From a somewhat similar perspective, colours represent the type of investment that one might expect from a business enterprise that is sensitive to market forces. In biology, this sort of reasoning involves what is often called the ultimate explanation for some trait in a living creature. Equally, it can be termed a distal or historical explanation. It is the mode of explanation that is commonly used in evolutionary theory. It deals with ‘deep time’, often many thousands or millions of years. Its justification rests on natural selection, which is the most commonly accepted mechanism of evolution. In selectionist or Darwinian language, the explanation implies an adaptation—a fitness of design—of the flower to the environment. Selectionist arguments tend to be ‘substrate-free’: they can be decoupled from the material properties of whatever is used for actually implementing the design.

However, just like any other material object, a flower is made up of atoms and molecules. This fact makes it possible to come up with a perfectly acceptable but quite different answer to our question. One can say that flowers are coloured because, as the culmination of complex chemical reactions, certain pigments are deposited; and these pigments have absorption and reflection spectra that makes us describe them as coloured. The reasoning has shifted from the rarefied plane of costs and benefits to a more mundane plane involving catalysis, diffusion, solubility, molecular structure and energy levels. In contrast to the evolutionary explanation, this one invokes proximal factors only. It deals with the here and now—relevancy scales—range may vary from nanoseconds to minutes or, at the most, hours.

The science behind the second explanation is little more than high school or undergraduate-level physics and chemistry. But in the case of the flower, physical reasoning is applied to a somewhat strange object. It is simultaneously elegant and messy. It is by and large a solid, largely soft and composed of distinct parts. Its building_blocks are tiny, flattened, fluid-filled enclosures. Amazingly, the enclosures contain many things that seem to be of no relevance for the property that we are interested in, i.e. colour. If observed over longish periods of time, the object is seen to have had a past that saw dramatic transformations in its appearance. It is as far removed as can be imagined from that ideal of the experimentalist, the prepared system.

But, at the heart of the proximal explanation for coloured flowers there is an incontestable fact. When you get down to it, living creatures are no more than unusual forms of organised matter.

How can the distal and proximal explanations be reconciled? How does one go about showing that a given combination of material constituents, physical forces and chemical reactions could have led to a particular evolutionary outcome in terms of shape, form, structure and function? Many factors—among them the vastly different time-scales—make this a very difficult problem. Broadly speaking, there are two approaches that have been adopted in trying to look for a solution.

A time-honoured strategy, known in evolutionary biology as the comparative method, is to search for resemblances between species. Similar sets of entities (say intracellular chemicals, cells, or tissues) might be functionally organised in similar ways and lead to similar outcomes in a wide range of organisms. For example, say A stands for sunlight and X for stored sugar. There may be the same chain of inputs and outputs leading from A to X, represented symbolically as A → B → C → ···→ X, which is found in individuals that belong to many different species. For an evolutionary biologist, the following hypothesis immediately suggests itself: the chain appears to be a general, if not universal, feature of living organisms because it existed in a common ancestor of all the species.

If further work supports this hypothesis and disfavours rival hypotheses—for example, the hypothesis that independent evolutionary paths have led to the same end—that means that the problem of getting from A to X may have been solved just once. Everything can be pushed back to ‘initial conditions’. The analysis does not address the importance of precisely why, when it did so for the first time, evolution settled on a particular chain of intermediates between A and X. That sort of question, and indeed the whole issue of natural selection in biochemical evolution, has been poorly investigated. (A recent book by A. Cornish-Bowden, The Pursuit of Perfection, provides a much-needed corrective.)

There is another way of trying to reconcile proximal and distal explanations in biology. The second way goes counter to the prevailing fashion today, which is to ascribe all the properties exhibited by living matter to the activities of genes.
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But here is a puzzle. Organisms that are very different genetically, can display remarkably similar pathways of development. In a wide range of animal groups — for example, fish, frogs and mice — the fertilised egg becomes a hollow ball of cells which begins to pinch inward at one place, continues moving and becomes the precursor of a primitive backbone and musculature. Elementary textbooks of zoology show us how alike the early embryos of these three groups look. One would imagine that the processes involved in their morphogenesis (form-building) must be very similar too. However, adult fish, frogs and mice look and act quite unlike each other. Many of those later differences are certainly because of their different genetic constitutions. Is it possible, then, that at least some of the common patterns seen in embryonic development — in particular, patterns that can be exhibited by inanimate matter — may be due to factors that are related to gene activity in only a loose sense? Speculating further, could the evolution of genetic networks primarily serve as a means of refining patterns rather than of specifying them?

