Phenomics
https://doi.org/10.1007/s43657-021-00037-8

COMMENTARY

Why Do We Care More About Disease than Health?

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Received: 5 September 2021 / Revised: 26 November 2021 / Accepted: 3 December 2021
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Abstract
Modern Western biomedical research and clinical practice are primarily focused on disease. This disease-centric approach has yielded an impressive amount of knowledge around what goes wrong in illness. However, in comparison, researchers and physicians know little about health. What is health? How do we quantify it? And how do we improve it? We currently do not have good answers to these questions. Our lack of fundamental knowledge about health is partly driven by three main factors: (i) a lack of understanding of the dynamic processes that cause variations in health/disease states over time, (ii) an excessive focus on genes, and (iii) a pervasive psychological bias towards additive solutions. Here I briefly discuss potential reasons why scientists and funders have generally adopted a gene- and disease-centric framework, how medicine has ended up practicing "diseasecare" rather than healthcare, and present cursory evidence that points towards an alternative energetic view of health. Understanding the basis of human health with a similar degree of precision that has been deployed towards mapping disease processes could bring us to a point where we can actively support and promote human health across the lifespan, before disease shows up on a scan or in bloodwork.

Keywords Health · Medical care · Genomics · Personalized medicine · Energetics · Preventative medicine

Healthcare or Diseasecare?

Across modern cultures, what we call *healthcare* should, to be strictly accurate, probably be called *diseasecare*. The fabric of modern Western healthcare—a reactive and palliative approach of symptoms management guided by the diagnosis of known disease states—is woven out of three main things: (i) a fundamental lack of understanding of health, (ii) genomic evidence from rare medical disorders generalized to common diseases, and (iii) an unconscious bias that pushes us to fix problems by adding rather than removing (Fig. 1).

The typical healthcare scenario is as follows: a worrisome symptom brings Patient SH, a 52-year-old women, to notice that something is "off" in her body. She consults her healthcare specialist (who actually specializes in disease, more on this later), who performs a careful medical examination and orders the indicated blood tests and a scan. The goal of these tests is to identify or rule out a few suspected differential diagnoses that partially match SH's clinical picture. Thankfully, in this case, the result is quite clear. A set of disease biomarkers unambiguously identify the suspected diagnosis. In this case also, the prescribed solution is simple and effectively implemented within days: a minor surgical procedure and a couple prescription drugs to be taken until her follow up appointment in three months. Secondary medication is also prescribed to counteract the frequent side effects of the primary treatment. The stated goal of this type of care is clear: to get rid of the diagnosed disease. In addition, the success of the treatment is evaluated by the disappearance of the disease biomarkers. This, is modern diseasecare at its best. When it works, it alleviates suffering and significantly prolongs life. Often, however, this form of care produces mitigated results and is unsustainably expensive (Box 1).

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Published online: 28 January 2022

