Medicine, Health Care and Philosophy (2018) 21:457–466
https://doi.org/10.1007/s11019-017-9820-z

SCIENTIFIC CONTRIBUTION

From art to science: a new epistemological status for medicine? On expectations regarding personalized medicine

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Published online: 20 December 2017

Abstract
Personalized medicine plays an important role in the development of current medicine. Among the numerous statements regarding the future of personalized medicine, some can be found that accord medicine a new scientific status. Medicine will be transformed from an art to a science due to personalized medicine. This prognosis is supported by references to models of historical developments. The article examines what is meant by this prognosis, what consequences it entails, and how feasible it is. It refers to the long tradition of epistemological thinking in medicine and the use of historical models for the development of medicine. The possible answers to the question "art or science" are systematized with respect to the core question about the relationship between knowledge and action. The prediction for medicine to develop from an 'empirical healing art' to a 'rational, molecular science' is nonsensical from an epistemological point of view. The historical models employed to substantiate the development of personalized medicine are questionable.

Keywords Personalized medicine · Individualized medicine · Epistemology · History of medicine · Medicine as art · Medicine as science · Nomopragmatic · Nomological

Introduction

Current medicine is undergoing a transformation which is predominantly driven by scientific innovation. In this process, personalized medicine—or individualized medicine as it is sometimes called—is attributed a particular status. According to its proponents, important progress is to be found chiefly in this direction. Only systems medicine, which displays identical or similar components, would be able to raise expectations to a comparable level.

Nevertheless, no one is able to reliably predict how personalized medicine will develop from here on out and whether the expansive promises will prove to be justified, even if interventions based on personalized medicine are already being successfully practiced. The future is inherently uncertain. And so are statements regarding the possibility that this expected, and partly promised, progress will indeed occur and whether it will be beneficial to patients. In the same vein, this article does explicitly not intend to predict the extent to which these promises will come to pass.

This essay explores a rather specific prognosis. Among the numerous statements regarding the future development of personalized medicine, a few can be found that accord medicine a new scientific status. A leap in categories is expected to occur. Due to the implementation of personalized medicine, medicine itself is to be transformed from an art to a science. This paper will examine what is meant by this expectation, what consequences it entails, and how feasible it is. Answers to these questions should make a contribution to the issue surrounding the consequences of personalized medicine as well as the scientific status it should reasonably be ascribed with.

The role of expectations

The question about medicine's future scientific status is in no way of purely epistemological interest. It is also about expectations, since they allow for insights into those conditions of medicine that are considered to be shortcomings, as well as into their historical genesis. Expectations allow us to gauge those aspects of medicine which might currently

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be interpreted as negative, or have been interpreted so in the past, and the way medicine is expected to adjust to them. Expressions of expectations point towards and evaluate medicine's past, current and future conditions. They refer to historically grown, influential interpretive (self)-conceptions (Borup et al. 2006; Tutton 2012).

Once expectations gain persuasive power they influence the direction of future efforts "by attracting allies and their resources to support work to realize these visions" (Tutton and Kimberly 2013, p. e184). They also predestine the future to become a self-fulfilling prophecy (Tutton 2012, p. 1722). Not only do expectations establish the categories of future successes, they predetermine their measurability and verifiability. Therefore, expectations about medicine's future scientific status are by no means trivial. Once erroneously derived, a false scientific status might lead to fundamental misunderstandings with far-reaching consequences, such as an assessment of medicine's essential characteristics could be inaccurately assessed, important aspects of what constitutes medical work could be neglected, as well as unreasonable demands be placed upon it. These dangers also apply to expectations regarding personalized medicine.

On terminology

It should be noted that certain terminological ambiguities with regard to personalized medicine exist, which allow for conclusions about associated expectations. The talk is about personalized medicine, individualized medicine, stratified medicine, goal-oriented medicine, customized medicine, precision medicine, or systems medicine. All definitions of these terms differ and are not very precise. It seems to hold true, that "[n]o one can tell what exactly Individualized Medicine is" (Dabrock 2012, p. 11; see also; Abettan 2016). But which term is the most appropriate in light of the current terminological confusion? Schleidgen et al. (2013) have thoroughly examined this discussion and propose the following:

PM [personalized medicine, U.W.] seeks to improve stratification and timing of health care by utilizing biological information and biomarkers on the level of molecular disease pathways, genetics, proteomics as well as metabolomics (p. 1).

