

CLAUDE BERNARD

The Definition of Life

Ancient Theories and Modern Science

English reading edition

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About this edition

Claude Bernard published this essay in the *Revue des Deux Mondes* on 15 May 1875, third series, volume 9, pp. 326–349. The opening page gives the title *Définition de la vie*; the volume’s contents expand it to *Définition de la vie, les théories anciennes et la science moderne*. This English edition follows the original journal facsimile, using the supplied Wikisource print and frozen page transcriptions as working witnesses. The article was subsequently collected in *La Science expérimentale* (Paris: J.-B. Baillière et fils, 1878), pp. 149–212. Original volume; journal record.

Bernard approaches the definition of life through a history of competing explanations, a defence of experimental science, and an account of nutrition as the continuous destruction and renewal of living matter. His concluding distinction turns on the ordered succession of an organism’s changes: the mind conceives their unity, while physiology investigates the physical and chemical conditions through which they occur. His examples and biological claims belong to the scientific setting of 1875.

The translation preserves the four sections, paragraph divisions and signature. Small bracketed numbers identify the original journal pages. Symbolic footnotes translate retained foreign expressions and provide editorial explanations needed during the reading; their symbols restart in each of the four sections. Supplements S2, S3, S8 and S13 retain longer terminology discussions. The journal article has no authorial footnotes. Important French terms appear in brackets at their first substantive use. *Evolution* and *evolutive* retain Bernard’s vocabulary for an ordered course of formation and change; *development* follows *développement*. Their senses overlap, as the footnote at the first use of “evolution” explains. Quotations are translated from Bernard’s French, including his quotations of authors who wrote in other languages.

Two readable repairs to the printed syntax are identified in footnotes at the affected passages. The working transcription also corrects *qu’ont rencontre* to the journal’s *qu’on rencontre* on p. 347. The companion research files document the witnesses, publication history and comparison with A. R. Macdonough’s 1878 English translation and Ralph H. Virtanen’s later excerpt.

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The Definition of Life

I

[326] From the remotest antiquity, celebrated philosophers or physicians have regarded the phenomena that unfold in living beings as emanating from a higher, immaterial principle acting upon inert and obedient matter. Such was the thought of Pythagoras, Plato, Aristotle and Hippocrates, later accepted by the mystical philosophers and scholars of the Middle Ages, Paracelsus, Van Helmont and the scholastics. During the eighteenth century this conception reached the height of its favour and influence with the celebrated physician Stahl, who gave it a more definite form by establishing *animism* [*animisme*]. Animism was an exaggerated expression of the spiritual nature of life; Stahl was the determined and most dogmatic champion of these ideas, perpetuated since Aristotle. We may add that he was their last representative: the modern mind has not welcomed a doctrine whose contradiction with science had become too evident.

On the other hand, in opposition to these ideas, we find philosophical tendencies anticipating the facts and attempting, even before physics and chemistry had been established and the phenomena of inanimate matter were known, to establish an identity between the phenomena of inorganic bodies and those of living bodies. This conception underlies the atomism of Democritus and Epicurus. The atomists recognise no moving intelligence; the world moves eternally of itself. They recognise only one kind of matter, whose elements, by virtue of their shapes, possess the ability to attach themselves to one another, form the most varied combinations, and constitute inorganic, lifeless bodies as well as organised beings that live and feel, like animals, or are rational and free, like human beings.

[327] This second hypothesis thus assumed an exclusively materialist form from the outset. Yet, remarkably, the philosophers most firmly convinced of the soul's spiritual nature, such as Descartes and Leibniz, were soon to adopt an analogous view, attributing all perceptible manifestations of vital activity to the operation of inanimate forces. The reason for this apparent contradiction lies in the almost absolute separation they established between soul and body. Descartes gave a metaphysical definition of the soul and a physical definition of life. The soul is the higher principle manifested in thought; life is merely a higher effect of the laws of mechanics. The human body is a machine made of springs, levers, channels, filters, sieves and presses. This machine is made for itself; the soul is added to it to contemplate, as a mere spectator, what takes place in the body, but intervenes in no way in its vital functioning. Physiologically, Leibniz's ideas have much in common with those of Descartes. Like him, he separates soul from body and, although he admits a concordance between them pre-established by God, denies them any reciprocal action. "The body," he says, "develops mechanically, and mechanical laws are never violated in natural movements; everything takes place in souls as though there were no body, and everything takes place in the body as though there were no soul."

Stahl understood the nature of life's phenomena and the relations between soul and body quite differently. In vital acts he rejects every explanation they might share with the mechanical, physical and chemical phenomena of inanimate matter. Himself a celebrated chemist, he attacks with particular force and authority the exaggerations of the physician-chemists or iatrochemists, such as Sylvius de Le Boë, Willis and others, who explained all the phenomena of life through chemical actions: fermentations, alkalinity, acidity and effervescence. He maintains that chemical forces are not merely different from the forces governing life's phenomena: they are antagonistic to them and tend to destroy the living body rather than preserve it. According to Stahl, therefore, there must be a vital force

[*force vitale*] that preserves the body against the action of external chemical forces ceaselessly tending to invade and destroy it; life is the triumph of the vital forces over the chemical forces.* With these ideas Stahl founded *vitalism* [*vitalisme*], but he did not stop there: this was only a first step towards animism. This vital force, he says, which constantly struggles against physical forces, acts intelligently, with a calculated design,^[328] to preserve the organism. Now, if the vital force is intelligent, why distinguish it from the rational soul? Basil Valentine and his disciple Paracelsus had multiplied without measure the existence of intelligent immaterial principles, the *archaei*,[†] which governed the phenomena of the living body. Van Helmont, the most celebrated representative of these doctrines of the archaeus, who combined experimental genius with imagination at its most unrestrained, had conceived a whole hierarchy of such immaterial principles. In the first rank stood the rational and immortal soul, merging into God; next came the sensitive and mortal soul, whose agent was another principal archaeus, itself commanding a host of subordinate archaei, the *blas*. Stahl, who a century later continued Van Helmont's work, simplifies all these conceptions of intelligent principles, governing spirits or archaei. He admits only one soul, the immortal soul, which also governs the body. For him the soul is the very principle of life. Life is one of the soul's modes of functioning, its *life-giving act*. The immortal soul, an intelligent and rational force, directly governs the matter of the body, puts it to work and directs it towards its end. It not only dictates our voluntary acts: it makes the heart beat, the blood circulate, the lungs breathe and the glands secrete. If the harmony of these phenomena is disturbed, if illness occurs, it is because the soul has failed to perform its functions or has been unable to resist the external causes of destruction effectively. Such a doctrine had something strange and contradictory about it, for the action of a rational soul upon vital acts seems to imply conscious direction, whereas the simplest observation teaches us that all the functions of nutrition [*nutrition*][‡]—circulation, secretion, digestion and so forth—are unconscious and involuntary, as though, in the words of a physiologist-philosopher, nature had prudently sought to shield these important phenomena from the whims of an ignorant will.[‡]Stahl's animism was thus marked by an exaggeration that led his successors, if not to abandon it, at least to modify it profoundly.

