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'The Wisdom of the Body': the Usefulness of Systems Thinking for Medicine

Abstract

An attempt is made to evaluate the application of system thinking to medical problems. Two examples clarify the difference between the atomistic approach and considering the organism as a whole. After elucidation of the roots of system thinking – especially in connection with natural systems – some consequences of the integrative approach for both the theory and the practice of medicine are discussed, as well as its significance for medical education.

Introduction

Practising physicians may, at first encounter, feel rather alien to notions such as 'levels of observation', 'integration' and 'systems theory', and they may question its relevance to their everyday activities in consulting rooms, on hospital wards or on house calls. It is in a step-wise fashion that we shall illustrate the importance of these concepts for the practice of medicine. The steps consist of three successively higher levels of abstraction: first the ordering of observations in general, then the theory of medicine, and finally the practice of medicine. Because we do not wish to lose the attention of practically minded readers before we have reached the level of the practice of medicine, we begin by giving two examples, one from each author. The purpose of these examples is to clarify how closely the daily activities of jobbing physicians relate to the hierarchical categorisation of observational data. We wish to emphasize that the two examples are not mere illustrations, chosen in retrospect from a theoretical point of view, but that these represent archetypes from personal experience that induced us to explore the underlying principles.

Example 1: geriatrics

Only in a few countries geriatrics has developed into an independent specialty. It covers one of the three periods of life: youth, adulthood, and advanced age. Each phase represents a specific combination of elements of behaviour and pathophysiology which pervades the medical problems and the course of illnesses. For geriatrics these basic elements may be summarised as follows.

The initial characteristics are quantitative in the sense that mental and physical performance retain quality but show a limitation of time for the effort needed, which means that the necessity of rest periods should be recognised. With further advance of age, disorders at the level of organs develop according to ordinary patterns, but these disorders may be multiple. In addition, general symptoms may appear that are expressions of reduced integration of the functions of separate organs: reduced sensation of thirst, appetite, regulation of temperature, urinary continence, etcetera. Another important aspect of integration is the early backfiring of disturbed somatic functions to mental functions. The presenting symptoms may consist in disturbed or reduced processes of mentation, which are restored to normal only after effective treatment of somatic disease. Such a course of events cannot be well explained by a unidirectional cause-and-effect mode of thinking, which has led specialisation in medicine to develop according to diseases of organs. In geriatrics a major component of clinical syndromes and of complications during interventions may be the result of a reduced capacity of integrative processes required for the organism to function as a whole. Typical examples are fundamental changes in pharmacological response, and the difficulty in overcoming stressful conditions postoperatively.

Example 2: 'stroke scales'

Not all strokes are equally severe. The eventual outcome is determined not so much by whether the underlying process is infarction or haemorrhage, at least not after the first few days, but by the extent of brain damage. In short, there are mild strokes (small lesions) and severe strokes (large lesions). In clinical trials of interventions aimed at preventing ischaemic stroke in patients at high risk, and particularly with new drugs aimed at limiting the extent of ischemic brain damage within hours after the event, many of which are emerging in the 1990's, it is essential to measure the severity of a stroke in the long term. If, in a secondary prevention trial, only the *number* of subsequent strokes is counted (observation at the level of the *group of individuals*), then a given drug might in reality prevent only small strokes, and the efficacy of the drug might be overestimated. In trials of acute stroke it is even more obvious that the efficacy of the drug has to be measured at the level of the *individual*, because it is not realistic to expect that the stroke will be completely reversed by the drug. At this stage neurologists become divided, that is, in the choice of measures for the severity of stroke.