According to this definition, the two most commonly used terms are actually gross misnomers: the individual characteristics of human beings are not limited to "biological information and biomarkers". The personal characteristics of human beings—their self-consciousness, their ability to reason and their rationality—are not even mentioned by personalized medicine in its search for molecular biomarkers. Personalized medicine refrains from the use of personal information, such as "psycho- and sociomarkers" (Raspe 2015, p. 97, see also; Abettan 2016). However, at the same time it attempts to be "personalized" by focusing on biomarkers. Not only is this highly counterintuitive and quite "simply labelling fraud" (Borck 2016, p. 180), but, rather alarmingly, it denies human beings the very thing that can rationally be conceived to be their personality (Dabrock 2012). This article uses the term "personalized medicine" only because it has become commonplace. Pragmatism is the sole reason for this, since commonly used terms cannot simply be changed by decree, even if their use is inappropriate.

At the most, personalized medicine uses novel means, but it does not so in pursuit of long established medical goals, i.e. to provide individual and effective help for patients. Tellingly, the FDA introduces its definition of the term 'personalized medicine' by quoting Hippocrates (FDA, p. 5; see also Gadebusch Bondio and Michl 2010; Sykiotis et al. 2005; Yurkiewicz 2010). These goals are unquestionably desirable and this assessment is ultimately based on two elementary ethical principles of medicine: beneficence and non-maleficence.

The history of medicine's scientific status

The prognosis, made in the context of personalized medicine, for medicine itself to develop from an art to a science is not new. It is a classic issue within medical thought. For all of its written history, medical practitioners have asked themselves which epistemological status medicine can lay claim to. The ancient Greek allocation for it to be a τέχνη (téchne, lat.: ars) came progressively under pressure from the seventeenth century onward, with the pressure increasing with the success of the natural sciences (Toellner 1982; Wiesing 1995). After much controversy numerous protagonists adopted the idea for medicine to solely become a natural science during the nineteenth century (Labisch 2000; Toellner 1988, for British medicine see Sadler 1978).

Using a linear historiography of progress, the aim to remodel medicine into a natural science became one of the most influential interpretations of the *entire* history of medicine. In the introduction to his voluminous "Handbook of the History of Medicine" (1903), Max Neuburger started off with a historically all-encompassing statement towards this end:

"Recent medicine is characterized […] by a tendency, clearly emerging from its graduation of evolution […], to by and by replace the art with a solidified science, which bridges the gap between theory and practice not with speculative hypotheses and empirical rules, but with laws of nature" (Neuburger 1903, p. 1).

This quote points to an influential idea, relating to the relationship between theory and practice, as well as knowledge and action. The idea permeates medicine's

self-conception more or less explicitly since at least the mid-nineteenth century and can also be found in our contemporary debates about personalized medicine: the characteristics of the natural sciences are to be transferred to medical practice. The idea of medicine as a science is based on the hopeful assumption that scientific knowledge is capable of influencing medical practice in such a manner as to make it adopt the very same properties, i.e. to be precise and reproducible. Medical practice would rid itself of its oft-lamented uncertainty, because the properties of science would automatically diffuse into it (Wiesing 1995; Toellner 1988, 1993; Labisch 2000). Physicians would gladly act the same way scientists do. By promising a 'rational therapy,' Rudolf Virchow made this idea very explicit:

"Were biology to be complete, were we to know the laws of life and the conditions of their manifestation precisely, were we to know for certain the results of every change in those conditions, we would have a rational therapy and the unity of the medical science would be established. But we are far removed from such knowledge and the dualism between science and art is irresolvable at present" (Virchow 1849, p. 21).

The aspiration for practical medicine to adopt the characteristics of the natural sciences is often re-articulated in the wake of technological developments. "[…] science and art are powerful recurring discourses within medicine often invoked when new technologies are introduced in the clinic" (Tutton 2012, p. 1722; see also; Munson 1981). On that account Komaroff (1982, p. 10) perceived "increasing attempts to transform the 'art' of medical decision-making into a 'science'" during the twentieth century, even before the advent of personalized medicine (see also Grémy 1999).