The ideas of Descartes and those of Stahl had made a deep impression upon science and created two currents that were to reach our own time. Descartes had laid down the first principles and applied mechanical laws to the workings of the human bodily machine; his followers extended and made more precise the mechanical explanations of the various vital phenomena. Among the most celebrated of these iatromechanists, Borelli must be named first, followed by Pitcairn, Hales, Keil and, above all, Boerhaave, whose influence was predominant. For its part, iatrochemistry, which is only one aspect of^[329] Cartesian doctrine, pursued its course and was definitively established with the advent of modern chemistry. Descartes and Leibniz had laid down the principle that mechanical laws are everywhere identical: there are not two mechanics, one for inanimate bodies and another for living bodies. At the end of the last century, Lavoisier and Laplace demonstrated that neither are there two chemistries, one for inanimate bodies and another for living beings. They proved experi-

* **Stahl's opposing forces.** The printed demonstratives *celles-ci* and *celles-là* appear reversed: their normal reference makes chemical forces triumph over vital forces. The translation names the forces explicitly, following the surrounding argument that vital forces preserve the body against chemical destruction. This is a repair to the printed sentence (p. 327). Return to text.

† **Archaei and blas.** *Archaei* is the plural of *archaeus*: a governing principle or spirit in the doctrines Bernard is describing. He uses *blas* here for the subordinate members of Van Helmont's hierarchy. The surrounding sentences explain their assigned roles (p. 328). Return to text.

‡ **Nutrition.** Bernard means the processes by which the organism maintains and renews itself, including circulation, secretion and digestion. Section III analyses nutrition as the interdependence of assimilation and dissimilation. This is broader than taking in food. For the word's history, see supplement S2. Return to text.

mentally that respiration and the production of heat take place in the bodies of human beings and animals through combustion phenomena entirely similar to those occurring during the calcination of metals.

It was around the same period that Bordeu, Barthez and Grimaud distinguished themselves in the Montpellier school. They were Stahl's successors; nevertheless, they retained only the first part of their master's doctrine, vitalism, and repudiated the second, animism. Unlike Stahl, they insist that the principle of life is distinct from the soul; but with him they admit a vital force, a governing vital principle whose unity accounts for the harmony of vital manifestations and which acts outside the laws of mechanics, physics and chemistry.

Vitalism, however, gradually changed its form; the *doctrine of vital properties* marked an important epoch in the history of physiology. In place of the metaphysical conceptions that had prevailed until then, here was a physiological conception seeking to explain vital manifestations through the very properties of the matter composing tissues or organs. Already at the end of the seventeenth century Glisson had designated *irritability* as the immediate cause of the movements of living fibre. Bordeu, Grimaud and Barthez had glimpsed the same idea more or less vaguely. Haller attached his name to the discovery of this motor faculty by making known his memorable experiments on the irritability and sensitivity of the various parts of the body. Yet it was only at the beginning of this century that Xavier Bichat, in a flash of genius, understood that the explanation of vital phenomena must be sought not in a higher immaterial principle but, on the contrary, in the properties of the matter within which those phenomena occur. Bichat certainly did not define vital properties: he assigned them vague and obscure characteristics. As often happens, his genius lay not in discovering the facts but in understanding their meaning, by being the first to advance this general, illuminating and fruitful idea: in physiology, as in physics, phenomena must be related to properties as their cause. "The relation of properties ^[330] as causes to phenomena as effects," he says in the preface to his *General Anatomy*, "is an axiom almost tiresome to repeat today in physics and chemistry; if my book establishes an analogous axiom in the physiological sciences, it will have achieved its purpose." Continuing, he adds: "There are in nature two classes of beings, two classes of properties, two classes of sciences. Beings are organic or inorganic; properties are vital or non-vital; sciences are physical or physiological..."

It is important here, from the outset, to understand Bichat's thought correctly. One might suppose that he would draw closer to the physicists and chemists, since, like them, he places the cause of phenomena in the properties of matter. The opposite happens: Bichat moves away from them and separates himself as completely as possible. The aim pursued in every age by iatromechanists, physicists and chemists has been to establish a resemblance, an identity, between the phenomena of living bodies and those of inorganic bodies. In opposition to them, Bichat lays down the principle that vital properties are absolutely opposed to physical properties. Instead of joining the camp of the physicists and chemists, he therefore remains a vitalist with Stahl and the Montpellier school. Like them, he regards life as a struggle between opposing actions; he accepts that vital properties preserve the living body by restraining the physical properties that tend to destroy it. When death occurs, it is simply the triumph of physical properties over their antagonists. Bichat, moreover, sums up his ideas completely in his definition of life: *life is the sum of the functions that resist death*. In other words, life is the sum of the vital properties that resist physical properties.

This view, which treats vital properties as a kind of metaphysical entity, never clearly defined but opposed to ordinary physical properties, undoubtedly led research into the same errors as the other

vitalist theories. Nevertheless, freed from errors almost inevitable in its time, Bichat's conception remains a conception of genius upon which modern physiology was founded. Before him, philosophical doctrines, whether animist or vitalist, hovered too high above reality and too far from it to provide a fruitful impetus to the science of life; they could only numb it by playing the part of those idle sophisms that formerly prevailed in the schools. Bichat, on the contrary, by decentralising life, embodying it in the tissues^[331] and relating its manifestations to the properties of those same tissues, placed them, if one wishes, under the dependence of a principle still metaphysical, but lower in philosophical dignity and capable of becoming a scientific foundation more accessible to the spirit of inquiry and progress. In a word, Bichat was mistaken, like his vitalist predecessors, about the theory of life; he was not mistaken about physiological method. His glory lies in having founded that method by locating the immediate causes of life's phenomena in the properties of tissues and organs.

Bichat's ideas brought about a profound and universal revolution in physiology and medicine. The anatomical school emerged from them, ardently seeking the explanation of the phenomena of health and disease in the vital properties of healthy and altered tissues. Meanwhile, advances in physical methods and the brilliant discoveries of modern chemistry, casting a vivid light upon vital functions, protested daily against the radical separation and opposition that Bichat, like the vitalists, believed he saw between nature's organic and inorganic phenomena.

Thus, even close to our own time, we find in Bichat and Lavoisier representatives of the two great opposing philosophical tendencies that we discerned in antiquity, at the very origin of science: one seeking to reduce the phenomena of life to the laws of chemistry, physics and mechanics; the other, on the contrary, wishing to distinguish them and place them under the dependence of a particular principle, a special power, whatever name it is given—soul, *archaeus*, *psyche*, plastic mediator, governing spirit, vital force or vital properties. This already ancient struggle is therefore not yet over; but how must it end? Will one doctrine succeed in triumphing over the other and ruling unchallenged? I do not think so. Scientific progress gradually weakens, in equal measure, these first exclusive conceptions born of our ignorance. Since the unknown alone gives them strength, as it disappears the struggles must cease, the opposing doctrines vanish, and the scientific truth that replaces them reign without a rival.