Forgacs and Newman’s book demonstrates the attractive features of this approach for reconciling the proximal and distal explanations. Basically, their point is that many gene-based properties of developing embryos are sophisticated versions of the properties that the embryos would be expected to exhibit anyway — simply because they are material entities. The properties could be the sorts of equilibrium (or steady-state or time-dependent) outcomes that would be expected to result from the rules of physics and chemistry as applied to cells and tissues that are subject to appropriate constraints. In other words, shape, form and order in biological systems could be solutions to certain ‘boundary conditions’. What then of genes and evolution? Could it be that over time, natural selection has made use of genetic variation to mould the spatial and temporal structures provided by physics and chemistry so that the ones that were best adapted to the environment were produced ever more reliably? This is the line of thought, or better, research programme, that Biological Physics of the Developing Embryo put forward. It shows how to go about implementing the programme. With admirable clarity and sufficient detail, Forgacs and Newman demonstrate that physical reasoning can usefully be applied to a variety of phenomena in the developing embryo. They show how much can be learnt about the behaviour of cells, tissues and embryos by an intelligent application of generic principles related to diffusion, viscosity, surface tension, elasticity, enzyme kinetics and feedback.

There is a history behind this way of looking at embryonic development. The twentieth century saw enormous advances in the understanding of living systems. First there came the rediscovery of Mendel’s laws of heredity followed by the elaboration of those laws into the elegant analytical framework known as genetics. Then we saw the gradual unravelling of the chemical transactions inside living cells, especially of the ways in which the constituents of living matter are assembled, maintained and broken down. The steps whereby a fertilised egg became an embryo, long remained a mystery. Thanks to a brilliant application of genetics, some aspects of the mystery were cleared up. The mechanisms of signal generation and communication in the nervous system got clarified over a long stretch of time. The topping was provided by the revolution ushered in by the discovery of the structure of DNA and, one might say, of the games played by DNA, RNA and proteins.

This, the molecular biology revolution, seems to have swept all before it. As a consequence, almost every area of biology acquired a seemingly self-evident DNA-based underpinning. If not immediately obvious, it was taken for granted that the goal of further research was to demonstrate the underpinning. The assumption was that all traits of living systems had to have meaningful ‘molecular’ explanations — implying, explanations based on transactions involving DNA, RNA or proteins.

In some cases the benefits of a molecular biology-based approach were quickly realised. It was obvious that molecular biology held out the promise of providing insights into what was going on inside a single cell. At the same time, it was equally obvious that many aspects of organisms had to do with traits exhibited at coarser scales — at the scale of cells and tissues. These traits were crucial for the shaping of embryos and into determining what made the individuals of one species of plant or animal look different from another. Years before molecular biology made an appearance, many felt that the reason why plants and animals looked the way they did had to be explained in terms of the properties of cells and tissues, and in terms of the consequences of chemical reactions when combined with diffusion and feedback. The scale of the problem was too far removed from molecular dimensions for a purely molecular description of development to be feasible. Long ago, in a classic entitled On Growth and Form, D’Arcy Thompson said that if one wanted to understand the architecture of organisms, one had to apply mathematical laws and physical principles, especially the laws of geometry, to living matter. Among others, Rashevsky, Turing and Waddington tried to push the application of physical ideas to biological development.

Fittingly, Cambridge University Press, which published D’Arcy Thompson’s book in 1917, has brought out a worthy successor to it in 2005. Indeed, one way to describe Biological Physics of the Developing Embryo is to say that it is an extension of D’Arcy Thompson’s great work. The book begins with a discussion of viscosity, diffusion, osmosis and elasticity, basic properties that are required for understanding how a smooth, round, single-celled egg can turn into a many-celled, bumpy-surfaced embryo that looks like (in our case) six cylinders joined to one another. In parallel, as the fertilized egg begins to assimilate nutrients and grow in size, division of labour sets in among its constituent cells. In genetic language, some genes continue to be active in all cells but other genes restrict their domain of activity to some cells. By making use of stability analysis, Forgacs and Newman show how this can be achieved via the help of chemical reactions with feedbacks and auto-catalysis. The role of mechanical forces in cell movement, mutual adhesion, tissue organisation and tissue shape comes next. It is followed by a consideration of body patterns and symmetry, the first things that excite wonder when one sees a plant or animal. The treatment includes an analysis of physical diffusion in combination with chemical reactions, especially oscillatory reactions. The intricacies of organ formation (blood vessels, salivary gland and limbs) are handled carefully. However, this and the following chapter, on fertilisation, were somewhat difficult to grasp — probably because with the exception of limb de-
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dvelopment, the topics that these chapters deal with were the least familiar to me.