During the nineteenth century, three ideas were conductive to the conviction that medical practice would benefit from the natural sciences by adopting their properties and becoming equally precise: firstly, all that preceded it was deemed to have been overcome, absurd, or simply false. Within such an ahistorical self-conception, prior history of medicine degenerated into unimportant prehistory (Tsouyopoulos 1982). Secondly, the evolution of medicine could only proceed rationally in one direction. One only had to focus *all* energy on the natural sciences in order to progress swiftly. Thirdly, all other, non-scientific elements of medical practice, such as the not further specified 'medical art', were deemed temporary, at best tolerated, but ultimately surmountable elements that would disappear in the future. Practical medical problems at the bed-side were demoted to temporary pseudo-problems, which could surely be rendered non-existent, were one to focus on the natural sciences. Only limited attention was to be granted to practical medical problems. Such directions diverted the scientific interest away from the clinical practices of physicians. The laboratory, not the bed-side, became the focal point of medical thinking. These developments coincided with power struggles and hierarchical shifts, affecting all medical professions (Sadler 1978). All these effects of attempts to reframe medicine as a natural science can be found in our contemporary literature on personalized medicine as well.

The program to transform medicine from an art to a science was never uncontroversial however. Especially practicing physicians pointed towards the differences between the natural sciences and the practice of medicine. They anticipated great danger for patient care when science-based knowledge improperly influenced medical practice (Gadebusch Bondio and Michl 2010, Toellner 1988; Sadler 1978). The confidence that medicine had found the only appropriate epistemological standard in the natural sciences was soon to be disappointed. Even the increasing attempts referenced by Komaroff (1982) proved unable to satisfy the expectation of medical practice to adopt the properties of the natural sciences. The same is true for our current medical practice, as it remains complex and far removed from the precision of the natural laws. It is constantly characterized by uncertainties and can only be computerized to a limited degree. Nevertheless, even if medical practitioners express justified concerns, even if the practice falls short of the expectations to adopt the properties of the natural sciences, the hope for medicine to become a science is still recognizable today—also in personalized medicine.

Personalized medicine: from art to science?

A search in PubMed for the keywords "personalized medicine", "individualized medicine", "precision medicine", "science" and "art" yields the following particularity: the term with the most hits is "state of the art". This 'state of the art', however, always seems to relate to the development of science. This nomenclature is revealing, especially since the progression of science paradoxically does not lead to a new 'state of the science', but to a new 'state of the art'!

In addition, several authors once again promise an epistemological leap in categories, only now facilitated by personalized medicine: "The increased precision promised by personalized medicine will move the profession from an 'art' to a 'science'" (Cornetta and Brown 2013, p. 311). A report in the journal *Deutsches Ärzteblatt*, quoting a statement made by Regine Kollek, proclaims something similar (Hempel 2009, pp. A 2069–2070): medicine will develop "from an empirical art of healing to a rational, molecular science". The subtitle to Yeh and Kramer's article (2017) reads quite alike: "Moving the Art of Medicine toward Science". Diaz-Rubio (2012, p. 371) also emphasizes the procedural character of this change: "Clinical medicine starts to be a science thanks to […] personalized medicine."

And when art is mentioned, the proponents of personalized medicine attach the term 'still': "Much of medical practice remains semi-empirical. i.e., trial and error: medicine is *still* more an art than a science" (Woodcock 2007, p. 167, emphasis U.W.). The assessment is that the status as an art, which medicine still holds, should be changed as soon as possible and that it can be done so via personalized medicine. Roses (2000, p. 857) also substantiates the temporal transition from art to science, by stating that Sir William Osler "would be re-considering his view of medicine as an art and not a science" (similar to Yeh and Kramer 2017; Diaz-Rubio 2012). Or, more climactically: "Molecular medicine is transforming everyday clinical practice from an art to a rational ortho-molecular science" (Konstantinopoulos et al. 2009, p. 60).

Even if the pair of opposites of art and science is not mentioned, a transformation toward science or a scientific basis is anticipated: personalized medicine "will help transform the scientific basis of therapy" (Woodcock 2007, p. 167). Not only its proponents, but political institutions agree with this position. Without explicitly referencing the question about science or art the White House, within President Obama's initiative on precision medicine, confirmed a transformation: "This is leading to a transformation in the way we can treat diseases such as cancer" (The White House, Office of the Press Secretary 2015, January 30th).

Of course, not all authors promise a transformation from art to science in the context of personalized medicine. Some are more restrained and speak of a "turn with epistemic and ethical implications" (Gadebusch Bondio and Michl 2010, p. A 1063), call for harmony between art and science (Hui et al. 2015), or speak of a merger of the two (Dirette 2016). Apparently, the prediction of medicine transforming from an art to a science due to personalized medicine is contested, even amongst its proponents. This essay now investigates whether the prediction is justified.