II

We may say of Bichat, as of most great pioneers of science, that his merit lay in finding a formula for the unsettled conceptions of his time. All^[332] his contemporaries' ideas about life, all their attempts to define it, are in a sense merely an echo or paraphrase of his doctrine. Pelletan, a surgeon of the Paris school, teaches that life is the resistance offered by organised matter to the causes that ceaselessly tend to destroy it. Cuvier himself develops the same thought: life is a force that resists the laws governing inanimate matter; death would be simply the return of living matter to the sway of those laws. What distinguishes the corpse from the living body is this principle of resistance, which sustains or abandons organised matter. To give his idea a more striking form, Cuvier presents us with the body of a woman in the radiance of youth and health, suddenly struck by death. "Look," he says, "at these rounded and voluptuous forms, this graceful suppleness of movement, this gentle warmth, these rose-tinted cheeks, these eyes bright with the spark of love or the fire of genius, this face enlivened by flashes of wit or animated by the fire of the passions: everything seems to combine to make her an enchanting being. A moment is enough to destroy this spell: often, without apparent

cause, movement and feeling cease; the body loses its warmth, the muscles sag and reveal the angular projections of the bones; the eyes grow dull, the cheeks and lips livid. These are merely the preludes to more horrible changes: the flesh turns blue, green and black; it attracts moisture, and while one portion evaporates in foul emanations, another flows away in putrid fluid that soon dissipates in its turn. In a word, after a few days nothing remains but a few earthy and saline constituents; the other elements have dispersed into the air and water to enter into other combinations.” “It is clear,” Cuvier adds, “that this separation is the natural effect of the action of air, moisture and heat—in a word, of all external agents—upon the dead body, and that its cause lies in the elective attraction of the various agents for the elements composing it. Yet this body was equally surrounded by them during life; their affinities for its molecules were the same, and those molecules would equally have yielded to them had they not been held together by a force superior to these affinities, which ceased to act upon them only at the moment of death.”

These ideas of contrast and opposition between vital forces and external physicochemical forces, which we encounter in the doctrine of vital properties, had already been expressed by Stahl, but in obscure and almost barbarous language. Set out by Bichat with luminous simplicity and great stylistic charm,^[333] the same ideas captivated and carried all minds with them. Bichat does not merely affirm the antagonism between the two orders of properties that divide nature; in characterising them, he sets them in striking opposition. “The physical properties of bodies,” he says, “are eternal. At creation these properties took possession of matter, which will remain constantly imbued with them throughout the immense succession of centuries. Vital properties, on the contrary, are essentially temporary; inanimate matter, as it passes through living bodies, becomes imbued with these properties, which are then united with physical properties. Yet this is no lasting alliance, for vital properties are by nature liable to exhaustion: time wears them out within the same body. Heightened in early life and remaining, as it were, stationary in adulthood, they weaken and disappear towards its end. It is said that Prometheus, having fashioned some statues of human beings, stole fire from heaven to animate them. This fire is the emblem of vital properties: while it burns, life is sustained; when it goes out, life is extinguished.”

It is solely from this contrast in the nature and duration of physical and vital properties that Bichat deduces all the distinguishing characteristics of living and inanimate bodies, and all the differences between the sciences that study them. Since physical properties are eternal, he says, inanimate bodies have neither a necessary beginning nor a necessary end, neither age nor evolution [*évolution*]; their only limits are those assigned to them by chance. Vital properties, on the contrary, are changeable and of limited duration; living bodies are mutable and perishable; they have a beginning, a birth, a death and successive ages—in a word, an evolution they must traverse.* Since vital properties are constantly at war with physical properties, the living body, the theatre of this struggle, undergoes its vicissitudes. Illness and health are simply the changing fortunes of this combat: if physical properties triumph definitively, death follows; if, on the contrary, vital properties regain their dominion, the living being recovers from illness, heals its wounds, repairs its organism and returns to the harmony of its functions. Nothing similar is observed in inanimate bodies; these remain immutable, like the death they resemble. Hence a profound distinction between the sciences he calls vital and those he calls non-vital. Since physicochemical properties are fixed and constant, the laws of the sciences

* **Evolution and development.** Here *évolution* means an ordered course of formation and change, including an individual's life and, in the following comparison, the history of celestial bodies. Read it in that local sense. “Evolution/evolutive” and “development/develop” preserve Bernard's two word families, whose meanings overlap. See supplement S3 for period usage and etymology. Return to text.

dealing with them are likewise constant and invariable; their effects can be predicted and calculated with certainty. Since vital properties have instability as their essential characteristic, and all ^[334] vital functions admit a multitude of variations, nothing in their phenomena can be predicted or calculated. We must therefore conclude, says Bichat, “that absolutely different laws govern the two classes of phenomena.”

Such, in its broad outlines and consequences, is the doctrine of vital properties, which long dominated the schools despite the just criticisms to which it is open. We shall briefly examine whether the division of phenomena into two great groups, as established by the doctrine of which Bichat became the eloquent defender, is well founded, or whether it is a systematic conception rather than an expression of truth. First, is it true that bodies belonging to inorganic nature are eternal and that living bodies alone are perishable? Might there be between them merely differences of degree whose great disproportion deceives us? The life of an elephant, for example, may certainly seem an eternity compared with that of a mayfly; and when we consider human life in relation to the duration of the cosmic environment we inhabit, it must seem an instant in the infinity of time. The ancients thought in this way: they contrasted the living world, where everything is subject to change and death, with the stellar world, immutable and incorruptible. This doctrine of the incorruptibility of the heavens prevailed until the seventeenth century. The first telescopes then made it possible to observe the appearance of a new star in the constellation of Ophiuchus; this change in the heavens, taking place, as it were, before the observer’s eyes, began to shake the ancient belief: *materiam cœli esse inalterabilem*.[†] Today astronomers are familiar with the idea of a stellar world in continual motion and evolution. “The heavenly bodies have not always existed,” says M. Faye; “they have had a period of formation; they will likewise have a period of decline, followed by final extinction.” The eternity of celestial bodies invoked by Bichat is therefore unreal; they have an evolution like living bodies, a slow evolution when compared with our hurried lives, an evolution embracing a duration out of all proportion to those we are accustomed to consider around us. Moreover, before astronomers knew the laws governing the movements of heavenly bodies, they imagined stellar powers and forces, just as physiologists recognised vital forces and powers. Kepler himself admitted a *governing stellar spirit* through whose influence “the planets follow learned curves through space without striking the stars that pursue other courses, without disturbing the harmony ordained by the divine geometer.”

^[335] If living bodies are not the only bodies subject to the law of evolution, neither is the capacity to regenerate and heal exclusive to them, although it manifests itself more actively in them. Everyone knows that a living organism, when mutilated, tends to reconstruct itself according to the laws of its particular morphology: the wound heals in animal and plant alike, the loss of substance is made good, and the being is restored to its form and unity. This phenomenon of reconstitution, of *redintegration* [*réintégration*], deeply impressed natural philosophers, who dwelt at length on life’s tendency towards individuality, which makes the living being a harmonious whole, a kind of little world within the great one.[‡] When the harmony of the organic structure is disturbed, it tends to re-establish itself. Yet these facts can be explained without invoking a force or vital property at odds with physics. Mineral bodies, indeed, prove to possess the same morphological unity and the same tendency to restore it. Like living beings, crystals have their own forms and particular plan, and

[†] **The matter of heaven.** The Latin *materiam cœli esse inalterabilem* means “that the matter of heaven is unalterable”. Bernard presents it as the proposition answered by observations of change in the heavens. Source: p. 334. Return to text.

