of the dinosaurs, most of my consulting was with the graphics people.

What do we know about how dinosaurs behaved?
They were more like robins than crocodiles. Their spikes and shields were too flimsy for fighting and were more likely to be for display, like the bony crests on some modern birds. Some dinosaurs had feathers and probably 'danced' like birds. If you built a Jurassic Park, it would be more like the Serengeti than *Jaws*. I wrote a script once for a film where scientists come out of their time machine to see triceratops dancing and showing off their coloured shields. Nobody would go to that movie. ■

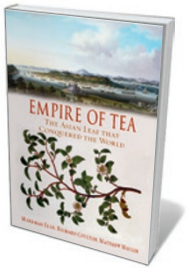
INTERVIEW BY JASCHA HOFFMAN

This interview been edited for length and clarity.

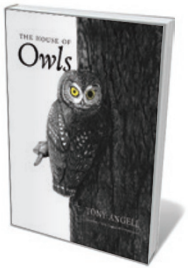
Books in brief



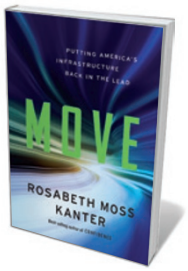
The Worm at the Core: On the Role of Death in Life
Sheldon Solomon, Jeff Greenberg and Tom Pyszczynski RANDOM HOUSE *(2015)*
How do we cope with the knowledge of mortality? In this considered treatise, psychologists Sheldon Solomon, Jeff Greenberg and Tom Pyszczynski present their "terror management theory", positing that we hold off existential fear through our cultural world view and sense of personal significance. Drawing on several disciplines and many experimental-psychology studies, they conclude that embracing ambiguity and cultivating meaning in life create the basis for the finely calibrated courage that we need to face our inevitable end.



Empire of Tea: The Asian Leaf That Conquered the World
Markman Ellis, Richard Coulton and Matthew Mauger REAKTION *(2015)*
'Tea' has at least five meanings: the shrub *Camellia sinensis*; its leaf; the dried commodity; the infusion made from it; and the occasion for consuming the infusion. As Markman Ellis, Richard Coulton and Matthew Mauger show in this stimulating volume, history is steeped in the stuff. In eighteenth-century Britain, tea smugglers murdered customs officers; across the Atlantic, excise duty provoked the Boston Tea Party. In 1920, say the authors, John Maynard Keynes "imagined tea at the centre of the modern mercantile world". With 290 billion litres of tea imbibed in 2013, the taste for it seems set to grow.



The House of Owls
Tony Angell YALE UNIVERSITY PRESS *(2015)*
Wildlife artist and naturalist Tony Angell, who memorably explored corvid behaviour with John Marzluff (see N. Clayton *Nature* **484,** 453–454; 2012), here turns to the owl. A self-confessed strigiphile, Angell has had western screech owls (*Megascops kennicottii*) nesting outside his home in Washington state for 25 years, and his exquisite monochrome illustrations testify to that intimate coexistence. Angell delves, too, into the owl in culture, and the ranges and habitats of the 19 species found in North America. A treat for fans of these strangely remote, inquisitive, astonishingly sharp-eared and -eyed raptors.



Move: Putting America's Infrastructure Back in the Lead
Rosabeth Moss Kanter W. W. NORTON *(2015)*
The US transport infrastructure is riddled with "pain points and bottlenecks", from delayed flights to crumbling bridges. So notes Harvard business professor Rosabeth Moss Kanter in this propulsive study, which argues for an overhaul of US transport to boost the economy, ease commuting and curb emissions. Kanter delivers a number-crunched analysis of the state of road, rail and air transport, and details progress on intelligent transportation and smart cities. But with government and industry preventing advances, the prime hurdle, she notes, is a lack of political will at the top.

Spirals in Time: The Secret Life and Curious Afterlife of Seashells
Helen Scales BLOOMSBURY SIGMA *(2015)*
Structurally elegant and often stunningly marked, seashells have obsessed scientists for centuries — as attested by the millions housed in London's Natural History Museum alone. In this engaging study of molluscs, marine biologist Helen Scales covers a wealth of research on this vast phylum, from findings on shell shape and colour (rococo formations may deter predators, whereas pigmented patterns could be a mollusc's way of tracking its own construction process), to the ecosystem services performed by oyster beds. **Barbara Kiser**