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# Improving the effectiveness of healthcare and public health: A multiscale complex systems analysis

**Yaneer Bar-Yam, Ph.D.**

New England Complex Systems Institute
24 Mt. Auburn St., Cambridge, MA 02138
email: yaneer@necsi.org url: http://necsi.org

**Abstract**

The healthcare system is struggling with a mismatch between the large, simple (low-information) financial flow and the complex (high-information) treatment of individual patients. Efforts to implement cost controls and industrial efficiency that are appropriate for repetitive tasks but not high complexity tasks lead to poor quality of care. A multiscale complex systems analysis suggests that an important step toward relieving this structural problem is a separation of responsibility for two distinct types of tasks: that of medical care of individual patients from prevention and population health. These distinct types of tasks require qualitatively different organizational structures. The current use of care providers and organizations for both purposes leads to compromises in organizational process that impact adversely on the ability of healthcare organizations to provide either individual or prevention/population services. Thus, the overall system can be dramatically improved through establishing two separate, but linked systems with distinct organizational forms: (a) a high efficiency system performing large-scale repetitive tasks such as screening tests, inoculations, and generic health care, and (b) a high complexity system treating complex medical problems of individual patients.

## Introduction

The structure and processes of the existing healthcare system have been designed around the need to respond to medical needs of a self-presenting individual. Widespread recognition of the importance of prevention and population health[1-4] has led to efforts to charge the healthcare system to respond to these needs. There is, however, limited recognition that imposing on the same organization the need to respond to such radically different tasks leads to ineffectiveness and inefficiency. Instead, it should be understood that a distinct system (or subsystem) that is well adapted to the task of prevention and population health services can be much more effective and efficient at those tasks and, by serving these needs, help to solve many of the existing difficulties of the healthcare system. Thus, imperatives of public health, that are concerned with prevention and population health, may be better served by developing organizations that serve these needs directly. This is an organizational approach to the separation of tasks rather than an approach based upon questions of public or private financing or delivery. A more precise analysis distinguishes tasks that are repetitive, "large scale," and variable "highly complex." Distinct organizational structures are effective at these distinct types of tasks. Separating medical care for individual patients from preventive and population health services provides a first and important line of distinction between highly complex and large scale health care services.

The concepts of scale and complexity can be used to analyze various aspects of organizational structure. A formal multiscale analysis implies that to be effective there must be a matching between the scale and complexity of the functional capabilities of the organization and the scale and complexity of the tasks to be performed. We will consider two aspects of the healthcare system. The first juxtaposes large scale financial flows, and complex medical decision making. We will argue, based upon the multiscale framework, that the serial coupling between large scale and complex is largely responsible for organizational turbulence and ineffectiveness in the healthcare system. In seeking to resolve this problem we will then focus on the second aspect of the healthcare system: the aforementioned distinction between complex medical decision making and large scale prevention and population health tasks. We argue that the development of separate organizational forms for tasks at different scales is one of the essential steps toward addressing the structural problems with the healthcare system. In particular, that it will both help to relieve the financial and organizational turbulence of the healthcare system and lead to greater effectiveness of both complex medical care and large scale prevention and population health services.

The following sections discuss: 1) key relevant aspects of the structure of the healthcare system, 2) the method of multiscale analysis, 3) the application of multiscale analysis to show the underlying instabilities and ineffectiveness of the healthcare system, 4) the matching of scales and task assignment to separate organizational structures, and 5) description of a systematic approach to changing the system structure for improved efficiency and effectiveness by promoting the development of organizations that are designed for and dedicated to public health through prevention and population based care.

**The structure of the healthcare system**

Today, it is widely understood that the healthcare system suffers from low quality and high medical error rates.[5,6] Measures of the quality of care as a return on expenses[5] and the incidence of medical errors[6] depict a severely under-performing system despite the expansion of medical knowledge and the use of increasingly sophisticated technology and training.