[‡] **Redintegration.** *Réintégration* names the restoration of a whole through replacement or repair of its parts. Bernard uses it in the comparison of a repaired crystal with a regenerating organism, and later for the regeneration of tissues. “Redintegration” preserves that recurring technical term; the accompanying language of restoration makes its sense explicit. Sources: pp. 335–336, 342–343. Return to text.

they are susceptible to the disturbing actions of their surroundings. The physical force that arranges crystalline particles according to the laws of an elaborate geometry has results analogous to those of the force that arranges organised substance in the form of an animal or plant. M. Pasteur has reported instances of crystalline healing and reintegration that deserve our full attention. He studied certain crystals and subjected them to mutilations that he saw repaired very rapidly and very regularly. His investigations as a whole show that “when a crystal has been broken at any point and is placed back in its mother liquor, then, while the crystal enlarges in every direction through the deposition of crystalline particles, very active work can be seen taking place upon the broken or deformed part; within a few hours, it has not merely fulfilled the requirements of regular overall growth in every part of the crystal, but has also restored regularity to the mutilated part.” These remarkable instances of crystalline reintegration closely resemble those presented by living beings when they receive a wound of greater or lesser depth. In the crystal, as in the animal, the damaged part heals and gradually resumes its original form; in both cases, the work of tissue re-formation is much more active at that point than under ordinary evolutive [*évolutives*] conditions.

The brief considerations we have just set out, and which we could develop indefinitely, seem sufficient to show that the deep line of demarcation which vitalists have sought to establish between [living bodies and] inanimate bodies with respect to their duration, ^[336] their evolution and the restoration of their form is unfounded.[§] As for the struggle they have supposed between physical forces or properties and vital forces or properties, it expresses a profound error.

The doctrine of vital properties teaches that inanimate bodies possess only one order of properties, physical properties, whereas living bodies possess two kinds, physical and vital properties, constantly struggling, antagonistic and tending to prevail over one another. “During life,” says Bichat, “physical properties, fettered by vital properties, are continually restrained in the phenomena they would tend to produce.” It would follow logically from this antagonism that the more power vital properties acquired and the more they predominated in a living organism, the more its physicochemical properties would be overcome and diminished; conversely, vital properties would appear all the weaker as physical properties grew more powerful. It is precisely the contrary proposition that expresses the truth, and this truth has been demonstrated abundantly by the work of Lavoisier and his successors. Life is fundamentally the image of combustion, and combustion itself is merely a series of chemical phenomena directly linked to manifestations of heat, light and life. Remove oxygen, the agent of combustion, from the atmosphere: the flame immediately goes out, and life immediately stops. If the quantity of the combustion-supporting gas is diminished or increased, vital phenomena, like the chemical phenomena of combustion, will be heightened or reduced in the same proportion. It is therefore not an antagonism that we must see between chemical phenomena and vital manifestations; on the contrary, it is a perfect parallelism, a harmonious and necessary connection. Throughout the whole series of organised beings, the intensity of vital manifestations is directly proportional to the activity of organic chemical manifestations. Evidence presents itself on every side. When a human being or animal is seized by cold, the chemical phenomena of organic combustion first decline; then movements slow, sensitivity and intelligence grow dull and disappear, and torpor becomes complete. On waking from this lethargy, vital functions resume, but always in parallel with the reappearance of chemical phenomena. When life is suspended in a dried infusorian and restored under the influence of a few drops of water, it is not because desiccation has attacked life or vital properties; it is

[§] **The incomplete comparison.** The journal prints a comparison “between mineral bodies”, followed by the example of a maimed animal. The translation supplies “[living bodies and]” to complete the comparison required by this sentence and its preceding argument. The brackets identify the added words. Source: p. 335. Return to text.

because the water necessary for ^[337] physical and chemical phenomena is lacking in the organism. When Spallanzani revived rotifers that had been dried for thirty years by moistening them, he simply caused the physical and chemical phenomena that had ceased for thirty years to reappear in their bodies. The water brought nothing else, neither force nor principle.

How could we understand an antagonism, an opposition, between the properties of living bodies and those of inanimate bodies, when the constituent elements of both are the same? Buffon, in seeking to explain the difference between organised and inorganic beings, had been logical in supposing that the former possessed a special elementary organic substance absent from the latter. Chemistry has completely overturned this hypothesis by proving that all living bodies are formed exclusively of mineral elements borrowed from the cosmic environment. The human body, the most complex of living bodies, is materially constituted by fourteen of these elements. We can readily understand how these fourteen simple substances, uniting and combining in every possible way, can produce infinite combinations and form compounds endowed with the most varied properties. What we could not conceive is that these properties should belong to a different order or essence from those combinations themselves.

In summary, the opposition, antagonism and struggle between vital phenomena and physicochemical phenomena admitted by the vitalist school is an error thoroughly refuted by the discoveries of modern physics and chemistry.

There is more: vitalist doctrine rests not only upon false hypotheses and erroneous facts; by its nature it is contrary to the scientific spirit. In seeking to create two orders of sciences, one for inanimate bodies and the other for living bodies, this doctrine ends quite simply by denying science itself. Bichat, as we already know, lays down the principle that the laws of the physical sciences are absolutely opposed to those of the vital sciences. In the former, everything would be fixed and invariable; in the latter, everything variable and inconstant. The divergence between these two orders of sciences must leave them strangers to one another and render them incapable of lending each other any assistance. This is the conclusion Bichat necessarily reaches. "As the physical and chemical sciences," he says, "were perfected before the physiological sciences, it was thought that the latter could be clarified by associating them with the former; they were confused instead. This was inevitable, for to apply the physical sciences to physiology is to explain the phenomena of living bodies ^[338] by the laws of inert bodies. Now that is a false principle; all its consequences must therefore bear the same stamp." If we now ask what distinguishes this science of living beings, Bichat replies: "It is a science whose laws, like vital functions themselves, admit a multitude of variations; which eludes every kind of calculation; in which nothing can be foreseen or predicted; in which we have only approximations, most often uncertain." These are scientific heresies of such enormity that they would be difficult to understand if we did not see how the logic of a system must inevitably have led to them. To acknowledge that vital phenomena cannot be subject to any precise law or any fixed and determinate condition, and to admit that phenomena so defined constitute a vital science itself characterised by vagueness and uncertainty, is to abuse the word *science* strangely. It seems there is nothing to reply to such reasoning, because it is itself simply the negation and absence of all scientific spirit.