No reference to the epistemological discussion

It is noteworthy that the terms in question, science and art, are never defined in any detail in the debate on personalized medicine. The relevant literature also seems ignorant of the thoroughly differentiated and extensive discussion on the epistemological status of medicine (see an overview in Bærøe 2017). Moreover, historical references are wholly absent: it is never mentioned that efforts to transform medicine from an art to a science do actually have a long history and that the promised transformation revives a well-known idea with an age-old tradition.

This unawareness is regrettable because historical knowledge would be helpful for a better understanding: The allocation of meaning to the term art is made complicated by a historical change. Up to the nineteenth century art was an expression for an ancient τέχνη (téchne), a discipline supposed to realize effective actions. "This concept and its Latin equivalent, *ars*, encompassed a broad range of activities—rhetoric as well as carpentry, medicine as well as sculpture" (Schatzberg 2012, p. 556). However, by shifting the focus of the term to 'fine arts', "the term lost its utility in the theoretical discourse on the relationship between knowledge and practice" (ibid). This complicates the discussion even today, because art is often linked only to the properties of the fine arts, but not to a τέχνη (téchne) as opposed to an ἐπιστήμη (épistéme), a discipline producing generalized knowledge only. However, precisely this differentiation between an art as a practical discipline as opposed to a fine art is not part of the discussion about personalized medicine.

But the terms trigger numerous connotations. Art and science are perceived to be a pair of contrasts with nothing in common. Usually, the 'soft' subjects with high communication requirements are ascribed to art (e.g. Sleeman 2013). Art is associated with inaccuracy, intuition, emotion and communication, or with uncertain therapeutic decisions. In contrast, science is associated with predictability, precision, with mathematizability and "toward greater mechanistic understanding of health, disease and treatment" (Woodcock 2007, p. 164), precise justifications for actions, and algorithmic reproducibility.

Historical models of future developments

The predicted transformation from art to science is not only historically a well-known topic. Rather specific historical ideas are linked to this process, such as how medicine actually does proceed over the course of time and how it should do so: science is both the engine of a very fast-paced historical change, as well as the aim of historical changes; science enables progress, at the end of which a transformed medicine as a science awaits. However, the development of science proceeds faster than developments in medicine's other areas. "One could argue that these technologies are advancing so rapidly that what we teach today will be obsolete by the time personalized medicine is in common practice" (Cornetta and Brown 2013, p. 310). These disparate developmental speeds require unusually "aggressive" measures: "Aggressive development of continuing medical education programs to assist physicians in practice is also needed" (ibid).

But there is more: according to the proponents of personalized medicine science does not only develop faster compared to other elements of medicine, it is supposed to accelerate. President Obama's initiative "promises to accelerate biomedical discoveries" (The White House, Office of the Press Secretary 2015). The short statement made by

the White House uses the term "accelerate" three times. The acceleration's potential is said to be immense, since the process has only just begun: "The potential for precision medicine to improve care and speed the development of new treatments has only just begun to be tapped" (The White House, Office of the Press Secretary 2015). Other authors carry the rhetoric of change to an extreme, judging the speed at which medicine is transforming as so high that they change the usual order of past, present, and future: "Personalized medicine in oncology: the future is now" (Schilsky 2010, p. 363).

The rapid progress, predicted and facilitated by personalized medicine, displays a very specific characteristic: to some authors it is deemed to be mandatory, only the speed with which it occurs remaining uncertain. For Lesko (2007, p. 807) there is no doubt that personalized medicine "is the future of medicine, with the only remaining question being how soon it will come about". Woodcock (2007, p. 164) employs a similar rhetoric: the transformation is only logical. "In fact, the concept of 'personalized medicine' is a sort of shorthand used to represent the logical next steps in progression of medical science". According to this statement, the course towards personalized medicine is mandatory. Therefore, everyone, who would suggest something different as the next step violates logics, i.e. a fundamental principle of thought. That is why all efforts to reach the next logical step "cannot come too soon" (Woodcock 2007, p. 169). To put it bluntly: one cannot overstate the acceleration of logical change and there is no speed limit.

