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COMMENTARY

Nutritional biology: a neglected basic discipline of nutritional science

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Abstract On the basis of a scientific-philosophical analysis, this paper tries to show that the approaches in current nutritional science—including its subdisciplines which focus on molecular aspects—are predominantly application-oriented. This becomes particularly evident through a number of conceptual problems characterized by the triad of 'dearth of theoretical foundation,' 'particularist research questions,' and 'reductionist understanding of nutrition.' The thesis presented here is that an interpretive framework based on nutritional biology is able to shed constructive light on the fundamental problems of nutritional science. In this context, the establishment of 'nutritional biology' as a basic discipline in research and education would be a first step toward recognizing the phenomenon of 'nutrition' as an *oecic* process as a special case of an organism–environment interaction. Modern nutritional science should be substantively grounded on ecological—and therefore systems biology as well as organismic—principles. The aim of nutritional biology, then, should be to develop near-universal 'law statements' in nutritional science—a task which presents a major challenge for the current science system.

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The seed that is analyzed will no longer germinate.
(Erwin Chargaff, 1905–2002).

Introduction

The philosophy of science—or the reflection on one's own scientific discipline—constitutes an essential component of enlightened sciences. In the field of nutritional science, only few scientific-philosophical analyses have been brought forth in the past (Doring and Rimbach 2014; Ströhle and Döring 2009a, b, 2010). These have been supplemented by a number of methodological studies in the context of the reductionism debate (Fardet and Rock 2014; Hoffmann 2003; Jacobs and Tapsell 2007; Temple 2002).

As stated elsewhere (Ströhle and Döring 2009a, b, 2010), nutritional science is a biopsychosocial multi-disciplinary field, but not an inter-disciplinary one. In contrast to a multi-disciplinary field, an inter-disciplinary field exhibits additional theories which unify the individual subdisciplines with each other. Evolutionary developmental biology, or in short 'evo-devo,' is an example of such a 'true' inter-discipline. Among others, it unifies population genetics, developmental biology, and ecology (Abouheif et al. 2014; Muller 2007; Noble et al. 2014). The field of nutritional science is still waiting for such an integrative approach. However, the multi-disciplinary field of nutritional science is well suited to contribute to the solution of everyday-life problems, since they are often multifactorial in nature. Hence, the phenomenon of 'nutrition' can—and also should—be analyzed from different perspectives—

taking into account biological, psychological, and sociological aspects. At the same time, it seems necessary as well as legitimate to privilege one of these aspects in an epistemic fashion. The paper at hand focuses on the biological aspects of nutritional science. It deliberately does not take into account nutritional epidemiology, which is an independent and clearly delimited discipline. From a scientific-philosophical perspective, this paper will outline the current state of nutritional science in the field of biology, reveal its conceptional difficulties, and present a basic concept of nutritional biology.

Problem area: *application orientation*

If one takes a look on the historical development of nutritional science, some fundamental discoveries (e.g., identification of essential nutrients) in the nineteenth century and the beginning of the twentieth century can be identified. These discoveries were honored by several Nobel Prizes (Hopkins 1965). Since nutritional science was established and institutionalized as a 'stand-alone' discipline, it focusses mainly on biomedical and hence 'everyday problems.' Therefore, today, research in the field of nutritional science is primarily conducted in a technological as well as an application-oriented fashion. Three major diseases are in the focus of nutritional medical research: diabetes, obesity, and diseases related to the microbiota. This application focus within the field of nutritional science is therefore based on a historical self-limitation, which could of course basically be welcomed. Nevertheless, the self-critical question of whether this application orientation is sufficient to legitimize nutritional science as a genuinely scientific discipline needs to be asked. A necessary follow-up question is, then, whether applied research can profit from a basic-oriented nutritional science. De facto, such a basic-oriented nutritional science only exists marginally. From our viewpoint, the respective discipline—nutritional biology—is suitable to complement the application orientation of nutritional science. In a narrow sense, the aim of nutritional biology is to identify laws of nutrition and to formulate them with as much explanatory and projection potential as possible. Hence, nutritional biology strives for universality. What is more, nutritional biology has a heuristic value, i.e., it can potentially steer nutritional science in an innovative direction.