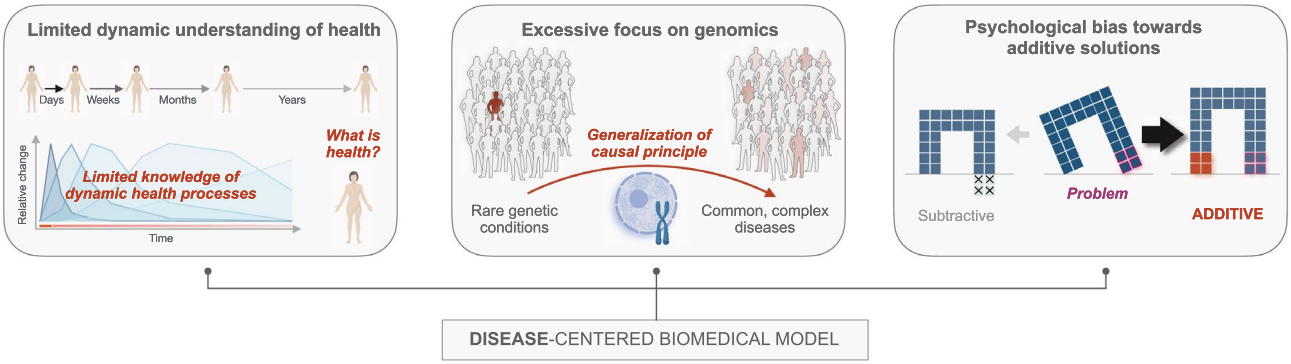

Fig. 1 Three structural factors that contribute to the prevailing disease-centric biomedical model. (Left) The scarcity of dynamic information about important molecular, cellular, physiological, and behavioral factors over short and long time scales occlude our ability to perceive and understand health as a dynamic phenomenon. (Center) The discovery of disease-causing genes for rare disorders provided compelling demonstrations that genetic defects can cause diseases. Generalizing this principle to all common chronic diseases provided the rationale for the hypothesis that genetic differences are at the origin of disparities in disease risk and longevity in the general population. The hypothesis that genomics will explain the source of individual variation in disease risk, longevity, and other health-related outcomes is only partially or not well-supported. In contrast, the alternative hypothesis that risk of disease and longevity are mainly determined by non-genetic, modifiable factors is strongly supported (see text for discussion). (Right) Illustration of the human implicit bias towards additive solutions (Adams et al. 2021). This psychological bias explains why individuals tend to approach and solve problems—including health problems—with additive strategies, rather than with equally effective subtractive strategies

Box 1

Diseasecare is expensive. As one example, in the United States alone, every year, diseasecare costs ~ 4 trillion US dollars—that is 4,000,000 million. Barring any change, this number is expected to grow another 50% by 2028 (National Health Expenditure Data 2020). The majority of this unprecedented budget goes to either detecting diseases (diagnostic tests), treating diseases (surgery and medication), and managing symptoms (medication) caused by diseases and iatrogenic interventions. A negligible fraction of this budget goes towards supporting and promoting health, that is, to prevent disease before it manifests in the first place. The result of this massive spending is not glorious. Despite the unparalleled resources devoted to diseasecare, the US is one of the only developed countries that has seen the lifespan of its people decline over the past 5 years (Venkataramani et al. 2021).

What is Health?

We do not do much to promote health, because we do not know what *health* actually is. By now, we know a fair amount about the molecular features of specific disease states. We have biomarkers with good specificity and sensitivity characteristics for dozens of diseases and disorders. The bulk of the major national and international funder's research portfolio, which largely guides the research focus, is devoted to diseases. This sustained investment aims to produce new knowledge about what goes wrong in common disease states, with the assumption that if we know what goes wrong, we can prevent or reverse it.

But understanding what goes wrong in each disease brings little if any insight into what could be done to prevent the disease in the first place. Examining disease networks has identified target nodes representing shared molecular pathways and vulnerabilities, particularly shared metabolic etiologies (Menche et al. 2015). However, whether and how this information can be practically implemented to promote health before the appearance of disease remains to be established. Perseverating down the same disease-focused path, the newly defined priority items for precision medicine laid out by the NIH leadership emphasize the need to identify additional biomarkers and genetic risk factors for diseases (Denny and Collins 2021). Agenda-setting initiatives rooted in a deep focus on disease.

Our prevailing biomedical paradigm and our science drive the focus of the research agenda. Without a clear scientific model of what health is, and how to study it, it is hard for the academic workforce to research health, let alone for funders to support it.

If not the absence of disease, then what is health? In a recent insightful book, Peter Sterling defines health as the ability to optimally adapt to challenges (Sterling 2020). Simply put, health is the ability to respond to daily situations in the most optimal or efficient way, with the least amount of strain or damage. These challenges are simple things, such as waking up in the morning, climbing stairs, engaging in

mental activity and planning ahead, dealing with inter-personal conflict, eating a different kind of food than usual, or running a couple miles. Health is a property of the person that emerges not just from our biological heritage, but also from a number of interrelated behavioral and psychosocial factors that shapes our biology and mind as we develop and age (Greene and Loscalzo 2017). Growing evidence that personal-history characteristics, psychosocial, and behavioral factors shape health outcomes (Schroeder 2007) and aging trajectories (Elliott et al. 2021) will need to be integrated with genomics to successfully and explicitly refocus our biomedical models towards human health.