If, because of personalized medicine, medicine becomes a science, then art is something temporary, something that has to be overcome, and ultimately it soon will, and should, disappear. So, it is clear that art is medicine practiced due to a lack of knowledge in the face of human diversity; art is the compensation of this lack, a makeshift solution (also see Tutton 2012). Once science becomes successful certain problems and certain academic disciplines will become obsolete. Amongst those is ethics, its obsolescence being caused by medicine's completion. Ethics is only necessary on the journey towards that supposed completion: in a historical development scheme similar to that of Virchow, Konstantinopoulos et al. (2009, p. 61, in part verbatim by Papavassiliou 2010, p. 453) predict: "Nevertheless, in as much as mankind has consciously decided to embark on this bold but wonderful journey to decipher the molecular "secrets" of life, sooner or later the riddles of health and disease will be solved. Until that time, the ethical implications of the advances in molecular medicine must not be underestimated." By the time "the riddles of health and disease will be solved," there will be little if anything left for ethics to do. The development of medicine towards science, according to Konstantinopoulos et al., is a history of completion; "it should only be a matter of time" until "the ultimate standard of care" ({Papavassiliou 2010 #435, p. 453}) will be achieved. Here, something akin to an adventist perspective becomes apparent, a quasi-religious history of redemption, delivering medicine from the necessity of ethics.

Considering the statements made about the historical development of personalized medicine, it becomes clear, that patterns are referenced which are quite familiar from different contexts. It is a history of progress, of acceleration, that is mandatory because it is logical. It is a history of completion, a near religious history of redemption that will ultimately rid medicine of certain practical problems, ending its former history.

However, the texts never address the potential and speed of development for an art. The same applies to the questions whether the art can progress in the context of personalized medicine. For some authors it is sufficient to eliminate art from medicine, although many epistemologists (without referencing personalized medicine) point towards medicine's inevitable future to continue as an art, even given progressive technological developments (e.g. Gadamer 1996, Hofmann 2003; Munson 1981; Wieland 1993).

What does personalized medicine have to offer?

In order to clarify whether the predicted change in medicine's scientific status is realistic, it is necessary to first examine what novel scientific statements and rules personalized medicine would allow for under those conditions. It should be kept in mind that physicians still have to act under the rule of personalized medicine. They cannot exclusively focus on knowledge gain, but, since they are doctors, should attempt to perform their medical duties to the best of their abilities. If personalized medicine were to ignore this, it would practice a kind of therapeutic nihilism, something it certainly does not intend to do. On the contrary, it actually promises advancements in treatment for the benefit of patients. Thus, the question is not if doctors should act as doctors in personalized medicine, but whether and how their actions will be impacted by personalized medicine. Specifically, regarding the change from art to science one should ask: what will change in medicine's knowledge base, and what will change in medical actions? Will they adopt the properties of science?

For this purpose it is appropriate to resort to a distinction made by Mario Bunge (1985). He distinguishes between nomological and nomopragmatic statements as well as technological rules. According to Bunge, nomological statements contain knowledge about law-like correlations. For example: "The hormone insulin reduces blood sugar levels." Nomological statements can be deterministic, in which case they always apply; or they can be probabilistic, meaning they

apply only with a certain probability. They are subject to the criterion of truth. They are by nature general statements and do not refer to specific conditions. In medicine, they are currently being generated in the laboratory, i.e. under artificial, idealized conditions.

Nomopragmatic statements, on the other hand, refer to an action. They relate to an activity, intended to influence, to change something, and, therefore, they differ from nomological statements. For example: "The subcutaneous administration of insulin reduces blood sugar levels." Nomopragmatic statements possess extended meaning compared to nomological statements. If one wants to deduce a nomopragmatic statement from a nomological one, additional information must be considered, because other factors might influence the consequences of an action. This is because actions, especially in medicine, usually interact in a broader context. Additional factors influence the effectiveness insulin has in an organism, and it also has to be determined how the insulin is administered: under the skin, into a muscle, or into a vein. Nomopragmatic statements usually have only statistical validity, since medical interventions rarely produce results with 100% certainty. Therefore, a nomopragmatic statement can have a different probability of success than the nomological statement on which it is based.

Compared to nomological and nomopragmatic statements, a technological rule is not explanatory, but directive and instructive. Something *should* be done. For example: "In case of high blood sugar levels, administer insulin subcutaneously." In this case, too, other information than just a nomopragmatic statement has to be taken into consideration. Other consequences that result from the intervention have to be clarified. Like any other medication, the administration of insulin can have desired and undesired effects. Insulin does not only affect blood sugar levels, but is connected to varying bodily processes, such as the metabolism of fatty tissue, cellular growth, etc. Besides, technological rules always relate to other possible courses of action. In case of high blood sugar levels, numerous alternative treatment options would have to be considered to lower them.