Intuitively, neurologists often choose the conventional neurological examination as a measure of outcome, because this is what they are used to – though for purposes of diagnosis! For the sake of quantification the neurological examination is codified into a so-called 'stroke scale', consisting of several functions (language, power of each of the four limbs, etcetera), with different values being assigned to each element. There are quite a few of such stroke scales on record (Van Gijn, 1992a), but the similarities are much greater than the differences. The fundamental error underlying the use of stroke scales is the assumption that the state of the individual (as an undivided whole) can be reconstructed from measurements at a lower level, that is, from a variety of elementary functions of the brain (the *divided individual*, or measurement at the level of the *organ*). There are more than echoes of phrenology in this assumption, even apart from the insoluble problem of the weighting and adding up of separate items. The traditional features of the neurological examination give an astonishingly incomplete picture of the individual as a whole. Mood, initiative, speed of thinking, and the ability to do two things at the same time are only some of the essential features of human life that can be severely affected by stroke but are sadly ignored in 'stroke scales' (Van Gijn, 1992b). To put it briefly: a patient is more than the sum of his signs.

The answer is not to add yet more items (of course such ratings are unreliable), but to choose a higher level of measurement, that takes account of all defects at the same time (*integration*). After all, everyday life consists of a multitude of tasks that are integrated and difficult to separate. This applies to something as trivial as putting the refuse sacks on the pavement to be collected. This requires an adequate memory to do it on the right day of the week, the dexterity and visuospatial ability to tie the tops with small pieces of wire, and the power and balance to carry the sacks outside. The level of measurement that is needed for appropriately assessing the severity of stroke is higher than the level of the organ but truly at the level of the person as an *undivided individual*. This implies assessment of activities of daily life (disability scales), or even at the level of social interaction (handicap scales). (WHO, 1980)

Levels of organisation in general

The two examples clearly show that different levels of organisation can be distinguished in natural systems. The hierarchy of biological systems is not limited to groups of individuals, persons, and organs, but extends as far down as subatomic particles and as far up as the entire biosphere (Brody, 1973). The central tenet of systems theory is not only that each level of organisation (for instance a molecule) is made up by elements from a lower level of organisation (atoms in this case), but also that the properties of the compound depend upon the relationships between the constituent elements at the lower level. Because of the complexity of these relationships, the characteristics of complex 'wholes' at higher levels cannot usually be predicted from the observed characteristics of the parts. For instance, it is impossible to predict the stereometric structure of proteins from the properties of the constituent amino-acids, any more than it is to predict the course of a game of soccer from the properties of the 22 players in the two teams, or the behaviour of a mass of people from the usual behaviour of the individuals in the mass. In other words, *the whole is more than the sum of its parts*. This principle is diametrically opposed to that of *reductionism*, which posits that all aspects of complex macro-phenomena can be understood by reference to the properties and interactions of their micro-constituents (Blois, 1988 and Foss & Rothenberg 1988). The systems theory should not be confused with vitalistic holism, which assigns special qualities to life that can never be explained in terms of lower levels of organisation (Wolpert 1992). Systems theory has to do with the degree of complexity and with mutual interactions, not with special qualities outside the realm of conventional science.

System thinking and natural systems

Before discussing systems thinking in relation to the theory of medicine, we should like to show briefly the roots of this method of thought, which dates back to the period of Enlightenment of the 18th century. It is associated with notions of change and progress, and in particular with evolution of knowledge of society, the natural world and the universe. The expansion of knowledge formed an impetus to philosophy to look for general rules along which different objects of great complexity develop and can be better understood. And indeed H. Spencer (1820-1903) published in 1862 his 'First Principles' of a philosophical system explaining how 'an incoherent homogeneity changes to a definite coherent heterogeneity'. At the time Spencer was an influential philosopher, but new fields of knowledge had to be developed before complex systems such as living organisms could be analyzed for characteristics that started with the 'whole' – the system – and led on to integrated and interconnected subsystems.

One hundred years later philosophers such as Von Bertalanffy in 'General Systems Theory' (Von Bertalanffy, 1968) and E. Laszlo in 'The systems view of the world' (Laszlo, 1972) are able to draw on knowledge of disciplines that might be regarded as a kind of basic sciences for the subject of systems theory: cybernetics, information theory, Gestalt psychology (see below), and new chapters in thermodynamics. Systems theory concerns the organisation of matter into a 'whole' or a 'complexity', which is able to perform a task. Complexity exists in two types: open and closed systems. Living organisms are open systems, because of access to energy and matter, and disposal of these in the environment. This flow of energy and matter permits adaptation through self-organizing subsystems, and maintenance of dynamic equilibria aiming at homeostasis. Reasoning led Laszlo to formulate the following characteristics of natural systems:

1. Natural systems are wholes with irreducible properties.

2. Natural systems maintain themselves in a changing environment.
3. Natural systems create themselves in response to the challenge of the environment.
4. Natural systems are coordinating interfaces in Nature's hierarchy.