A Gene-Based Disease Focus

Where does our excessive focus on disease come from? In part, this is fueled by an excessive focus on genes. Early advances in sequencing technology elucidated the genetic cause of some rare *monogenic* diseases: inherited disorders that can be traced to a single faulty gene. Clinically, discovering that the cause of suffering in a debilitated patient is in fact written in the simple 4-letter genetic code is a deeply satisfying scientific experience. For decades, finding faulty genes explaining disease became the mechanistic holy grail for physician–scientists; and also provided much-awaited answers for many desperate patients. There was a time when finding a new mutation and cloning a gene also could make a scientist's career. As a result, the appeal of the ultimate mechanistic/genetic explanation of rare diseases was gradually stretched, generalized, and applied to all domains of biomedicine, unconsciously pushing our general scientific endeavor to improve human health towards mass genomics. The hot question became: what if *all* human diseases were caused by defective genes? Could all common illnesses, including that which brought Patient SH to consult, be baked into her genome?

This simple *hypothesis*—that genomics would provide answers to all diseases—initially culminated in 2003 when the human genome project was completed (International Human Genome Sequencing Consortium 2004). Since then, fueled by ever-cheaper next generation DNA sequencing (NGS) costs, and the hope to discover simple answers for all complex diseases, other large-scale efforts to sequence as many genomes as possible have been initiated and completed (UK-Consortium et al. 2015). Although these projects have yielded phenomenal resources for biomedical research, they have largely not yielded the expected answers about the causes of human diseases (Moraes and Goes 2016).

Hundreds of risk alleles have been identified. However, mostly, we have learnt that the majority of common illnesses that plague the modern industrialized world are primarily *not* of genetic origin. Even for some rare disease groups, such as amyotrophic lateral sclerosis (ALS) and multiple sclerosis, > 80% of patients have no identifiable genetic cause (Gregory et al. 2020). In other words, across many areas of medicine, the gene-centric hypothesis has not been well supported. Nevertheless, increasingly larger genome-wide association studies (GWAS) continue to unearth genetic variants of increasingly small effect sizes, accounting for fractions of percentages of added disease risk (Vujkovic et al. 2020). GWAS studies involve increasingly large populations, routinely > 100,000 individuals, which allows to identify more variants with smaller effects sizes.

To provide one example, a study combining genotyping data with neuroimaging in > 30,000 healthy adults published in the journal *Nature* reported that "common genetic variants influence human subcortical brain structures" (Hibar et al. 2015). In this case, the proportion of explained variance in brain volume for the strongest hit was 0.52%. Given that naturally occurring volumetric differences in brain regions between individuals are large, and that brain volume is not a direct driver of behavior or neuropsychiatric symptoms, the physiological significance of a half percent of explained variance is rather uncertain. Nevertheless, these types of findings appeal to our implicit desire to explain health and disease disparities through genes. They are a good illustration of *confirmation bias*: we gravitate towards data that support our internal hypotheses. Such findings also are frequently published with acclaim in high-impact journals and, therefore, leave lasting psychological marks—often incommensurate with the effect size of the actual findings—on the scientific community, as well as the lay public.

Following the relatively disappointing GWAS era came genome-wide polygenic risk scores (PRS)—weighted sums of multiple risk alleles in the germline genome that an individual carries. The refined hypothesis is that combining multiple genes/variants together will explain why people get sick. The story is unsurprisingly slightly more compelling. Compared to single-variant approaches, polygenic risk scores account for significantly more variance in the risk of cancer (Mavaddat et al. 2019), depression (Wray et al. 2018), and other common diseases (Khera et al. 2018). However, clinically, there remains gaps in best practices, accurate risk communication, and regulatory frameworks that make it unclear how useful PRS will be to enhance human health (Polygenic Risk Score Task Force of the International Common Disease 2021). Some have argued that the clinical utility of PRS has been overestimated (Curtis 2019) and massively overstated (Sud et al. 2021). With PRS, individuals (predominantly those of European ancestry) can be statistically stratified on their potential risk of developing a disease relative to the average population. But the bottom line is that we still do not know why specific individuals, such as Patient SH, get sick *when* they do. And why others with the

same statistical risk profile manage to remain disease-free for decades? The answer(s) may not be found in the genome.

Why are Genes so Appealing?

Beyond the seductive hypothesis that all human disease may simply be written in the genome and our confirmation bias, there is at least one another reason why genes are so scientifically and economically appealing. If the basis of a specific disease happens to be in a gene, it implies that the resulting protein is at fault. If a protein is at fault, then it has the potential to be druggable (Lindsay 2003). In other words, identifying a disease-causing gene means that a drug with some level of specificity for that faulty protein can be developed, sold, and prescribed to suppress the symptoms of the disease.