Yet how often have analogous arguments been repeated! How many physicians have professed that physiology and medicine would never be more than half-sciences, conjectural sciences, because the principle of life or the secret nature of diseases could never be grasped! These assertions, which still reach our ears like distant echoes of outworn doctrines, need no longer detain us. Descartes, Leibniz and Lavoisier taught us that matter and its laws do not differ in living and inanimate bodies; they

showed us that there is only one mechanics, one physics and one chemistry in the world, common to all beings in nature. There are therefore not two orders of sciences. Every science worthy of the name is one that, knowing the precise laws of phenomena, predicts them with certainty and masters them when they lie within its reach. Everything outside this character is merely empiricism or ignorance, for there can be neither half-sciences nor conjectural sciences. It is a profound error to believe that in living bodies we must concern ourselves with the very essence and principle of life. We cannot ascend to the principle of anything, and the physiologist has no more to do with the principle of life than the chemist with the principle of the affinity of bodies. First causes elude us everywhere, and everywhere alike we can reach only the immediate causes of phenomena. Now these immediate causes, which are simply the very conditions of ^[339] phenomena, admit a determinism [*déterminisme*] as rigorous in the sciences of living bodies as in those of inanimate bodies.[¶] There is no scientific difference among all the phenomena of nature except the complexity or delicacy of the conditions under which they manifest themselves, making the phenomena more or less difficult to distinguish and specify. Such are the principles that must guide us. We shall therefore conclude without hesitation that the duality established by the vitalist school between the sciences of inanimate and living bodies is absolutely contrary to science itself. Unity reigns throughout its domain. The sciences of living bodies and those of inanimate bodies rest upon the same principles and employ the same methods of investigation.

III

Although vitalist doctrines have succumbed through the essential error of their principle of dualism or antagonism between living and inorganic nature, the problem remains. We must answer this age-old question: what is life? Or again this other question: what is death? For these two questions are closely linked and cannot be separated.

The living being is essentially characterised by *nutrition*. The organic structure is the seat of a perpetual nutritive movement, an internal movement that leaves no part at rest: each part, ceaselessly and without respite, draws nourishment from its surroundings and discharges its wastes and products into them. This molecular renewal eludes direct observation; but since we see the beginning and the end, the entry and departure of substances, we conceive the intermediate phases and picture a current of matter continually passing through the organism, renewing its substance while preserving its form. This movement, which has been called the *vital vortex*, the *material circulus*^{*} between the organic and inorganic worlds, exists in plants as well as animals, is never interrupted, and becomes both the condition and the immediate cause of all other vital manifestations. The universality of such a phenomenon, its constancy and its necessity make it the fundamental characteristic of the living being, the most general sign of life. It will therefore occasion no surprise that some physiologists have been tempted to use it to define life itself.

Yet this phenomenon is not simple; it must be analysed and its mechanism more deeply penetrated, so that we may clarify the idea of life suggested by a superficial examination.^[340] Nutritive movement comprises two distinct but connected and inseparable operations: one by which inorganic matter is fixed or incorporated into living tissues as an integral part, and another by which it separates from

[¶] **Determinism.** Here *déterminisme* concerns the precise conditions under which a phenomenon occurs and can be reproduced or modified experimentally. The immediate context contrasts these accessible conditions with first causes, which Bernard says elude inquiry. The term's force in this passage follows that methodological distinction. Source: pp. 338–339. Return to text.

^{*} **Circulus.** Latin for a circle or circuit. Here the “material circulus” is the circulation of matter between the organic and inorganic worlds; Bernard later speaks of the nutritive *circulus* (pp. 339–340). Return to text.

them and leaves them. This incessant double movement is ultimately a perpetual alternation of *life* and *death*, that is, of the destruction and rebirth of the organism's constituent parts. Vitalists have failed to understand nutrition. Some, imbued with the idea that the essence of life is resistance to death, that is, to physical and chemical forces, naturally had to believe that once a living being had reached its full development [*développement*], it had only to maintain itself in the most stable possible equilibrium by neutralising the destructive influence of external agents. Others, who understood the phenomenon better and appreciated the organism's perpetual transformation, refused to admit that this movement of molecular renewal was produced by the general forces of nature and attributed it to a vital force. Neither group saw that it was precisely organic destruction, brought about under the influence of general physical and chemical forces, that provoked the incessant movement of exchange and thus became the cause of reorganisation.

Acts of organic destruction or disorganisation reveal themselves immediately to us: their signs are evident, burst forth externally and recur with every vital manifestation. Acts of assimilation [*assimilation*] or organisation, on the contrary, remain entirely internal and have almost no phenomenal expression. They preside over an organic synthesis that silently and invisibly assembles the materials later to be expended in life's clamorous manifestations. It is a remarkably important truth to grasp that these two phases of the nutritive *circulus* express themselves so differently: organisation remains latent, while disorganisation has all the phenomena of life as its perceptible sign. Here appearance deceives us, as it almost always does: what we call a phenomenon of life is fundamentally a phenomenon of organic death.

The two factors of nutrition are therefore assimilation and dissimulation [*désassimilation*], in other words, *organisation* and *disorganisation*.[†] Dissimulation always accompanies the vital manifestation. When a movement occurs in a human being or animal, part of the muscle's active substance is destroyed and burnt; when sensitivity and will manifest themselves, the nerves wear out; when thought is exercised, the brain is consumed, and so forth. We may thus say that the same matter never serves life twice. Once an act has been accomplished, the particle of living matter that served ^[341] to produce it no longer exists. If the phenomenon recurs, new matter has lent it assistance. Molecular wear is always proportional to the intensity of vital manifestations. Material alteration is all the deeper or more considerable as life shows itself more active. Dissimulation expels from the depths of the organism substances all the more oxidised by vital combustion as the organs have functioned more energetically. These oxidations or combustions generate animal heat, give rise to the carbonic acid exhaled through the lungs and to various products eliminated through the body's other excretory outlets.[‡] The body wears out, undergoes consumption and loses weight, expressing and measuring the intensity of its functions. Everywhere, in a word, physicochemical destruction is united with functional activity, and we may regard the following proposition as a physiological axiom: *every manifestation of a phenomenon in a living being is necessarily linked to organic destruction*.

Such a law, which links the phenomenon being produced to the matter being destroyed—or, to put it better, to the substance being transformed—contains nothing peculiar to the living world; physical nature obeys the same rule.

[†] **Assimilation and dissimulation.** Bernard uses these for the incorporation and organisation of material, and its breakdown and departure. They are the two interdependent movements of nutrition. His ensuing claims about the consumption of muscle, nerve and brain substance belong to this historical physiological account. See supplement S8 for the word's history. Return to text.

[‡] **Carbonic acid.** The French *acide carbonique* is retained as "carbonic acid". In this historical use, the exhaled gas is carbon dioxide. The TLFi records *acide carbonique* as an older name for *gaz carbonique*, alongside the distinct chemical use for the acid formed with water. Sources: p. 341; TLFi, "carbonique", A, remark. Return to text.

A living being in the fullness of its functional activity therefore does not display the greater energy of a mysterious vital force. It simply presents, within its organism, the full activity of the chemical phenomena of combustion and organic destruction. When Cuvier depicts life blossoming in a young woman's body, he is wrong to believe, with the vitalists, that physical and chemical forces or properties are then subdued or held in check by the vital force. On the contrary, all the physical forces are unleashed, the organism burns and consumes itself more vigorously, and that is precisely why life shines in all its splendour.