The last chapter discusses the evolution of multicellular development. It contains the idea that I have mentioned earlier: the developmental mechanisms of today have been achieved by gene-based fine-tuning. This insight highlights a feature of natural selection that is sometimes forgotten, namely that it both moulds traits and moulds them reliably. Besides tending to achieve the appropriate mean value for a trait, in general natural selection tends to reduce the variance in the trait. Genetic fine-tuning can act on ancestral, poorly defined outcomes that are achievable via physics and chemistry acting in concert with a skeletal genetic ensemble that is needed for metabolism and reproduction. Physics and chemistry lead to approximate outcomes; further evolution makes them more and more precise. The way it does so is by making opportunistic use of a number of undirected processes, among them gene duplication, mutation and gene shuffling (recombination). The variants that result are tested and those that lead to an increase in reliability are preserved. The randomness inherent in evolutionary change makes it inevitable that finally, what is seen includes a great deal of genetic clutter. The clutter obscures the underlying physics. It can become difficult to perceive that there is any interesting physics at all.

The strengths of this book are the use of lucid prose, the gentle way in which the required physics is brought in, and the successful fusion of formal ideas with factual information concerning known genes, their activators and repressors. I should not omit to mention the illustrations, which are artistic. Students with a background in physics, chemistry or mathematics, and an interest in biological problems, will benefit greatly from this book, which can serve as an excellent text for a course in developmental biology. Forgacs and Newman have assimilated much from a vast and diverse literature. They manage to convey a great deal of information, interesting in itself, about embryonic development; my guess is that most developmental biologists will be familiar with only a tiny part of it. In contrast to what could have been a micro-manager’s guide to development, Biological Physics of the Developing Embryo tries to look at the big picture.

But Forgacs and Newman go beyond that. They point the way to a plausible merger of the two levels of explanation in biology: the one obtained after applying deterministic physical laws to the developing embryo, and the other based on a consideration of the contingent historical process of evolution. Marx would have liked it.

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The book under review is a collection of mainly field studies on the contemporary applications of traditional knowledge (TK) in the development context. The studies cover a wide range of fields like healthcare, agronomy, livestock and veterinary sciences, water management, architecture and weather forecasting. It also has a section on methodology of traditional sciences and technologies and a section on policy issues related to traditional knowledge. It will serve as a useful introduction to the living traditions of indigenous knowledge in India and Sri Lanka and may surprise readers by the vitality and extent of their application.

This book has materialized in the context of a 10 year effort in promoting ‘endogenous development’ via, a network of individuals, non-profit and community-based agencies, researchers and universities spread across 12 countries across Asia, Africa, Latin America and Europe called Compas.

In the introductory chapter the editors bring to notice the disparity in the public resource allocation and policy attention to TK compared to modern science. They also highlight that there is a completely different epistemological foundation for TK and point to the lack of appreciation of this fact by the mainstream scientists. They point out that there is strong revival of interest in TK today, which is an outcome of the critique of the modern mainstream monoculture.

In the first chapter titled ‘Knowledge and sciences in the global context: Contradictions, competitions, coexistence, complementarity and coevolution’, the author makes a comparative overview of TK in various continents and points out their common features. He advises us to look at worldviews, sciences and values not as universal but as expressions of a pluralistic reality. He therefore advocates intercultural/inter-scientific dialogue for mutual learning and co-evolution of knowledge systems.

Five papers in the agricultural section deal with various aspects of TK such as vrikshayurveda, documentation and validation of traditional knowledge, tribal agriculture and low external input agriculture. In this section Y. L. Nene gives a large number of examples of scientifically validated traditional agriculture practices like Kunapajala, a fermented liquid manure, made of various materials such as flesh, fat, marrow of animals, sesame oil cakes, ghee, etc., which is very effective for improving plant health. Yet another interesting article in this section is on ‘Nawakekulam’, a traditional agricultural practice of Sri Lanka, which minimizes water usage in cultivation. It is claimed that by reviving ‘Nawakekulam’ the national rice production can increase by 70%, increasing yield per acre. This section also contains well-researched articles from Gandhigram Rural Institute and Centre for Indian Knowledge Systems. The article on tribal agriculture touches upon interesting subjects such as tribal almanacs, soil, seed testing methods, intercropping systems, songs and proverbs.

Six papers in the veterinary section cover aspects like documentation and assessment of local veterinary practices both in India and Sri Lanka, mass pro-