This simple pipeline where molecular defects are pharmacologically targeted works strikingly well in the context of some cancers (Vaux 2011), and in *some* rare monogenic disorders. For example, a gene-targeted drug treatment (costing ~ 750,000 - 2,125,000 US dollars (Darrow et al. 2020)) can alters abnormal splicing of the SMN1 gene and practically cure spinal muscular atrophy, a debilitating pediatric neuromuscular disorder (Mullard 2017). However, for most common diseases not primarily written in genes, there has not been a successful pharmacological path to cure. For example, in the case of depression, which stands as one of the most debilitating condition worldwide (Lim et al. 2018), the evidence for genetic etiology is controversial and in most people, antidepressants work similarly well as placebos (Troeung et al. 2013). The same is true for obesity, for which there is still no curative drug, despite decades of investment in the gene–protein–drug pipeline. The financial and public appeal of drugging diseases remains a positive feedback process that reinforces our search for disease-causing genes.

Health is Not Written in Genes

In a recent call to action to realize the promise of personalized medicine, two leading investigators who have been at the helm of large-scale genomic sequencing efforts put it simply: "To provide individual care and prevent disease, we need to go beyond genetics in risk scores and include metrics that follow a person's changing environment and health" (McCarthy and Birney 2021). These metrics include behaviors (e.g., physical activity, nutrition, sleep), psychosocial factors, and environmental exposures. These factors also interact as complex networks with our biology to shape our health and the disorders that bring us to the clinic (Greene and Loscalzo 2017). Combined, modifiable factors account for the majority of disease risk for chronic, non-communicable conditions that threaten people's health in developed countries (Schroeder 2007).

The common complex human diseases and longevity are not simply written in genes. For obesity, all genetic risk alleles combined explain no more than 20% of disease risk (each gene explains on average much less than 1% of someone's risk) (Locke et al. 2015). Among individuals with the worse 10% polygenic risk score for obesity, ~60% of individuals are neither obese nor severely obese (Khera et al. 2019). In the war against cancer, several risk variants were also discovered—genes that when mutated, increase the risk of getting cancer. However, genes do not confer absolute risk: many people with the feared risk variant never actually develop the illness (Mavaddat et al. 2019), and many cancers exhibit no mutations (Versteeg 2014).

And let us consider aging and longevity. The best estimate, from a study of 50 million individuals, taking into account important potential confounds including assortative mating, showed that less than ~7% of how long humans live is genetically inherited (Ruby et al. 2018). The outstanding ~93% is influenced by other factors, such as social circumstances, what we eat, our behaviors, psychobiological processes, and access to medical care (Schroeder 2007). Therefore, the evidence is quite convincing: although some highly penetrant genetic mutations undoubtedly cause devastating diseases, genes do not play a dominant role in common disease risk and longevity.

Humans are Biased Towards Additive Solutions

Why do we persist in the search for disease-causing genes and drugs despite repeatedly failed attempts to identify definitive genetic drivers of common human diseases? Beyond confirmation bias discussed above, our scientific stubbornness may be at least driven by another recently identified fundamental human psychological bias that makes it hard to see alternative solutions.

Humans are biased towards additive solutions. When we face a problem, we can either remove potential causative or irritating factors (*subtractive* solution), or add something in an attempt to mend or palliate the issue (*additive* solution) (see Fig. 1, right). Across a number of contexts, people systematically overlook subtractive solutions (Adams et al. 2021). Instead, we gravitate towards additive solutions even when they are equivalent or even inferior. This pervasive human bias towards additive solutions is undoubtedly reflected in how we think about disease: "What can I *take* to make it go away?". It also aligns with how doctors practice medicine: "Confirm diagnosis X, add/prescribe drugs Y and

Z to the treatment". The alternative *substractive* approach—which will almost certainly seem odd to most reader—would consist in asking something like: "What can I *remove* or *stop* doing to make the disease go away?". The outcome of subtractive approaches could be equally effective as the additive approach, yet we naturally disregard them.