Problem area: *theoretical foundation*

Furthermore, our analysis shows that currently, nutritional science is marked by a dearth of theoretical foundation. Data 'hunting and gathering'—rather than theory building—is clearly in the focus of attention. This stadium is characteristic of all 'new' sciences; it could, for example, be observed during the beginnings of biology in a similar fashion. At the same time, a look at the historical development of the modern natural sciences also reveals that this limitation can be overcome. Nevertheless, there is currently no sign for the establishment of chairs for 'theoretical nutritional science.' The encouragement of a culture of asking questions about the conceptional foundation of nutritional science would, however, be a first viable step into the direction of a 'mature' science. Nutritional biology already offers concepts to strengthen the theoretical foundation of nutritional science. Simpson and Raubenheimer, for example, put forth the framework of 'nutritional geometry' and tested it empirically (Lee et al. 2008; Raubenheimer et al. 2015). According to this framework, the nutrition choice of living beings is determined by the quantitative ratios between the nutrients; here, the optimization of Darwinian fitness is the most important target.

Problem area: *canonical questions*

The underlying questions of nutritional science often times remain opaque. This might be due to the fact that *ad* hoc or post hoc hypotheses are dominant in the biomedical field. Accordingly, nutritional science does not have a collection of canonical, i.e., *fundamental* questions—which presents a contrast to sciences such as mathematics (David Hilbert: '23 unsolved problems in mathematics'). One of the canonical questions of biology is for example: 'How does a multi-cellular organism develop out of a fertilized egg cell?' Such 'world mysteries' have, as far as we are aware, not been manifested in current nutritional science. In the past, however, nutritional science has both raised fundamental questions and also solved them to a large extent. The function of nutrients, for example, which substantiates its essentiality, is part of today's canonical nutritional science knowledge base. From our viewpoint, elaborating a catalog of questions which builds on the classical understanding of nutritional science would prove helpful for its advancement. After all, 'a good question already provides half an answer.' The following questions should be included: Which nutrients are absolutely essential and why? (current example: McCall et al. 2014). What is the external role of a nutrient in a biosystem? How can the part-whole relation between nutrients, single foods, and dietary patterns be adequately characterized with regard to organismic processes? Nutritional biology, too, can contribute to the elaboration of such canonical questions of nutritional science. Among them are, for example, the questions of how the search for and selection of food 'function' from a neurophysiological point of view and how both change in the course of an individual development, respectively. In addition to these proximate approaches, ultimate approaches are in the focus of nutritional biology. Here, questions from the field of evolutionary biology, for example concerning the adaptability of living beings to changing nutrition environments or the specific modification of a food environment by organisms (‘niche construction’) and its biological consequences in the sense of a coevolution of nature and culture, are studied (Laland et al. 2010; Döring and Ströhle 2015; Rendell et al. 2011).

Problem area: *molecularization*

‘Molecularization’—i.e., the endeavor to reduce phenomena on the organism, individual organ, or tissue level to molecular processes and explain them in terms of biochemistry or molecular biology, respectively—is well advanced in nutritional science, which is in line with the bioscientific mainstream (see Ströhle and Döring 2009a, b, 2010 for an overview). In the field of nutritional science, molecularization is mainly used to create a scientific basis for practical questions. For this purpose, molecular mechanisms are explained in model systems and contextualized with regard to the human nutritional physiology. Hence, molecular nutritional science prefers a *reverse*-translation approach (‘from the model system to humans’). From a methodological point of view, this approach exhibits characteristics of classical micro-reductionism. Consequently, the emergent properties of biotic systems can only be captured in a fragmentary fashion. This is why we propose the utilization of *forward*-translation approaches (‘from humans to the model system’). These approaches aim at first depicting the human nutritional phenotype in a suitable model organism as accurately as possible and then explaining it. A fundamental problem of translational approaches is, however, that in the majority of cases, model suitability can only be assessed after human subject research. This is due to the fact that in the factual sciences, an analogy model is defined as an object x_1, whose essential properties match those of the matter to be represented (x_2). Consequently, only that x_1 which is analogous to x_2 with regard to the properties considered to be essential can serve as a model of x_2. This means that a considerable amount of prior knowledge about the actual object of research—in this case the human being—is necessary to choose the ‘right’ model. However, a model is chosen because the knowledge of the actual object of research—in this case again the human being (Ströhle 2010)—is limited. Another reason is the limited access to the sample in humans for example or any other more practical reasons (e.g., time of development).