About the role of the scientist Laszlo stated in his monograph that he '.. concentrates on structure on all levels of magnitude and complexity, and fits detail in the general framework. He discusses relationships and situations, not atomistic facts and events. By this method he can understand a lot more about a great many more things than the rigorous specialist, although his understanding is somewhat more general and approximate. Yet some knowledge of connected complexity is preferable even to a more detailed knowledge of atomized simplicity, even if it is connected complexity with which we are surrounded in nature and of which we ourselves are a part'.

Gestalt psychology: the perception of 'wholes'

Gestalt psychology has contributed to the development of systems theory in medicine, though largely in an indirect fashion. It has been a separate movement in psychology for four decades, from its inception by Wertheimer around 1912, until its incorporation into the mainstream of psychology (Boring, 1950). It has mainly to do with the analysis of perception. It was a reaction against the common conviction, propounded by Wundt, that sensory perception was nothing but a composite of constituent sensations, without integration (the 'sinnlose Und-Verbindung', in Wertheimer's words). This reductionistic concept of perception ('Inhaltpsychologie') prevailed at a time when all things and substances in the universe had been reduced to nothing more than a variety of combinations of less than a hundred elements of the periodic system of Mendeleyev. If the material world worked that way, why not the psychical?

One of the many ancestors of the movement was von Ehrenfels, who explained in 1890 that a square, for instance, has a quality of its own ('Gestaltqualität') that cannot be predicted from the qualities of the four constituent lines. Furthermore, phenomenology was in the air: Hering and Fechner had taken up the tradition established in physiology by Goethe and Purkinje to approach sensation, particularly visual phenomena, by methodical description of 'immediate experience' rather than by mathematical analysis and deductive generalisation.

History has it that Wertheimer first developed his ideas about Gestalt psychology with the aid of a toy stroboscope that he bought while on vacation, in the summer of 1910. Seen movement as produced by stroboscopic phenomena has independent properties: it can be recognised and distinguished from the stationary state, but it cannot defined analytically, in terms of constituent elements. In short, the movement is something in itself, a 'whole'. The Gestalt psychologists (Wertheimer being the founder, but

Köhler and Koffka the most vociferous proponents) also showed the relativity of visual perception: an animal, having learned to choose the larger or the brighter of two objects, would continue to choose the larger or the brighter even when the objects were changed in such a way that he now rejected what before he had preferred. Another example of the autonomous integration of visual perception is the constancy of a perceived object in shape, brightness or hue, despite variations in the angle from which it is regarded, or in the intensity or the colour composition with which it is illuminated.

Gestalt psychology has also contributed to our understanding of patterned behaviour, which integrates responses from the motor system, the autonomous nervous system, and the hormonal system (Weiner, 1992). But its main emphasis was on perception, and it is the origin of what we now call 'pattern recognition', for instance in clinical diagnosis. Pattern recognition is the instantaneous realisation that the patient's presentation conforms to a previously learned picture or pattern of disease (Sackett et al., 1992). It is usually visual (psoriasis, parkinsonism), but it can be auditory (increasing dysarthria in myasthenia gravis), or the pattern may consist of different stimuli: a woman who complains about pins and needles in her hands with a creaking voice evokes in a flash the diagnosis of hypothyroidism, which any of the constituent symptoms would not have done so immediately. Gestalt psychology has learned us that observations at a certain level cannot always be explained in terms of what happened at lower levels: integration of the constituent elements adds an extra dimension.

The integrative approach to the theory of medicine

Excessive fragmentation of medical knowledge seems to be the main cause for difficulties of communication within the profession and between doctors and patients. This obviously results from the extensive specialisation which occurred in knowledge and skills in the past 50 years. The specialisation is in turn the consequence of the means of enquiry by means of 'the' scientific method, which approaches problems along unidirectional cause-and-effect-thinking, aiming at an abstract mathematical description of results obtained by observation or experiment. Laszlo characterises this method as the 'atomistic view' (Laszlo, 1972). This mechanistic view has been very successful for the study of inanimate matter, as testified by the industrial revolution.