Because this additive bias is unconscious (Adams et al. 2021), it is transmitted (i.e., inherited) in biomedicine down the academic and medical lineages. Thus, like other implicit biases, scientists and doctors biased towards additive solution seamlessly transmit their disregard for subtractive solutions as they train new doctors how to think about diseases, genes, and drugs. Subtractive solutions also cannot be prescribed, placing them at a disadvantage against the additive solution for which orders can be written. Patients alike, biased towards additive solutions to their symptoms and diseases, demand in no uncertain terms drugs to be prescribed to them, reinforcing the search for genes, and the focus on disease.

Who Actually Cares About Health?

So if your doctor and the healthcare industry care primarily about disease rather than health, who actually cares about health? The good news is that a growing portion of the scientific community has begun to recognize that we have largely failed to understand and care for health (see for a few examples: McCarthy and Birney 2021; Yurkovich et al. 2020; Fried et al. 2021; Picard and Sandi 2021). Making explicit this transition from a disease-centric to a health-centric model for research and clinical care has three major implications.

First, knowing that your healthcare professional is actually a diseasecare expert makes them absolutely the best person to consult when something is clearly wrong—no confusion here. However, what about *before one gets sick*? How do we assess someone's health?

It turns out that asking people how healthy they feel—called "self-rated health" or SRH—is the single best predictor of how well someone will do and how long they will live over the next 20–30 years (Idler and Benyamini 1997; Picard et al. 2013). Somehow, people are relatively good at knowing how healthy they are—at least better than their doctor and other objective medical assessments (Jylha 2009). SRH correlates with dozens of blood chemistry markers (Kananen et al. 2021). However, when controlling for these markers, SRH remains a significant predictor of mortality, suggesting that the self-assessment of health may be based in biology, but also transcend purely biological processes to involve subjective, or personal factors (Kananen et al. 2021). Even among terminal metastatic cancer patients with similarly poor prognoses, people who subjectively rate their health as excellent (motivated by a new outlook on life, connectedness with family, etc.) outlive their counterparts with a similar diagnosis and prognosis by more than an order of magnitude (Shadbolt et al. 2002). There is a tremendous research opportunity to understand the nature and value of subjective health experiences, and what this might actually tell us about health states and their underlying biology.

Second, turning our attention to health makes us realize that it is dynamic in a way that genes are not. Health states, including our ability to function and adapt in the world, change over time and are shaped by our responses to environmental exposures, socioeconomic status, developmental stages, psychosocial factors, and behaviors (Mutz et al. 2021). For instance, healthy physiology undergoes remarkable dynamic diurnal changes in temperature, alertness and mood, metabolism, behavior, and even in the size of vital organs (Liu et al. 2021) every 24 hours (Bass and Lazar 2016). Other markers, such as glycemic control (Schussler-Fiorenza Rose et al. 2019), and perhaps also mitochondrial energy production capacity in immune cells (Picard et al. 2018, Rausser et al. 2021), can worsen or improve from day-to-day, week-to-week, and month-to-month. Aging trajectories indexed by epigenetic methylation of nuclear genes (Waziry et al. 2021) or hair greying (Rosenberg et al. 2021) also are modifiable and even reversible. Health and aging are malleable and dynamic.

In comparison, our maternally and paternally inherited germline variants are set at the time of conception, subsequently layered with the accumulation of somatic nuclear and mitochondrial gene mutations. It is widely believed that *de novo* mutations may contribute to some cancers (Vaux 2011), but gene mutations may otherwise have limited specific biological effects (Robinson et al. 2021; Versteeg 2014) and even have anti-neoplastic effects in some contexts (Colom et al. 2021). Therefore, our genes change little over time, and mostly in one direction (accumulating mutations of uncertain significance), yet our health is highly changeable—capable of declining and improving over short and long periods of time.

A direct implication of the dynamic nature of health is that our methods to measure health will have to capture these dynamic states. In the same way that the contractile action of the heart (ECG, electrocardiogram) and neural activity of the brain (EEG, electroencephalogram) are captured as time series of dynamic electrical activity, we need to begin thinking about health as something that can change year-to-year, month-to-month, day-to-day, and maybe even over shorter time frames. Capturing longitudinal information through intensive, repeated, multi-omics measures (Schussler-Fiorenza Rose et al. 2019; Liang et al. 2020) offers exciting possibilities to prospectively capture deviations from an individual's optimal state of health, before the appearance of

disease. This idea aligns closely with the P4 concept of precision medicine, which aims to transform healthcare through *prediction, prevention, personalization of care, and patient participation* (Hood and Friend 2011). Deciphering how we can dynamically capture health at the whole organism level is a serious challenge for current and future generations of biomedical scientists.