Problem area: *abstraction*

Compared to the classical micro-reductionist methodology of molecular nutritional science, nutritional biology is based on a moderate version of micro-reductionism which combines reduction with integration. This is founded on emergent materialism; hence, we—along with others (Mahner and Bunge 1997)—assume that qualitative novelties—i.e., emergent properties—which do not possess any of their components (subsystems) for themselves occur in abiotic and biotic systems. The molecule ‘H_2O,’ for example, displays completely different qualitative properties from its components ‘H_2’ and ‘O’ (e.g., reaction behavior). The same holds true for ‘water,’ which as a system of H_2O molecules displays different properties from a single H_2O molecule (e.g., surface tension). Therefore, in a strict sense, the following can be stated: ‘H_2O’ $\neq$ water. A further example is the enzyme glucokinase in the ß-cells of the exocrine pancreas as a regulator of glucose-controlled insulin release. This cellular function of glucokinase is only achieved via interaction with other cell components. Apart from that, the cellular function of glucokinase does not reveal much about its biochemical function. It is another assumption of emergent materialism that the specific properties of a system—which also include the laws of nature—can only exist as a whole and not independent (Platonism) of the respective system (for details on emergent materialism, see Mahner and Bunge 1997). In other words, there are no laws in cell biology without cells. For this reason, cell biology can as little be completely reduced to biochemistry as the physiology of the digestive tract can be reduced to cell biology (see Fig. 1).

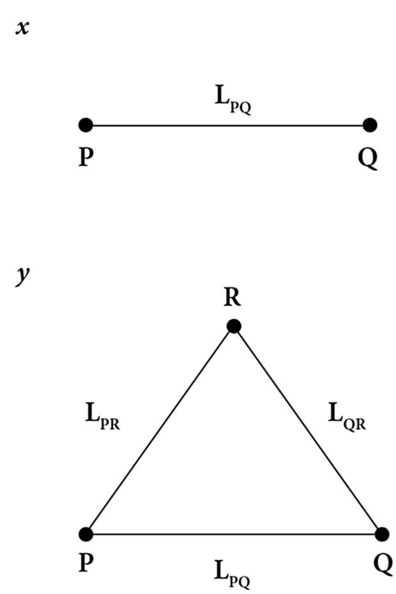

Fig. 1 Emergence of new laws (Mahner 2015)

Based on a moderate version of micro-reductionism (in terms of methodology) and emergentist materialism (in terms of ontology), respectively, phenotype-based *forward*-mechanismic approaches are in the focus of nutritional biology. Among other things, these approaches serve to causally explain universal nutritional phenotypes such as the increase in foraging of starving living beings with the help of classical forward genetics. In the ideal case, such approaches lead to the formulation of laws in nutritional biology. The respective model system, then, does not serve as a *translation model*, but as an *abstraction model*.

Whether the molecular level is indispensable for the formulation of nutritional laws is a question which has been met with skepticism in the field of nutritional biology. According to Sydney Brenner, the cell is the level of abstraction which is suitable (Brenner 2012). In a strict sense, there is no biology below the cellular level, because the cell is the most elementary biosystem. Consequently, the term 'molecular biology' would be an oxymoron—an angular circle. There can be no biology of non-living systems such as molecules, or biology as the science of living systems ceases to be genuine biology (Ströhle 2010). However, this point of view does not exclude that for an analysis of nutritional phenotypes, molecular techniques and biochemical knowledge are helpful to facilitate a deeper understanding of the respective subject area.

