determinants. *See* algebra.

determinism. Normally, the thesis that for everything that happens there are conditions such that, given them, nothing else could have happened. A *materialistic form of it was vigorously espoused by T. Hobbes (1588–1679). Impressed by the spectacular astronomical successes of the Newtonian programme, P. S. de Laplace (1749–1827) argued that given only a knowledge of the total mechanical state of the Universe at any moment of time 'nothing would be uncertain and the future, as the past, would be present to [our] eyes'. In the philosophical form articulated by Hume (1711–76) it appears as regularity determinism, viz. that for every event x there is a set of events y such that x and y are regularly conjoined under some set of descriptions.

While Kant (1724–1804) held determinism to be a necessary truth, because it could be shown to be a condition of the possibility of a coherent and unified experience, J. S. Mill (1806–73) regarded it as the most comprehensive general law of *Nature. However, because determinism is neither *inductively confirmable nor empirically refutable (failure to find a deterministic explanation can always be viewed as indicating a lacuna in our knowledge), it is now normally treated as a regulative principle rather than a substantive scientific proposition.

Free will has often been held to be compatible with (or even to presuppose) determinism, yet the common-sense view that determinism places our normal concepts of agency, choice and responsibility in jeopardy remains a strong one. Some philosophers have attempted rather rashly to infer from the *indeterministic character of *quantum mechanics the general untruth of determinism (and even the reality of free will). More pertinent perhaps are reflections on the conditions under which deterministic outcomes are actually possible (from which determinism as a metaphysical thesis derives its plausibility), which suggest that outside a few rather special closed contexts *laws in general set limits rather than prescribe uniquely fixed results.

It seems probable that the only sense in which science presupposes 'determinism', if and where it presupposes it at all, is the much weaker (non-Humean and non-Laplacean) sense, in which it presupposes the ubiquity of real (but not perhaps necessarily intelligible) causes, and hence the (however remote) possibility of *explanations. 'Determinism', as normally understood, can then be seen to rest on the error of supposing that because an event was caused to happen, it had to happen before it was caused.

See also causality (in quantum physics).

RB

development. Development involves unfolding of details, or change from a latent to a realized condition. Musical or mathematical development produces further articulation and expansion of a theme or an idea, for example. Biological development has historically referred to elaboration of *form from the *germ to a mature stage. Before the late 19th century, study of development concentrated on how the germ for an individual offspring gave rise to the fully realized adult expression of the appropriate form for the particular type of organism. Form was thought somehow already present in the germ the problem being how the developmental process brought the form from a latent to an actualized condition.

Aristotle (384–322 BC) provided an important starting point. Founding his own investigations of the chick and other organisms on work by predecessors such as the Hippocratics (5th–4th century BC), Aristotle concluded that *generation occurs when the male provides the form (including formal, efficient, and final causes) [*Aristotle's theory of cause] to the previously undifferentiated and unformed material of the female (which provides only the material cause). Once the offspring's germ is formed by the union of male and female elements, the form has simply to unfold, to move from a latent to a realized condition, a view prevailing until the 17th century, when biologists made careful studies of the developing germ material. For example, Fabricius (1533–1619) published illustrations of developmental details of the chick. His student William Harvey (1578–1657) further explored details even when they required questioning Aristotle's authority. Harvey emphasized the importance of the egg for providing form although his 'egg' was more a hypothetical than an observed entity. He could not see any physical egg in the uterus, for example, but he felt that the foetus must develop somewhere, namely in an egg. He stated that all things come from eggs (*ex ovo omnia*). Harvey also believed development occurs by *epigenesis, i.e. form emerges only gradually during embryogenesis rather than unfolding after being pre-existent from the beginning. He

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Harvey's epigenetic view was criticized, but his opponents could not retreat to an Aristotelian position because of Harvey's emphasis on the central role of the egg. Regnier de Graaf's (1641–73) claim that he had observed the previously elusive – and hence merely hypothetical – mammalian *egg, placed further emphasis on that female germ element.

In contrast to Harvey, the *preformationists believed that form pre-exists or is *encapsulated in the germ from the beginning. *Ovists, such as Marcello Malpighi (1628–94), argued the form of future generations pre-exists in the egg. Then, after Antony van Leeuwenhoek's (1632–1723) discovery of *spermatozoa, *Animalculists held that form pre-exists in that male germ element. Both Ovists and Animalculists believed in preformation. In fact, for the extreme Ovists, all future generations pre-exist in Eve's egg. And for the extreme Animalculists, the spermatozoa contained a tiny man, called by some an homunculus, which represents the form of all descendants.

Preformationists of various sorts predominated until the late 18th century, when Caspar Friedrich Wolff (1734–94) challenged them with his own epigenetic position, based on observations of the chick (a persistent favourite, easy to study). Wolff argued preformation offers no account of development but asserts without explanation or examination that all generation of form occurs during *heredity. He observed parts of the chick appear only gradually and are not simply inherited.

The 19th century brought new twists to epigenesis. Johann Wolfgang von Goethe (1749–1832), for example, pictured development as a *metamorphosis of an *archetypal unit into specialized body parts. Clearly not preformationist, Goethe's essentially philosophical account emphasized the developmental process and explained how the archetypal form changes, with new form emerging.

