Then and now

by Renée van Amerongen

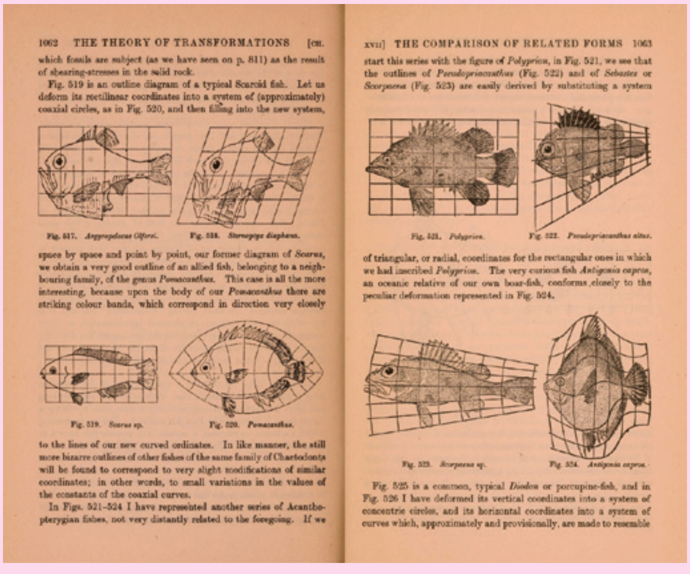
RENÉE VAN AMERONGEN
is MacGillavry fellow and associate professor *(tenured)* at the University of Amsterdam in the section of Molecular Cytology at the Swammerdam Institute for Life Sciences.

→ Throughout 2017, biologists around the world celebrated the centennial anniversary of *On growth and form* – a book written by D'Arcy Wentworth Thompson. Special issues of scientific journals, conferences and cross-media events seemed to pop up out of nowhere, like mushrooms in an autumn forest[1]. Why all the fuss over a piece of work that was published in 1917, by someone whose name suggests he walked straight out of a Jane Austen novel rather than a research lab?

When his seminal work was first published, D'Arcy Wentworth Thompson had just taken up a post as professor of natural history at the University of St. Andrews in Scotland. In *On growth and form*, he discusses the development of organisms, and in fact the evolution of entire species, in physical and mathematical terms. In doing so, he opened up a whole new way of looking at life. You could say that Wentworth Thompson is the founding father of a field that is nowadays known as quantitative biology. This was an important new development in 1917, since till then biology had largely been a descriptive science. Countless generations of biologists, from the time of Aristotle onwards, had made careful observations about different plants and animals and classified them into related species – but they had made very little progress in truly understanding the underlying mechanisms that allowed cells to organise themselves into such a diverse and beautiful complexity. All of this was to change in the 20th century, and for that we do not only have to thank the rise of molecular biology, but also the growing realisation that many of the robust patterns we see around us can ultimately be explained by the laws of physics.

Those who are interested can download and read the revised version of *On Growth and Form*, which was published in 1945. It is freely available online in a variety of 21st-century formats[2], and for a piece of work that was devised a century ago, it reads remarkably well. Wentworth Thompson just as easily discusses the growth rate of maize and human populations as he does the shape of spiral shells, sheep horns and deer antlers. He discusses how different cell types have entirely different shapes and explains how groups of cells can form tissues thanks to their propensity to clump together in much the same way that soap bubbles do. My personal favourite part is the final section, called 'the comparison of related forms', in which he transforms a complex animal such as a fish, into a coordinate system depicted by a two-dimensional grid (see Figure). Then by pushing and pulling the grid – that is, by merely exerting mechanical force on the grid – he can transform a member of one species into that of another related species. Of course, this exercise offers no real explanation, biological or otherwise – and Wentworth Thompson is the first to admit that. In the epilogue, he states: "… while I have sought to shew [show] the naturalist how a few mathematical concepts and dynamic principles may help and guide him, I have tried to shew [show] the mathematician a field for his labour – a field which few have entered and no man has explored."

Although Wentworth Thompson may not have realised it at the time, he planted the seed for a novel way of thinking. Nowadays it is entirely common to look beyond the boundaries of one's own field and to introduce principles from a seemingly unrelated discipline. Biologists frequently collaborate with (bio)physicists and mathematicians to make sense of the complex world under the microscope. Just this week I explained to my students how stem cells are capable of maintaining the lining of our intestinal tract, and for that I had to introduce concepts from the field of statistical physics. Down the hall from my own lab, systems biologists aim to capture molecular events in mathematical models to predict cell behaviour (see "Timing cell division", page 22). Across the street, scientists at AMOLF and CWI are using quantitative biology to describe and understand complex cellular activities, and so forth. We have come a long way since 1917 and D'Arcy Wentworth Thompson's landmark publication deserves every last bit of the attention it has received this year. Ω



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which fossils are subject (as we have seen on p. 811) as the result of shearing-stresses in the solid rock.

Fig. 519 is an outline diagram of a typical Scaroid fish. Let us deform its rectilinear coordinates into a system of (approximately) coaxial circles, as in Fig. 520, and then filling into the new system,

Fig. 517. *Argyropelecus Olfersi.* Fig. 518. *Sternoptyx diaphana.*

space by space and point by point, our former diagram of *Scarus*, we obtain a very good outline of an allied fish, belonging to a neighbouring family, of the genus *Pomacanthus*. This case is all the more interesting, because upon the body of our *Pomacanthus* there are striking colour bands, which correspond in direction very closely

Fig. 519. *Scarus* sp. Fig. 520. *Pomacanthus.*

to the lines of our new curved ordinates. In like manner, the still more bizarre outlines of other fishes of the same family of Chaetodonts will be found to correspond to very slight modifications of similar coordinates; in other words, to small variations in the values of the constants of the coaxial curves.

In Figs. 521–524 I have represented another series of Acanthopterygian fishes, not very distantly related to the foregoing. If we

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start this series with the figure of *Polyprion*, in Fig. 521, we see that the outlines of *Pseudopriacanthus* (Fig. 522) and of *Sebastes* or *Scorpaena* (Fig. 523) are easily derived by substituting a system

Fig. 521. *Polyprion.* Fig. 522. *Pseudopriacanthus altus.*

of triangular, or radial, coordinates for the rectangular ones in which we had inscribed *Polyprion*. The very curious fish *Antigonia capros*, an oceanic relative of our own boar-fish, conforms closely to the peculiar deformation represented in Fig. 524.

Fig. 523. *Scorpaena* sp. Fig. 524. *Antigonia capros.*

Fig. 525 is a common, typical *Diodon* or porcupine-fish, and in Fig. 526 I have deformed its vertical coordinates into a system of concentric circles, and its horizontal coordinates into a system of curves which, approximately and provisionally, are made to resemble

→ Reference
[1] ongrowthandform.org
[2] archive.org/details/ongrowthform00thom

→ Figure
Pages 1062 and 1063 from the 1945 edition of *On Growth and Form*.

"He planted the seed for a new way of thinking."