Insight into the role of complexity and scale in the healthcare system can be gained by considering the role of insurance and the financial flows that exercise increasing control over the services provided. The development of health insurance and the trend towards managed care have affected the structure of the healthcare system in significant ways, separating the flow of money from the interaction between physician and patient. As is well known, the primary financial flow in healthcare consists of regular payments by employers (or, less often, individuals) to insurance companies, other health plans, or Medicare (or through other taxes to Medicaid)—payments that are not directly dependent upon the actual services provided during that time period. Practically speaking the payment is often an electronic bank transfer once a month. Part of the money may be deducted from employee salaries, while the other part comes directly from the company. Either way, the payment amounts are decided upon in advance and are the same from month to month until rate changes take place, typically on a yearly basis. With respect to the nature of the actual care provided, this sum is essentially featureless: large scale and simple, having no information encoded into it about the services it will eventually fund. The insurance company, managed care organization, Medicare or Medicaid divides this large scale flow of money into smaller financial flows allocated to medical costs.[28]

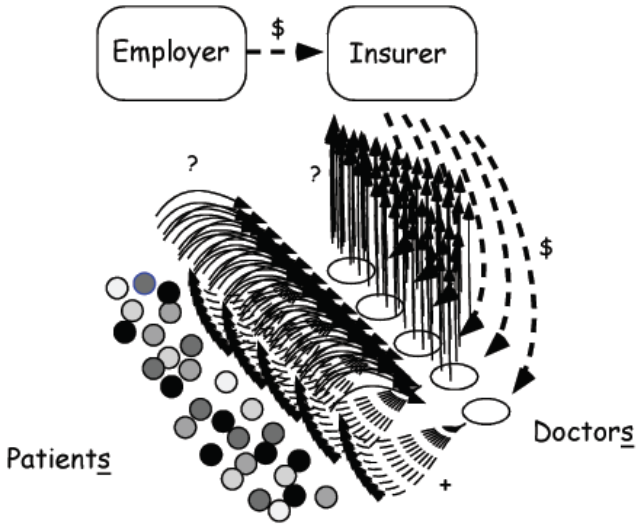


Figure 1: The structure of the healthcare system today. Information (indicated by ?) flows from patient to physician, and care (and information) flows back to the patient (+). Financial flows ($) proceed from employers to insurers (private or public, i.e. Medicare or Medicaid) and thence to care providers who provide information (?) about the care being provided. Insurers receive lump sum payments from insurers that are distributed in much smaller amounts to care providers for specific services.

The diagram in Figure 1 represents the flow of information, services, and money in the existing healthcare system. Information and medical care are exchanged in the transactions between physicians and patients, whereas the flow of money is largely from employers to healthcare insurers and thence to healthcare provider systems and individual practitioners. The difficulties in imposing efficiency and improving quality of care have their origins in the structure of these flows.

**Method: Multiscale analysis**

Using recent fundamental advances in complex systems research,[7,8] specifically Multiscale Analysis[9,10], we can identify the functional effectiveness of a system by comparing the set of actions a system *can* perform at different scales with the same analysis of its designated tasks. Here, scale refers to the redundancy, coherence or coordination of a task. Large scale tasks involve multiple individuals working as a coordinated unit, or multiple individuals performing the same task (e.g. mass immunizations). In contrast, small scale tasks require the attention of a single individual performing a unique task (e.g. one doctor diagnosing and treating an individual patient for a particular condition). To contrast two extreme possibilities, a system containing many individuals can be organized to perform a large number of small scale tasks, or a single large scale task. This illustrates a fundamental tradeoff in organizational structure and function.

There are more subtle tradeoffs that can be achieved in the organization of a system and the nature of the tasks that can be performed. These tradeoffs can be characterized by the "complexity profile" of a system: the complexity of possible actions as a function of scale. This mathematical construct specifies the number of distinct tasks that can be performed at each scale. It can serve as an analytic tool to provide an understanding of the role of organizational structure in organizational effectiveness.