For complex questions such as with living matter or organisms the integration of data is necessary but is rarely achieved. The current explosion of knowledge in molecular biology provides an apt illustration of the state of affairs. A mass of highly interesting data has become available, but until now this has contributed little to management of disease, and mainly to classification of disease (Tauber & Sarkar, 1992). The rapid growth of knowledge about the function of different body organs in the second half of the 19th century and the beginning of the 20th century was necessarily associated with a reductionist approach, in which each organ was more or less regarded as an isolated system in its own right. The next step, logical from a present day point of view but a giant step at the time, was the integrative approach, which took into account that different organs are in a constant state of interaction to maintain the individual in a steady state. We shall illustrate this for Sherrington's 'Integrative action of the nervous system', and for the homeostasis of the internal milieu (Starling's and Cannon's 'Wisdom of the body').

Sherrington's 'Integrative action of the nervous system'

Until the 19th century, all movements were thought to be initiated by the conscious brain, or rather, according to Galenic concepts, by an immaterial psychic principle that connected all parts of the body independently of physical structure. In 1833 and in subsequent years, Marshall Hall evoked 'reflex action' in limbs of decapitated animals. Hall fiercely stood up for his views of an independent 'excito-motory system' of the isolated spinal cord, independent from volitional movement and sensation. Not unexpectedly, the opposition was equally heated (about his experiments with decapitated tortoises: 'Will they live after they are made soup of?'), and questions of plagiarism were also raised, with regard to earlier work by Prochaska from Prague. The debate continued with different proponents, Pflüger and Lotze being the leading adversaries for and against the 'spinal soul', but gradually the concept took hold that separate segments of the spinal cord could execute reflex movements, independently from other segments of the nervous system (Fearing, 1930).

The notion of the central nervous system as a mere assortment of segmental reflexes was dispelled by the integrationist view of Sherrington (Sherrington, 1906). He emphasized the interaction between different subsystems in the central nervous system, by introducing concepts such as

- *internuncial paths*: these are networks of small interneurons which may be shared by different pathways and which convey, for instance in the spinal cord, the converged input from 'private paths' associated with single receptive points;
- *the final common pathway*: the terminal path to the effector organ, on which the internuncial paths converge in turn;
- *inhibition*: reciprocal innervation of antagonistic muscles, for example flexors and extensors of a hinged joint, at the segmental level;
- *control of reflexes by higher centres*: reflexes can be checked, released or modified by descending influences, volitional (influenced by conscious will) or not.

To put it into Sherrington's own words: 'The integrating power of the nervous system has in fact in the higher animal, more than in the lower, constructed from a mere collection of organs and segments a functional unity, an individual of more perfected solidarity.'

Starling and Cannon's 'Wisdom of the body'

In 1923 E.H. Starling delivered the Harveian Oration to the Royal College of Physicians in London, under the title 'The wisdom of the body'. He emphatically expressed his admiration for William Harvey's 'De motu cordis' (1628) as a fine example of well-planned experiments based on the mechanistic view, which did not fit the mainstream of medical thinking at the time. Harvey was struck by the variable amounts of blood the heart was able to circulate and apparently he suggested this as a subject for further research. About two centuries later Starling was involved with the study of these problems, from which eventually followed 'Starling's law of the heart', which relates the energy of contraction to the diastolic volume of the heart. But the need for energy may be increased 5-10 times, which means delivery of oxygen and calories at the right time and place and which requires the activity of the nervous system to integrate these events. Starling then draws attention to the just emerging field of endocrinology (no hormone is yet chemically identified at the time) as the system for chemical messages, and he defines the objective of the endocrine system as the chemical integration of the body. Starling illustrates this by referring to the work of Cannon, about the secretion of the adrenal medulla in conditions of stress, anger and fear, in the form of an integrated pattern.