Compared to nomological and nomopragmatic statements, technological rules adhere to different criteria: it is not relevant whether they are true or not, but whether they are applicable in order to achieve a certain goal. They are subject to the criterion of effectiveness. Therefore, they raise very practical questions that go far beyond idealized laboratory conditions: Is the rule reliable and feasible? What other factors play a role? Also, to what extend and under what circumstances can it be put into practice?[1]

The following insight is fundamental for the scientific understanding of personalized medicine, and may prove sobering for some: technological rules can be derived from true nomological and nomopragmatic statements and still prove to be ineffective. "The truth of a law does not guarantee the effectiveness of a technological rule based upon it" (Lukesch 1979, p. 336). Conversely, a highly effective technological rule can be discovered without a nomological and nomopragmatic statement. This might happen, for example, by means of clinical testing of coincidences, via trial and error, or by evaluating doctors' actions. Therefore, nomological statements are "neither necessary nor sufficient conditions for the derivation of technological statements" (Helfrich 2016, pp. 45–46).

But there is more to come. Technological rules are far from determining everything in medical practice. Their application in a specific case is by no means trivial. An additional, quite unique, and more complex step has to be introduced into the medical decision-making process concerning a specific patient. For example: it is a long way from the rule "administer insulin subcutaneously in cases of high blood sugar levels" towards the decision "In this patient and their specific situation I recommend for insulin to be administered subcutaneously". The question to be answered is whether this particular patient falls within range of that technological rule, something the rule itself cannot provide any guidance on. This requires judgment.[2] To that end, the words of Immanuel Kant should come to mind: "judgment cannot always be given yet another rule by which to direct its subsumption (for this would go on for infinity)" (Kant 1996, p. 279).

Even if a patient falls within range of a rule, it is not evident whether it is applicable. Technological rules usually refer to a very specific, isolated state, while patients often suffer from several diseases, which in turn influence the applicability of that technological rule. It has to be determined whether there are intolerances, contraindications, and a specific constitution of the patient as well as other possible influences. Therefore, numerous singular pieces of evidence about a patient have to be considered, and then a decision in the individual case has to be made.

Decisions in individual cases often lack precision, as all findings have to be interpreted. A technological rule and the fact that a patient displays a sign or a condition must be interpreted with regard to their significance in the context of disease and treatment. Moreover, all these findings have to be evaluated in a joint review. Physicians can neither forego

[1] .The distinctions of Bunge have been investigated among others for psychotherapy by Perrez (2011), for pedagogic psychology by Lukesch (1979), for business economics by Helfrich (2016) and for medicine by Sadegh-Zadeh (1980).

[2] On the structures and the difficulties of the implementation in the clinical everyday life see among others Tutton und Kimberly (2013, pp. e184–e185), Wieland (2004).

general laws or rules, nor singular statements, if they wish to successfully perform their work in an individual case.

Besides, medicine does not only draw on the natural sciences for its actions, but on the psychological and social sciences, as well as pedagogy, the communication sciences, even hermeneutics. The knowledge from these disciplines displays very different characteristics. Above all, they are by no means mathematizable. The same is true for singular, individual statements about a patient. Those, too, will have to be continuously acquired by a variety of methods, including those of the natural sciences (e.g. blood tests, X-ray examinations), or those of the humanities (psychoanalytical interviews), or the good old doctor-patient-interviews (anamnesis) (Abettan 2016). Here, too, singular statements about individual patients differ greatly in their characteristics.

If a decision is to be a true individual decision, all these findings have to be considered in an individual case. The example makes clear that in order to get from a nomological statement—"insulin reduces blood sugar levels"—to a therapeutic recommendation in a specific case—"take insulin"—many intermediate steps are necessary. And the character of a medical decision is markedly different from the character of nomological and nomopragmatic statements.

What changes due to personalized medicine?

The key question of this article is now: with regard to an individual case, what changes in the set of statements, rules, and judgments in personalized medicine? And in particular: do the properties of medical actions change? And can we therefore speak of a new epistemological status for medicine?

The most significant benefit of personalized medicine is to be expected for nomological statements, since these will be allowed to be phrased more specifically and in a more differentiated manner. In general, the group of patients a nomological statement applies to will become smaller and more homogenous, because it can be made more precise by new findings at the molecular level.