Third, from a mechanistic perspective, if genes are not the primary basis of health, then what is? The definition of health as the ability to optimally respond to challenges points to two key properties of living organisms: energy and communication. The *flow of energy* is the quintessential property of life and of our ability to respond to challenges (Picard et al. 2018). Energy is largely derived from subcellular respiration in mitochondria and likely enabled the evolution of multicellular life forms (Lane and Martin 2010). Energy brings our genes to life (literally), pushes blood through every capillary, and sustains all forms of mental and physical activities, including consciousness (Shulman et al. 2009). However, energy must be precisely regulated and directed through communication.

Communication is the exchange of information that enable cells and organs in a healthy body and mind to operate in a coordinated and cooperative manner. In the human body, information exchange occurs through the regulated release of hormones, cytokines, neurotransmitters, and other communication mechanisms. For example, metabolites needed by some vital organs are only produced by other organs, and shared across the organ network through the blood (Jang et al. 2019), illustrating the metabolic interdependency of organs. Similarly in the brain, neurons depend on a metabolic partnership with astrocytes (Magistretti and Allaman 2015), without which they die. In addition, allostatic responses to daily stressors are supported by systemic signaling via steroid hormones produced within mitochondria of endocrine glands (Selvaraj et al. 2018), which travel systemically to influence mitochondria in other cell types, such as the brain, creating an interconnected network of communicating mitochondria (Picard and Sandi 2021). Thus, health depends on the dynamic exchange not only of energy, but also the exchange of information between different parts of the organism.

Because life itself depends on the flow of energy and its organization by communication processes, energy and communication must be central pillars of health. Developing new technologies to capture biometrics that reflect the state of these pillars in people—before they get sick—is a promising avenue to move beyond genomics. To realize the promise of preventative and personalized medicine, we must adopt more holistic mindsets (McCarthy and Birney 2021) and work towards mapping individualized health patterns with sufficient specificity and sensitivity (Yurkovich et al. 2020).

Finally, an energetic view of health suggests that supporting the energetic state of the organism and optimizing biological communication may be viable strategies to promote health. This could explain the health benefits of the most widely recognized *health*-promoting intervention: exercise. Exercise forces the organism to transform more energy, enhancing the number and function of mitochondria through a process called mitochondrial biogenesis (Neufer et al. 2015); and exercise also promotes adaptive communication across the organ network (Murphy et al. 2020). Exercise is a temporary challenge that triggers a coordinated, whole-body response across multiple targets (receptors, cells, organs). Exercise training even optimizes energy efficiency and communication across the body and brain, such that after exercise training, life can be sustained at a lower metabolic cost—more efficiently (Careau et al. 2021). Because energy and communication are the fundamental pillars of health, and because exercise reinforces both of these processes, perhaps we need to look no further to understand why exercise makes people feel better and why it decreases the risk of practically every known common disease and age-related disorder. Although the beneficial effects of exercise have been known for centuries, perhaps a new science of health can use exercise as a successful case study, and extract useful principles to help us tackle the future of healthcare.

The Future of Healthcare

Recent developments are rather cheering. As mentioned above, there are now a growing number of scientists and stakeholders who have started to care about health: explicitly identifying the limitations of genomics (McCarthy and Birney 2021), and carving out cogent plans to move forward towards a holistic, personalized approach to research and healthcare (Yurkovich et al. 2020). As this trend continues to evolve, more resources will be allocated to understand the basis of human health.

Naturally, this new health focus should also re-tune the disempowering public discourse on the primacy of genes in people's health. The new discourse should instead reflect the state of scientific evidence around the large proportions of variance in disease risk (60–90%, depending on the disease) and aging (> 90%) that are attributable to modifiable behavioral, psychosocial, and environmental factors, rather than genetics. Moreover, instead of normalizing and monetizing palliative drug consumption (i.e., once the disease is there, add drug Y to get rid of symptoms), a health-centered model of care should empower individuals and, importantly, provide tangible tools to proactively care for our health.