Stahl rightly said that physical and chemical phenomena destroy the living body and lead it to death; but the truth escaped him because he failed to see that the phenomena of vital destruction are themselves the instigators and precursors of the material renewal concealed from our eyes deep within the tissues. Indeed, at the same time as combustion phenomena find their brilliant expression in external vital manifestations, the formative process takes place in the silence of vegetative life. Its only expression is itself: it reveals itself solely through the organisation and repair of the living structure. Since antiquity, life has been compared to a torch. Thanks to Lavoisier, this ^[342] metaphor has become a truth in our own day. The being that lives is like the torch that burns: the body wears out, the matter of the torch is destroyed; one shines with a physical flame, the other with a vital flame. For the comparison to be rigorous, however, we would have to conceive a physical torch capable of lasting, renewing and regenerating itself like the vital torch. Physical combustion is an isolated phenomenon, accidental in a sense, having harmonious connections in nature only with itself. Vital combustion, on the contrary, presupposes a corresponding regeneration, a phenomenon of the greatest importance whose principal characteristics remain to be outlined.

The movement of regeneration or organic synthesis presents two principal modes. Sometimes synthesis assimilates the surrounding substance to make nutritive constituents; sometimes it directly forms the elements of tissues from it. Thus, alongside the formation of the immediate products of chemical synthesis, we see phenomena of moulting or histological renewal appear, sometimes continuous and sometimes periodic. The phenomena of regeneration, redintegration and repair exhibited by the adult individual are of the same nature as the phenomena of generation and evolution through which the embryo originally constitutes its organs and anatomical elements. The living being is therefore characterised by both generation and nutrition. These two orders of phenomena must be united and merged: instead of making them two distinct categories, we make them a single act whose essence and mechanisms are entirely alike. In this sense it has rightly been said that *nutrition is simply continued generation*. Organic synthesis, generation, regeneration, redintegration and even healing are aspects of the same phenomenon, varied manifestations of the same agent: the *germ* [*germe*].[§]

The germ is the agent of organisation and nutrition *par excellence*[¶]: it draws surrounding matter towards itself and organises it to constitute the new being. Yet the germ can manifest its organising power only by itself carrying out combustions, acts of organic destruction. That is why, from its

[§] **Germ and cell nucleus.** *Germe* denotes the formative agent in Bernard's account. The next paragraphs connect the primordial germ, the egg cell, and cell nuclei as secondary germs responsible for nutrition and regeneration. "Germ" keeps these connections legible. The account is translated in its historical terms; it should not be read as a modern description of cellular mechanisms. Sources: pp. 342–344, 348–349. Return to text.

[¶] **Par excellence.** French: "above all others" or "pre-eminently". Bernard identifies the germ as the foremost agent of organisation and nutrition (p. 342). Return to text.

origin, it encloses itself within a cell, the egg cell, and surrounds itself there with elaborated nutritive materials called the *vitellus*.¹

The egg cell, thus constituted by the germ and the vitellus, develops the new organism by segmenting and dividing indefinitely into an innumerable quantity of cells, each itself provided with a germ of nutrition. This cellular germ, called the cell *nucleus*, draws towards itself and elaborates around it the ^[343] special nutritive materials destined for the functional combustions of each element of our tissues or organs. When natural or accidental phenomena of reintegration occur—for example, when a severed nerve regenerates and resumes its functions—it is again these cell nuclei which, like the primordial germ from which they derive, divide and multiply to reconstitute new tissues in the adult by repeating identically the processes of embryonic formation.

All these highly varied phenomena of regeneration and organic synthesis have, as we have already said, the distinctive characteristic of being, as it were, invisible externally. From the silence within an incubating egg, one could not suspect the activity unfolding there or the importance of the phenomena taking place; the new being, on emerging, will reveal through its vital manifestations the marvels of this slow and hidden labour.

The same is true of all our functions: each has, so to speak, its organising incubation. When a vital act is produced externally, its conditions have long been assembled in this silent and profound elaboration that prepares the causes of all phenomena. It is important to keep these two phases of physiological work in view. When we wish to modify vital actions, we must reach them during their hidden evolution; once the phenomenon bursts forth, it is too late. Here, as everywhere, nothing happens through a sudden chance event: the events apparently most sudden have had their latent causes. The object of science is precisely to discover these elementary causes so as to modify them and thereby master the subsequent appearance of the phenomena.

In summary, we shall distinguish two great groups of inverse phenomena in the living body: *functional* phenomena, or phenomena of vital expenditure, and *organic* phenomena, or phenomena of vital concentration. Life is maintained through two orders of acts entirely opposed in nature: dissimilative combustion, which wears out living matter in functioning organs, and assimilative synthesis, which regenerates tissues in resting organs. The agents of these two kinds of phenomena are no less different. Vital combustion borrows from outside the general agent of combustion, oxygen, and in its absence the *ferments* whose dissimilative action can intervene in the depths of the organism where air does not penetrate. Organising synthesis, on the contrary, possesses a special agent: the germ properly so called, or the cell nuclei, secondary germs that emanate from it and are distributed throughout all the elementary parts of the ^[344] living body. The conditions of functional dissimilation and those of organic assimilation are likewise separate. The same agents of combustion that wear out the organic structure during life continue to destroy it after death, when the phenomena of regeneration within the organism have ceased. It follows that all functional phenomena accompanied by combustion, fermentation or organic dissociation can occur outside living bodies as well as within them. Thanks to this circumstance, the physiologist can analyse vital mechanisms by means of experimentation. In a mutilated organism, the physiologist artificially maintains respiration, circulation, digestion and so forth, and studies the properties of living tissues separated from the body. In these dislocated parts, muscle contracts, glands secrete and nerves conduct excitations exactly as during life. Yet although tissues isolated from the totality of their organic conditions can still wear

¹ **Vitellus.** Latin for the yolk of an egg. Here it names the nutritive materials surrounding the germ within the egg cell (p. 342). Return to text.

out and function, they can no longer regenerate; their final death consequently becomes inevitable. Phenomena of organic renewal, unlike those of functional combustion, can manifest themselves only within the living body, each in a particular place. No artifice has so far been able to replace this essential condition of the activity of germs: that they occupy their place within the structure of the living body.

If we relied upon the profound differences just indicated to assign combustion and organic regeneration independent vital roles within the body, we would be greatly mistaken, for the two orders of phenomena are so interdependent in the act of nutrition that they are, so to speak, distinct only in thought; in nature they are inseparable. Every living being, animal or plant, can manifest its functions only through the simultaneous exercise of vital combustion and organic synthesis. It is on this ground that the chemical and anatomical schools must meet and be reconciled, for the solution of the physiological problem of life requires their combined contribution.