It is also to be expected that additional and more differentiated nomopragmatic statements will be found. In homogenous groups, the effects of actions can be predicted more precisely. Thus, given a progressing personalized medicine, one may hope for more nomological and nomopragmatic statements and for higher levels of precision.

Technological rules built upon this can also be formulated in a more nuanced manner. Once molecular investigation yields further findings, the results will be more easily predictable, the level of effectiveness will rise, and dosage will be determined more precisely within technological rules. Disruptive elements, which complicated therapeutic decisions beforehand, could be eliminated. An example for this successful strategy is the discovery of non-responders in pharmacotherapy: whenever a molecular factor causes medication to be ineffective, nomological and nomopragmatic statements can be phrased that likely allow for a technological rule to be established. This rule will be more effective than the ones that came before it, because those patients, for whom the medication is known to be ineffective, can now be disregarded. Within the framework of personalized medicine such gradual changes might come to be expected, all of which are highly desirable.

Nevertheless, the fundamental difficulties remain. The path from a nomological to a nomopragmatic statement and then to a technological rule will remain an arduous one. The necessary deductions are by no means either trivial or secure, but have to be re-established and re-evaluated in every individual case. This is because the effectiveness of interventions will continue to be influenced by a multitude of factors. Furthermore, their synergies are often unpredictable and cannot be completely incorporated into a technological rule.

Technological rules will have to continue to be generated from within a group. This group should be quite selective and should continuously be narrowed down by personalized medicine. But the statements stemming from group investigations will remain to be of a statistical nature. A rate of success of 100% will be unlikely, even if the progress of personalized medicine continues.

Also, many individual circumstances of patients will continue to be omitted during the process of phrasing a rule. The fundamental problem according to which rules relate to specific isolated states of being—which in reality never occurs in isolation—will continue to exist. In addition, personalized medicine will not only make use of new, more differentiated nomological and nomopragmatic statements, and possibly new technological rules, but it will continue to rely on the research findings of all kinds of endeavors in the sciences and humanities, provided they are considered useful by medicine. It is, after all, not to be expected that in personalized medicine all other discoveries of the sciences and humanities will prove to be superfluous.

The requirements for the application of a technological rule will remain unaltered; it still has to be determined which patients are subject to the rule in question. In order to reach a practical decision on a course of action, more information is needed than a rule contains. This is especially true for factual individual knowledge about patients. On the one hand this knowledge can become more differentiated, but on the other hand it can still result from all means of knowledge acquisition, not only from the molecular diagnostics: a patient's overall condition, values and preferences, the medical history, other therapeutic options with their own benefits

and side effects for this particular patient, and more, have to be taken into account when it comes to decisions about medical interventions.

In personalized medicine judgment remains an inevitable aspect of medical work. Because the information, whether a patient is subject to a specific rule in light of his individual conditions, cannot be part of the rule itself. Furthermore, personalized medicine's research findings are likely to be of a statistical nature. Actions, however, cannot be realized just to a certain degree (Wieland 1983, p. 39). Still, a hypothesis can be supported as to a certain likelihood, even if it contains a statistical statement. So, here, too, one may expect a gradual specification, but not an entire transformation in the application of rules. The trivialization and full mathematization of medical work is not to be expected.

Once all of this is taken into account, what exactly can be expected for the nature of medical work? Likely, more precise nomological, nomopragmatic statements, and technological rules will be introduces gradually. The overall structure of medical decision-making, however, will not change. The transition from statements to rules and judgments will remain. Thus, it is more than unlikely that medical decisions and the work of the doctor will take on the characteristics of molecular science.

Discussion: from art to science—what is realistic?

The prognosis for personalized medicine to transform the epistemological status of medicine—that art will turn into science—is ambiguous. It can, however, be systematized with respect to the core question about the relationship between knowledge and action. One possibility to understand science is for personalized medicine to focus only on knowledge production but to forgo action, i.e. for it to turn into a discipline only interested in knowledge. But this is impossible. Personalized medicine cannot be reduced purely to the production of scientific knowledge. It has to remain interested in substantiated action, in medical work. Personalized medicine continues to promise that it will foster more effective medical actions. To this extent, the proclaimed transition from an art to a science cannot mean for practical personalized medicine to develop into a purely knowledge-generating discipline.