With forthcoming knowledge about the mechanistic basis of health, we can also envision a new generation of interventions and diagnostic tools that would have a strong

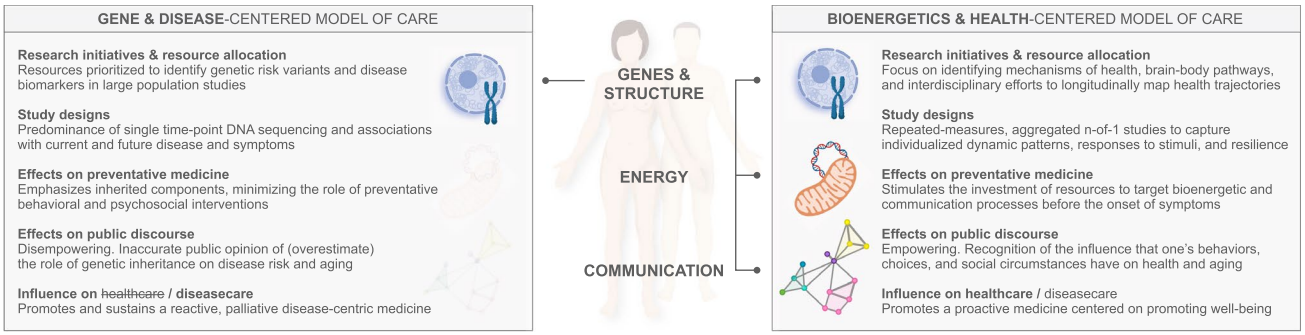

Fig. 2 Summary of the disease-centric and health-centric models of care. The pillars of health are energy and communication, two fundamental principles of living organisms that interact with genes to produce dynamic health states that vary across the lifespan. (Left) The focus on genomics sustains a disease-centered framework that influences how resources are allocated and how research is conducted. This scientific landscape in turn influences how medicine is taught and practiced, and shapes the public discourse around the malleability of health and individual empowerment about one's ability to effect change in one's health through behaviors. In modern Western cultures, these and other factors discussed in the text contribute to sustain *diseasecare*, a system of care delivery that relies on the diagnosis of disease states, deploys disease-specific pharmacological and surgical treatments, and determines therapeutic success based on disease indicators. (Right) An idealized health-centered model of care calls for research investment focused on understanding the basis of human health and its dynamic variation over time (e.g., (Yurkovich et al. 2020)). Realizing this model will require the development of new methods to monitor health states before the onset of symptoms, and has the potential to empower individuals to effect positive change in their health through behavioral changes

foothold in bioenergetics and communication. Although much work remains to operationalize and realize these ideas, the resulting approaches should be useful both to monitor and optimize health. It is stimulating to consider how novel interventions could be developed to stimulate organismal communication and energy transformation with the primary outcome of such interventions/trials being an improvement in organismal adaptive capacity (Fig. 2).

Conclusion

In summary, the dominant gene and disease-centered biomedical model has informed the research landscape, policy making, medical training and practice, as well as the public discourse around diseasecare. This dominant focus on disease has arisen from at least three main factors: (i) a fundamental lack of dynamic understanding of health processes, (ii) an excessive focus on genes, driven by the generalization of discoveries around rare monogenic disorders to common illnesses, and (iii) a pervasive bias towards additive solutions that perpetuates the emphasis on genes and pharmacotherapy. Given that the genetic origin hypothesis for most common human diseases has not been well supported, and the rise of new technologies, the time appears ripe to consider a different model focused on health.

A health-centered model of healthcare that incorporates principles of bioenergetics and communication has the potential to have major effects at multiple levels of the research and clinical continuum. Much work remains to operationalize health and to develop approaches to quantify, longitudinally monitor, and intervene upon valid health metrics. Progress in this direction should end up reducing the risk of diseases, and perhaps even produce a sizeable increase in lifespan. Making even small progress in this direction also would free up a substantial portion of the diseasecare budget, to instead be invested in promoting health and optimizing human development across the lifespan.

Acknowledgements I am grateful to Mary Elizabeth Sutherland for editorial assistance, to Judyann McNamara for discussions, and to Matthew Harms and Dan Belsky for pointing me to useful literatures.

Author Contributions MP wrote the paper.

Funding M.P. is supported by NIH grants R01MH119336, R01MH122706, R01AG066828, R21MH123927 and the Wharton Fund.

Code Availability Not applicable.

Declarations

Conflict of Interest The author declares no competing financial interests.

Ethics Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publication Not applicable.

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