IV

We have pursued nutrition, the characteristic phenomenon of life, into its innermost manifestations; let us see what conclusion this study can offer towards solving the so often attempted problem of the *definition of life*. If we wished to express that all vital functions are the necessary consequence of organic combustion, we would repeat what we have already stated: *life is death*, the destruction of ^[345] tissues; or we would say with Buffon: life is a minotaur, it devours the organism. If, on the contrary, we wished to emphasise this second aspect of nutrition—that life is maintained only on condition of a constant regeneration of tissues—we would regard life as a *creation* accomplished through a plastic and regenerative act opposed to vital manifestations. Finally, if we wished to encompass both aspects of the phenomenon, organisation and disorganisation, we would approach de Blainville's definition of life: "life is a double internal movement of decomposition, at once general and continuous."^{*} More recently Herbert Spencer has proposed the following definition: "life is the definite combination of heterogeneous changes, both simultaneous and successive." Beneath this abstract definition, the English philosopher seeks above all to indicate the idea of evolution and succession observed in vital phenomena. Such definitions, incomplete as they are, would at least have the merit of expressing one aspect of life. They would not be purely verbal, like that of the *Encyclopédie*, "life is the contrary of death"; or Bécclard's, "life is organisation in action"; or Dugès's, "life is the special activity of organised beings"—which amounts to saying: life is life. Kant defined life as "an internal principle of action." This definition, which recalls Hippocrates' idea, was adopted by Tiedemann and other physiologists. In reality, there is no more an internal principle of activity in living matter than in inanimate matter. The phenomena occurring in minerals certainly depend upon external atmospheric conditions; but the same is true of the activity of plants and cold-blooded animals. If human beings and warm-blooded animals appear free and independent in their vital manifestations, this is because their bodies possess a more perfect mechanism that enables them to produce heat in such quantity that they need not necessarily borrow it from their surroundings. In a word, the spontaneity of living matter is merely a false appearance. There are always external principles, foreign stimuli, that provoke the manifestation of the properties of a matter which remains equally inert in itself.

^{*} **De Blainville's definition.** The journal prints *un double mouvement interne de décomposition*: "a double internal movement of decomposition". Despite "double" and the preceding discussion of organisation and disorganisation, only decomposition is named. The translation preserves this wording; the supplied Wikisource text and the 1878 reprint (p. 199) agree (journal p. 345). Return to text.

We shall limit our quotations here, although we could multiply them indefinitely without finding a single completely satisfactory definition of life. Why is this so? Because, in considering life, we must distinguish the word from the thing itself. Pascal, who knew so well all the weaknesses and illusions of the human mind, observes that true definitions are in reality simply creations of our minds: *definitions of names*, or ^[346] conventions for shortening discourse. Yet he recognises primitive words that are understood without needing to be defined.

Now the word *life* belongs to this class. Everyone understands what is meant when we speak of life and death. It would, moreover, be impossible to separate these two terms or these two correlative ideas, for what lives is what will die, and what is dead is what has lived. When we deal with a phenomenon of life, as with any phenomenon of nature, the first condition is to know it. Its definition can be given only *a posteriori*,[†] as a conclusion summarising a prior study. Yet this is no longer, properly speaking, a definition: it is a view, a conception. Our task, then, is to determine what conception we should form of the phenomena of life today, in the present state of our physiological knowledge.

This conception has necessarily varied with the times and with the progress of science. At the beginning of this century, a French physiologist, Le Gallois, was still publishing a volume of experiments *on the Principle of Life and on the Seat of That Principle*. We no longer search for the seat of life; we know that it resides everywhere, in every molecule of organised matter. Vital properties are in reality found only in living cells; everything else is arrangement and mechanism. Life's infinitely varied manifestations are expressions, combined and diversified thousands upon thousands of times, of fixed and invariable elementary organic properties. It is therefore less important to know the immense variety of vital manifestations that nature seems never able to exhaust than to determine rigorously the properties of the tissues that give rise to them. That is why all the efforts of science today are directed towards the histological study of these infinitesimal beings that harbour the true secret of life.

However far we descend today into the inner workings of the phenomena peculiar to living beings, the question before us is always the same. It is the question posed in antiquity, at the very beginning of science: is life due to a power, a particular force, or is it merely a mode of nature's general forces? In other words, is there in living beings a special force distinct from physical, chemical or mechanical forces? Vitalists have always entrenched themselves behind the impossibility of explaining all life's phenomena physically or mechanically; their opponents have always replied by bringing an increasing number of vital manifestations within well-demonstrated physicochemical explanations. We must admit that the latter have constantly gained ^[347] ground and that, especially in our own time, they gain more and more every day. Will they thus succeed in bringing everything within their theories, or will there remain, despite their efforts, an irreducible *quid proprium* of life?[‡] This is the point to be examined. By carefully analysing all the vital phenomena whose explanation belongs to physical and chemical forces, we shall drive vitalism back into a more circumscribed domain, and one therefore easier to determine.

Of the two orders of nutritive phenomena that essentially constitute life and originate all its manifestations without exception, one—organic destruction or dissimulation—already falls entirely within

[†] **A posteriori.** Latin: "from what comes after"; here, on the basis of prior observation or investigation. Bernard says that a definition can be offered only as the conclusion of a study (p. 346). Return to text.

[‡] **Quid proprium.** The Latin *quid proprium* means something peculiar or proper to a thing: here, what belongs distinctively to life. Bernard returns to the expression when discussing the egg's evolutive property. Sources: pp. 347, 349. Return to text.

chemical actions. These decompositions in living beings are no more or less mysterious than those presented by inorganic bodies. As for the phenomena of organising genesis and nutritive regeneration, at first sight they appear to be of a wholly special vital nature, irreducible to general chemical actions. Yet this too is only an appearance, and to understand them properly we must consider the two aspects they present: an ordinary chemical synthesis and an organic evolution in progress. Vital genesis, indeed, comprises phenomena of chemical synthesis arranged and developed according to a particular order that constitutes their evolution. It is important to separate the chemical phenomena themselves from their evolution, for these are two entirely distinct things. As synthetic actions, these phenomena plainly depend only upon general chemical forces; examining them successively, one by one, demonstrates this clearly. The calcareous materials found in mollusc shells, birds' eggs and mammals' bones are certainly formed according to the laws of ordinary chemistry during the embryo's evolution. Fatty and oily substances are in the same position, and chemistry has already succeeded in artificially reproducing in the laboratory a great many proximate constituents and essential oils that naturally belong to the animal or vegetable kingdom. Similarly, the starchy substances that develop in animals, and that are produced by the union of carbon and water under the influence of sunlight in the green leaves of plants, are thoroughly well-characterised chemical phenomena. If the processes of synthesis are much more obscure for nitrogenous or albuminoid substances, that is because organic chemistry is still too little advanced; it is nevertheless quite certain that these substances are formed through chemical processes within the organisms of ^[348] living beings. Admittedly, it may be said that the agents of organic syntheses—germs and cells—constitute altogether exceptional agents. One could say equally, concerning the phenomena of disorganisation, that ferments too are agents peculiar to living beings. For my part, I think this is a general law: chemical phenomena in the organism are carried out by special agents or processes. Yet that changes nothing in the purely chemical nature of the phenomena taking place and the products resulting from them.