Problem area: *ontological foundation*

Ultimately, our analysis reveals that the research object of nutritional science—nutrition—is often described in an implicit fashion. An answer to the question of 'What *is* nutrition?' is presupposed in most cases. Answering this typical ontological question, however, is significant for the self-conception of nutritional science. If nutrition is primarily considered to be a physiological or biochemical process, for example, consequently only physiological and/or biochemical studies should be conducted in nutritional science. From the perspective of nutritional biology, however, nutrition is a specific organism–environment interaction, and thus an *oecic* process which accordingly is to be represented in an ecological fashion. Hence, nutritional biology would be a subdiscipline of ecology, which is traditionally known to be concerned with the analysis of organism–environment interactions.

Conclusion and outlook

While classical nutritional science has both postulated and answered fundamental questions about nutrition, modern nutritional science is primarily concerned with biomedical problems—mostly with regard to the 'molecular dimension' of life. One discernible symptom of this is the exponentially growing torrent of data, which is probably the best indicator for 'molecularization.' The current state of nutritional science is thus comparable to the situation as it has been described for the life sciences as a whole: 'On the one hand, they [the life sciences, authors' note] are more successful than ever: Experimental data, subsidies, public awareness—in all these areas, the life sciences are leading the way. On the other hand, they exhibit a theory deficit, and the lack of integrative concepts increasingly interferes with their otherwise successful research. While new data can still be produced at full speed, its interpretation leads to evermore inconsistencies which cannot be dissolved without an adequate theoretical framework. The reaction to this situation is divided as well: For some, the problem lies in the management as well as an improved visualization of the collected empirical data. The solution to the problem, then, is primarily a consequence of better research organization; ambitious disciplines such as bioinformatics are expected to remedy this. Others, including many bio-informaticians, consider the problem more fundamental, however. These scientists are convinced that a solution to the manifold interpretative problems cannot be found without new theoretical concepts which constitute an adequate interpretive framework for the life sciences' (Laubichler 2005).

The authors of this paper also take the view that the conceptional difficulties of current research in nutrition—characterized by the triad of 'dearth of theoretical foundation,' 'particularist research questions,' and 'reductionist understanding of nutrition'—can only be dissolved with the help of a suitable interpretive framework. General biology has elaborated several proposals which have essentially led to the establishment of a 'systems biology' and a revival of the venerable 'theoretical biology' (Laubichler 2005). In the field of nutritional science, such a development has not yet taken place. From the authors' point of view, the establishment of nutritional biology as a basic discipline would be a first step into the right direction: to consider the phenomenon of 'nutrition' as an *oecic* process in the sense of a special organism–environment interaction.

'Nutritional geometry,' a framework in nutritional biology put forth and tested empirically by Simpson and Raubenheimer, is likely to be groundbreaking for the further development of nutritional research. When teaching nutritional science, nutritional biology is also suitable to provide students with a sustainable theoretical foundation. Of course, an institutionalized study program in nutritional science needs a broader scope than just the nutritional biology perspective. Whether nutritional biology will play a role in future research and teaching, however, is assessed skeptically by the authors, since the current science system tends toward an operationalization of politically correct objectives which are eligible for third-party funding, rewards the mere collection of data, and punishes 'theorizing.' (Zehnpfennig 2015).

A thing *x* (material object) has two properties P and Q, which are lawfully related (related by the law L_{PQ}). A more complex object *y* may consist of some things of the same kind as *x*, but have in addition a new emergent property R. If R is an essential property, it must be lawfully related with either P or Q or both. As a consequence, y must posses at least one new law L_{PR} or L_{QR}, or both.

Compliance with ethical standards

Conflict of interest There is no conflict of interest. There is no financial support from a project sponsors or other third parties.

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