Similarly, but for different reasons, other German biologists endorsed the dynamics of development. Karl Ernst von Baer (1792–1876) described the detailed process by which an egg develops into distinct *germ layers and then into organs and body parts. Yet all these studies viewed epigenetic development as essentially an emergence of form which conforms to the particular morphological type of the parents. Epigenetic development was not thought to be random, but to culminate in the appropriate type of organism.

Charles Darwin (1809–82) called this latter assumption into question with his theory of *evolution. Introducing the word 'embryology' to refer to study of the developmental process, Darwin suggested it could hold the key to evolutionary understanding. Individual development, or *ontogeny, he hinted, might parallel or give clues about evolutionary ancestry, or *phylogeny. Ernst Haeckel (1834–1919), not an embryologist himself, carried Darwin's suggestion to the extreme with his *recapitulation idea in which ontogeny was said to recapitulate, or pass through the stages of, phylogeny. Although problematic and overstated, Haeckel's highly publicized views none the less stimulated embryology. Advances in microscopic and histological techniques, along with institutional support for embryological analysis, stimulated a virtual explosion of interest in embryology from the 1870s. Was development epigenetic and, if so, what directed the developmental processes, since the *type, previously thought fixed, was now subject to evolutionary change? Finally what was the relationship of heredity and development?

Various *research programmes arose in the 1870s and 1880s, emphasizing experimentation and analytical methods to study development and heredity of individuals and consequently of *species. Especially in Germany, contemporaries including Wilhelm His (1831–1904), Wilhelm Preyer (1842–97), Gustav Born (1851–1900), Hans Driesch (1867–1941), and Wilhelm Roux (1850–1924), called for experimental analysis of embryology, termed variously a *'physiology of development', a 'causal embryology', or *'developmental mechanics', for example. Roux's propaganda for the latter programme of developmental mechanics, or *Entwicklungsmechanik*, gained widest popularity.

Roux also endorsed August Weismann's (1834–1914) idea that the material of inheritance, the *germ plasm, is passed on intact from parent to offspring. The germ plasm cannot be affected by the parent's life style or *environment, therefore, but provides an immutable material basis for heredity, according to Weismann and Roux. The problem of inheritance thus should centre on the inherited material, study of development focusing on the way that inherited material acts to direct cell divisions constituting development.

Study of development and inheritance centred on the *cell and particularly on the *fertilized egg, recognized by the late 19th century as a single cell. Cytological study revealed the complex processes of somatic cell division, or *mitosis, and cell division producing germ cells, or *meiosis, by 1905. *Chromosomes seemed to provide some sort of preformed information, directing, even if not strictly determining, development. The epigenesis versus preformation issue was, therefore, transformed by the early 20th century into a discussion about qualitative and quantitative cell division and the extent to which cells differentiate independently or dependently, with the help of input from other cells and from the external environment.

In the 1890s, *cell-lineage studies were popular. By the 1910s, various specialized research groups devoted themselves to particular problems in development. For example, Edmund Beecher Wilson (1856–1939) and Theodore Boveri (1862–1915) pursued its cytological aspects, Thomas Hunt Morgan (1866–1945) explored the *genetic contributions to development, and Ross Granville Harrison (1870–1959) and Hans Spemann (1869–1941) attempted to explain how one stage in development gives rise to the next [*induction].

Recently, many geneticists have held that development is actually determined by *genes; thus the egg cell material is developmentally relatively uninteresting. James Watson (*b* 1928) and Francis Crick's (*b* 1916) model of *DNA (1953) strengthened interest in the genetic component of biological development. Yet experiments such as Robert Briggs' (*b* 1911) and Thomas J. King's (*b* 1921) on nuclear transplantation, begun in 1952, have shown that there is a more complex interaction of genetic and egg material than the radical hereditarians might prefer [*cell nucleus; *environmental-heredity controversy]. The *morphological structure, the genetic material, and the internal cellular and the external environment of the developing fertilized egg must all be considered. Although we understand much more than Aristotle about how a seemingly homogeneous egg cell becomes a complex adult, and despite notable contributions by such recent developmental geneticists as Eric Davidson (*b* 1937) and John Gurdon (*b* 1933), the process by which details latent in the germ become translated to adult form remains very little understood.

'Development' also refers to directional change more generally, discussed in *evolution and *evolutionism in man and society.

See also metamorphosis; monsters.

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developmental mechanics. *Entwicklungsmechanik*, or developmental mechanics, refers to Wilhelm Roux's (1850–1924) programme of causal analysis of embryological phenomena. Introducing the term in 1895, Roux consciously rejected the word choices of his contemporaries who also sought to analyze *development in physical or *materialistic terms using experimental methods [*reductionism]. He chose 'mechanics' to emphasize the mechanism of development and rejected the term 'developmental physiology', preferred by several of his contemporaries, in order to include study of form in development, or embryological *morphology, as well as study of function, or *physiology [*form and function].

Roux's *Entwicklungsmechanik* outlined an entire programme for research, designating both subject matter (development) and method (experimental analysis along mechanistic lines). Highly influential as the most widely published programme for the causal study of development, it inspired the growing international community of embryologists in the 1890s.

See also induction (biology); organizer.

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developmental physiology. *See* developmental mechanics.

developmental psychology. *See* cognitive psychology; evolutionism; experimental psychology; Gestalt.

Devil. *See* witchcraft.

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