Having examined chemical synthesis, let us turn to organic evolution. The agents of chemical phenomena in living bodies do more than produce chemical syntheses of extremely varied materials: they organise them and adapt them to the morphological construction of the new being. Among these agents of living chemistry, the most powerful and marvellous is unquestionably the egg, the primordial cell that contains the germ, the organising principle of the whole body. We do not witness the egg's creation *ex nihilo*:[§] it comes from the parents, and the origin of its evolutive potential is hidden from us; yet every day science traces this mystery further back. It is through the germ, and by virtue of the kind of evolutive power it possesses, that the perpetuity of species and the descent of beings are established. Through it we understand the necessary relations between the phenomena of nutrition and those of development. It explains the limited duration of the living being, for death must come when nutrition stops—not because food is lacking, but because the being's evolutive sequence has reached its term and the organising cellular impulse has exhausted its power.

The germ also presides over the organisation of the being by forming living substance from the surrounding materials and giving it the characteristics of chemical instability that become the cause of the ceaseless vital movements taking place within it. Cells, secondary germs, preside in the same way over nutritive cellular organisation. These are evidently purely chemical actions; but it is equally clear that the chemical actions through which the organism grows and builds itself are linked and succeed one another with a view to this result: the organisation and growth of the animal or plant individual. There is, as it were, a vital design that traces the plan of each being and each organ. Thus,

[§] **Ex nihilo.** Latin: "out of nothing". Bernard contrasts such a creation with the egg's origin from its parents (p. 348). Return to text.

although each phenomenon of the organism, considered in isolation, depends upon the general forces of nature, taken in succession and as a whole these phenomena appear to reveal a special connection; they seem directed by some invisible condition in the course they follow and the order linking them. The ^[349] synthetic chemical actions of organisation and nutrition therefore manifest themselves as though dominated by an impulsive force governing matter, conducting a chemistry adapted to an end and bringing together the blind reagents of the laboratory in the manner of the chemist. This power of evolution immanent in the ovum that is to reproduce a living being embraces, as we already know, both the phenomena of generation and those of nutrition; both therefore possess an evolutive character that is their foundation and essence.

It is this evolutive power or property, which we confine ourselves here to stating, that alone would constitute the *quid proprium* of life; for it is clear that this evolutive property of the egg, which will produce a mammal, a bird or a fish, is neither physics nor chemistry. Vitalist conceptions can no longer hover over the whole of physiology today. The evolutive force of the egg and cells is therefore vitalism's last stronghold. Yet in taking refuge there, vitalism plainly becomes a metaphysical conception and breaks its last link with the physical world, with physiological science. In saying that life is the guiding idea [*idée directrice*] or the evolutive force of the being [*la force évolutive de l'être*], we simply express the idea of a unity in the succession of all the morphological and chemical changes accomplished by the germ from the origin to the end of life.[¶] Our mind grasps this unity as a conception that imposes itself upon it, and explains it through a force. The error, however, would be to believe that this metaphysical force acts in the manner of a physical force. This conception does not leave the intellectual domain to act in turn upon the phenomena for whose explanation the mind created it; although it emanates from the physical world, it has no reciprocal effect upon it. In a word, the metaphysical evolutive force through which we may characterise life is useless to science, because, being outside physical forces, it can exert no influence upon them. We must therefore separate the metaphysical world from the phenomenal physical world that serves as its basis but has nothing to borrow from it. Leibniz expressed this demarcation in the words we recalled at the beginning of this study; science confirms it today.

In summary, although we can define life by means of a special metaphysical conception, it remains true that mechanical, physical and chemical forces are the sole effective agents of the living organism, and that the physiologist need take account only of their action. We shall say with Descartes: we think metaphysically, but we live and act physically.

Claude Bernard.

[¶] **Guiding idea and evolutive force.** These expressions name the unity conceived in the succession of the germ's changes. Bernard immediately distinguishes this conception from an effective physical cause. "Guiding idea" and "evolutive force" retain that role and the *évolution* word family. See supplement S13 for earlier English renderings. Return to text.

Supplementary notes

S2. Nutrition. Bernard uses *nutrition* for the processes by which the organism maintains and renews itself. Section III analyses this as the interdependence of assimilation and dissimilation. The term therefore includes much more than taking in food. English *nutrition* came through Old French from Late Latin *nūtritiō*, related to Latin *nūtrire*, to nourish or suckle. The American Heritage etymology relates this to the reconstructed Indo-European root *(s)nāu-*, associated with flowing and suckling. The asterisk marks a reconstruction, not an attested word. Sources: pp. 328, 339–344; American Heritage, “nutrition” and its roots appendix, *(s)nāu-*. Return to footnote.

S3. Evolution, evolutive, development. In this essay *évolution* often means the ordered course through which a living being forms, changes and reaches its term; Bernard also applies the word to celestial bodies. “Evolution” should therefore be read in its local context. The translation retains *evolution* and *evolutive*, and uses *development* or *develop* for the *développement* family. This keeps the two word families visible without making their meanings mutually exclusive. Littré records unfolding and physiological senses of *évolution* and organic growth among the senses of *développement*. The later pages of this essay explicitly connect nutrition, development and evolutive power.

The Latin ancestry of *evolution* is *ēvolūtiō*, from *ēvolvere*, to unroll: *ex-* plus *volvere*, to roll. American Heritage traces *volvere* to reconstructed Indo-European *wel-*, “turn, roll” (its root *wel-*²). *Develop* comes through French *développer* from Old French *desveloper*, with *des-* and *voloper*, to wrap; the dictionary treats the deeper origin of the latter as possibly Celtic. The resemblance of the two unfolding metaphors does not establish a shared derivation. Sources: pp. 333–336, 347–349; Littré, “évolution” and “développement”; American Heritage, “develop” and roots appendix, *wel-*², §7b. Return to footnote.

S8. Assimilation and dissimilation. Bernard describes *assimilation* as the incorporation and organisation of material, and *désassimilation* as its breakdown and departure. “Dissimilation” preserves his paired terminology. His claims about the consumption of muscle, nerve and brain substance are translated as part of his physiological account.

French *assimilation* derives from Latin *assimilātiō* or *assimulātiō*, the making of a likeness; the nutritional application is also documented in medieval Latin. Its relation to *similis*, “like”, leads through American Heritage’s etymology to reconstructed Indo-European *sem-*, “one, together with” (root *sem-*¹). The prefix in *désassimilation* marks reversal or undoing. Etymology helps explain the word’s construction; Bernard’s account establishes its physiological use here. Sources: pp. 340–344; CNRTL, “assimilation”, etymology; American Heritage, “similar” and roots appendix, *sem-*¹. Return to footnote.

S13. Guiding idea and evolutive force. The closing argument gives these expressions a precise role: they express the unity conceived in the succession of the germ’s changes. Bernard immediately separates that conception from an effective physical cause. The translation retains both the image of guidance and the *évolution* word family. Macdonough’s 1878 translation uses “guiding idea” and “evolutive force”; Virtanen’s 1960 excerpt uses “directive idea” and “developmental force”. Those alternatives illuminate the interpretive choice, while the present translation follows the French throughout. Sources: p. 349; A. R. Macdonough, “The Definition of Life”, *Popular Science Monthly Supplement* (1878), p. 523; Ralph H. Virtanen, *Claude Bernard and His Place in the History of Ideas* (1960), p. 73, with its source reference at p. 143, note 30. Return to footnote.