W.B. Cannon (1871-1945) was professor of physiology at Harvard Medical School since 1906. In 1932 he published the classic monograph 'The wisdom of the body', with a second and enlarged edition in 1939 (Cannon, 1939). The title was taken from Starling's Harveian oration, 'because the facts and interpretations coincide with those of prof. Starling, and because the facts and interpretations which I shall offer illustrate his view..'. The book is a treatise of physiology using the approach of systems thinking without explicit statement of this term. In his autobiography 'The ways of an investigator' (1945), the chapter entitled 'Some working principles' opens with: 'Our bodies constitute open systems engaged in continuous exchanges with our external environment'. This implied a shift away from the disease model based on the atomistic approach, towards a concept of disruption of dynamic equilibria in integrated systems. These systems strive for restoration (to health), but also through their interconnections they can cause misleading changes elsewhere in the organism.

Obviously Cannon studied integrated processes in action, at the interface of the organism as a whole with the external or internal environment (Traumatic shock, 1923; Bodily changes in pain, hunger fear and rage, 1929). Frequently the subject accentuated the autonomic nervous system, which 'has the task of adjusting the functions of the viscera to the advantage of the organism as a whole.' The introduction of 'the wisdom of the body' starts with the sentence: 'Our bodies are made of extraordinarily unstable material.' After showing that the pulses of energy which elicit responses in muscles and sense organs are minute, he continues: 'The structure itself is not permanent but is continuously broken down by wear and tear of action, and is continuously built up again by processes of repair....' Similarly dynamic systems strive towards reestablishment of the level of equilibrium and constancy. This process was called *homeostasis* by Cannon, because of its character of maintaining the steady state.

The integrative approach to the practice of medicine

The atomistic view of scientific knowledge created a similarly deterministic model of disease based on specific causes leading to morphological or functional abnormalities which have to explain the patterns of illness. It is the approach of an engineer who is confronted with a man-made machine which is out of order, and who consults the blueprint of the design. It cannot be stressed enough that doctors do not possess blueprints of humans, but have at their disposal only a model of how the material part of a human organism functions, constructed in analogy of highly developed mammals, but based on data which frequently were obtained in very reductionistic circumstances. Several fundamental properties of human individuals are not taken into account, such as consciousness, feelings, communications with a highly developed language, suited not only for signals but also for description and argumentation. The atomistic model of disease denies the behavioral factors that are so important for the concept of health.

Somatisation disorders and the failure of medical reductionism

Ideally, the discipline of medicine should embrace the entire span of hierarchical levels in the biosphere. After all, physicians consider events that occur at any or all of these levels (Blois, 1988): from gene defects at the molecular level, via disorders at the organ level, e.g. infarction of part of the brain, up to disruptions at the society level, for instance unemployment (Brody, 1973). Traditionally, however, explanations in medicine tend to account for clinical phenomena only in terms of events occurring at lower levels of organisation (Blois, 1988). This standard reductionist view fits in with the hierarchy of the so-called basic sciences: molecular biology, cell biology, histology, pathology, etcetera. The reductionist approach founders most blatantly with disturbances at the supra-individual level (Brody, 1973). The individual is not just a passive battlefield of, for instance, microbes and the immune system or of cancer cells and affected organs, but the disease ('absence of wellbeing') may result from disruption at higher levels, such as that of the family or society. Severe emotional stress by factors in parents such as incest, alcoholism or perhaps even a mere denial of affect, or factors in society such as economic poverty may induce in children an innate but unconscious inability to deal with emotions in an explicit fashion. Whatever the causal chain of events, many patients present to general practitioners and to hospital specialists with chronic, somatic, but emotionally coloured symptoms: backache, headache, muscle fatigue, abdominal pain, rectal pain, etcetera. These symptoms not only lack an obvious cause (that would in itself be a poor definition), but also the somatic complaints are presented against a background of ambivalent behaviour: the expressed wish to perform certain activities (work in a profession or at home) and yet not being able to, and also the passivity of being dependent on others, mixed with aggressiveness against those who fail to recognise or even to name the disease. 'Atomistic' doctors have been only too willing to provide names: whiplash syndrome, myalgic encephalomyelitis, fibromyositis, or irritable bowel syndrome.