But what will happen to the unavoidable medical actions in personalized medicine? Will they become science? It is hard to imagine how medical actions can become a "molecular science" even on a categorical level. It is inconceivable for a practical activity to become a science, simply by it employing certain knowledge. The use of findings from the molecular sciences in practical medical work does not make it a molecular science itself. This would be equal to renaming the act of painting a picture to applied color-manufacturing. The prediction for "medicine to develop from an 'empirical healing art' to a 'rational, molecular science'" (Hempel 2009, pp. A 2069–2070), is nonsensical from an epistemological point of view.

It is also based on non-existent antagonisms. The adjectives 'empirical' and 'rational' do not have to be mutually exclusive. Still less, they are not subsequent stages in the progress of medical history. The empirical verification of the effects of medical interventions is a rational process. To not perform it would actually be irrational. If there is one thing that personalized medicine cannot do without, it is the empirical verification of its effectiveness.

Since personalized medicine does not seem to be able to do without intervention, and since these interventions cannot become science, the question remains whether medical work can adopt the characteristics of a science. Will this work be precise, calculable, mathematizable, and predictable? Personalized medicine is likely to have a gradual but not a fundamental impact on medical decision-making and treatment. Should personalized medicine develop as expected, nomological and nomopragmatic statements would become more precise and substantiated, and technological rules should become more differentiated, more precise, and well-founded. Nevertheless, the deduction of a technological rule from nomological and nomopragmatic statements will not be trivialized by personalized medicine. The knowledge bases used by personalized medicine will not be mathematizable as a whole and will continue to have to be interpreted and weighted. Furthermore, the information relevant to medical work cannot simply be found on a molecular level only.

Practical medicine will continue to remain a discipline that is dependent upon the conversion of knowledge into action for its own interventions. The fundamental difficulty of practical medicine remains: How can a physician utilize the results of scientific research for therapeutic practice, if the results of science are so fundamentally different from a physician's actions? This problem will remain in personalized medicine, and that is why the characteristics of knowledge gained by the methods of the natural sciences will not be transferable to the characteristics of practical medical work. A fundamental change in medicine's character, a "transformative change" (Joyner and Paneth 2015, p. 1000), is not to be expected. Nevertheless, medical work can be expected to become gradually more precise and effective. It cannot be overstated that it is definitely a desirable outcome.

The prognosis that "[t]he increased precision promised by personal medicine will move the profession from an 'art' to a 'science'" (Cornetta and Brown 2013, p. 311) is not only unrealistic, but dangerous. It fuels expectations which cannot be met. It promises precision where it simply cannot be gained, and it distributes attention inappropriately: It diverts attention from the challenges of medical

practice. Because it is erroneously assumed to soon change anyway, the structure of medical practice is no longer the focus of attention. The medical art is stylized into a soon-to-be vanquished evil that simply has to be overcome, and is therefore not further dealt with. But the risk lies in the fact that this attitude is unjustified. Instead of awaiting the speedy death of the medical art, another question should be asked: What meaning can this art have in an age of personalized medicine?

The signaled change from art to science is reinforced with reminiscences to visions of historical developments. But medicine's assumed acceleration has to be considered from a more nuanced perspective. An increase in nomological and nomopragmatic statements within the framework of personalized medicine does not necessitate new technological rules and medical decisions at the same rate. It is beyond belief that there is to be only a single relevant, tremendously fast, even accelerating development within medicine. Other aspects of medicine will likely continue to develop. Besides, the historical models employed to substantiate the development of personalized medicine are questionable at best, since they promise developments that would render whole medical fields obsolete. One should refrain from the corollary announcement of a new age, devoid of certain problems. One should also desist arguing on the basis of unrealistic historical models, especially not phantasies of redemption. Historical models are not proof of medicine's future development. The historical sciences themselves very much doubt that history follows logical rules, which we could know and would allow us to predict the future (Schnädelbach 1987; Wiesing 2012). In his work on the structure of scientific revolutions, Thomas Kuhn (2015) demonstrated that science does progress by means of paradigmatic shifts. Shifts that certainly do not always proceed as rational, logical and positive, as many scientists and medical doctors would like them to.

If the trivialization of medical decision-making can be excluded and other imponderable elements remain, the total mathematization of medical work by means of developments in personalized medicine is not something to be reckoned with. In this context, Aristotle's well-known statement could prove to be true: "[F]or it is the mark of an educated mind to expect that amount of exactness in each kind which the nature of the particular subject admits" (Aristotle 1934, p. 1094 b 23–25). The same is true for personalized medicine. The transformation of medical practice from art to science is likely not to occur. However, personalized medicine might actually enable medical doctors to do to a greater extent what they should do anyway: to treat individually and successfully.

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