A blindly reductionist approach to chronic symptoms leads to abuse of modern medical technology, resulting in high costs, but not to that alone. Fervid investigation is bound to uncover some minor anatomical or biochemical abnormality (Wulff: 'a normal person is someone who has not been investigated enough'), and 'treatment' of this abnormality by means of an operation or the administration of drugs will inevitably worsen the symptoms. Somatisation of social ills is endangering the system of adequate health care in western countries, unless medical students and physicians are trained in recognising disruptions at higher levels than those dictated by the standard reductionist view. That most patients in waiting rooms do not suffer from gene defects or diseased organs is something medical students should be taught early on, and not something to be kept in the dark until the problem emerges in actual practice.

If symptoms cannot be explained by organic disease and emotional factors are suspected it is sometimes difficult and usually impossible to identify *the* cause or even a set of causes in terms of emotional problems. The predictable but naive reaction of most medical students when first encountering these problems is that at least the soul should be 'taken apart', if such an approach has failed at the somatic level. Dealing with somatisation disorder is even more difficult than recognising it (Goldberg, 1992), but much is gained by taking the symptoms seriously and by preventing iatrogenic damage.

Consequences for medical education

Systems theory having taught new ways of ordering the information we already have and are likely to get in the future, what does this imply for the teaching of medicine? The object of medicine is the patient in relation to his environment, which requires physicians to approach problems of disease not from an atomistic point of view, but from a wide context. But as a result of the explosive growth, after 1940, of the non-clinical sciences that are related to medicine, particularly of biochemistry and molecular biology, the body of medical knowledge has become not a continuous and coherent picture, but a barrel filled with isolated fragments of knowledge, collected from the atomistic point of view. Other than in disciplines such as physics or chemistry, where separate university curricula exist for theoretical knowledge ('scientists') and applied science (engineers), medical graduates are a crossbreed of medical biologists and 'health engineers'.

The science and theory of medicine and the practice of medicine have grown too far apart to justify the continuing existence of a standardised common system of education, at any stage in the continuum of pre-graduate and post-graduate training. The times of physician-scientists such as Mackenzie (1916: 'The soldier's heart') and Wenckebach (±1900: irregularities of heart rhythm) are long gone. The requirements of general knowledge and skills which should be common to all doctors (primary care physicians and specialists alike) have had too small an impact on the content of the curriculum of the medical student. The short term interests of specialised university departments in a faculty of medicine are often in conflict with these long term goals of society. The medical student as a future practitioner suffers from an overdose of compartmentalised specialisation. Preclinical disciplines make up a large part of the curriculum in the first three years; indeed these lay the groundwork for clinical science, but the groundwork could be as effective and solid without the mass of details needed only by the very few – moreover it will be years later when these few need it, at which time the specialised knowledge has to be updated anyway. And clinical specialists tend to put too much emphasis on technological skills necessary for diagnosis and intervention.

Physicians need to draw upon four categories of skills and knowledge to provide adequate management for their patients:

a) A quick and general assessment of the most important functions, based on the first few impressions: level of consciousness, respiration, circulation, mobility, speech, etcetera;
b) History and physical examination, morphological and functional;
c) Knowledge about the role of the patient as an individual in his social context, obtained via communication and via observation of behaviour;
d) Ancillary investigations, selected in the context of the preceding categories of information, aimed at detecting occult abnormalities of structure or of function.

The first three categories of knowledge and skills define what the general physician should be able to know and do before entering on a career in a hospital-based specialty, general practice, or social medicine, and even before starting clinical rotationships in medical subdisciplines. The period of rotationships should be used to practice the basic skills of medicine, not to acquire them, and also to obtain some experience in referral and intervention. Details about disease processes, organs, cells, or molecules that have no obvious connection to observable phenomena do no longer deserve to be part of the general medical curriculum. Evidence exists that appropriate emphasis on the essentials of medicine, that is, history and physical examination, leads to a greatly reduced need for 'specialised' investigations. Such an approach to medical education serves not only to contain costs, but also to save medicine from disintegration.

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