Multiscale analysis and the complexity profile[9,10] decompose the capability of a system according to scale. They are an extension of information theory[11,12] designed to capture the relationship between, the set of possible behaviors of a system on the one hand, and its interdependencies and communication channels on the other. The subject of this analysis is not the same as information asymmetry, incentive analysis or game theoretic analysis.[13-18] Instead it is a new formalism that can characterize the function and desirability of organizational forms.[19-24]

In a sense multiscale analysis is a generalization of statistical analysis that incorporates correlations of multiple variables rather than pairs of variables. Multiscale analysis considers the degree to which $k$-fold correlations between components of a system are present, where $k$ ranges over the full set of values from one to $N$, the total number of components of the system. Correlations may be equivalently described by mutual information[11,12], (when multiple variables are correlated, the same information can be obtained from measurements of any of the variables) and the multiscale analysis quantifies the number of variables of the system from which the same information can be obtained. In effect, this determines how many components of the system are engaged in the same activity, i.e. are coupled in their actions.

For a simple case consider $N$ components that are coupled to each other in groups of $q$ elements, and each group is tightly coupled so that only one action can be performed by each group so that the scale of action would be $q$, and the number of distinct actions at a particular time is the number of groups $N/q$. The complexity (or variety, or information), $C(k)$, as a function of scale, $k$, is defined as the effective number of actions that can be performed by a particular system at scale $k$ or larger (more formally it is defined as the logarithm of the number of possible states of the system). In the simple case just described the number of actions is $N/q$ for all $k$ less than $q$ and zero for larger $k$. Mathematical expressions that obtain $C(k)$ for systems with arbitrary probabilities of the set of states of the system can be found in the references.

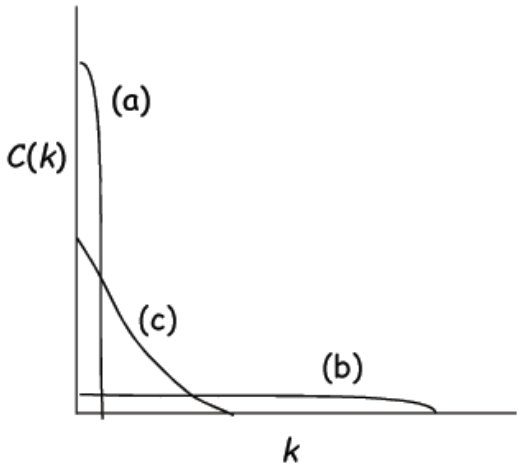


Figure 2: Complexity as a function of scale. Schematic illustration of the complexity $C(k)$ (vertical axis) as a function of scale, $k$ (horizontal axis, increasing to the right). A system with the highest possible fine scale complexity corresponds to a system with independent parts (curve a). When all parts act together the system has the largest scale behavior, but the same low value of complexity at all scales (curve b). Intuitively, what we call complex systems have various possible scales of behavior (curve c). The healthcare system is composed of one part (the physicians) that have a high fine scale complexity, and another part (the insurance system) that is large scale. The part that connects them is highly turbulent because of the differences between the two. This linkage also limits the effectiveness of the system when addressing either large scale or complex fine scale tasks.

The decomposition by scale is shown for illustrative cases in Figure 2, which describes the response capabilities of the system at each scale. Larger scales imply many individuals are performing the same (or directly coupled) tasks, while finer scales imply independently acting individuals. Distinct curves illustrate the relationship between organizational forms and the tasks they can perform. A system in which all individuals are performing the same or coupled tasks (curve (b)) can only perform a single act in response to an environmental demand, whether the demand is for one or many individuals to perform that act. This is quite different from a system (curve (a)) where individuals are independent, responding individually to distinct tasks, leading to many tasks that can be performed, each one of which draws the attention and efforts of one individual. An organization that has various ways in which individuals coordinate activity

into groups of different sizes would have the ability to act at different scales to differing degrees. One example is indicated by curve (c). The same analysis that describes the repetition of tasks among multiple individuals also can be used to describe the repetition of tasks over time, as compared to its variation when tasks are distinct at different times.

A fundamental result of multiscale analysis[9] is that for a particular set of components, the area under the $C(k)$ curve is independent of organizational structure. This can be readily seen for the simple case described previously where the area is given by the product of the largest scale of action $q$ (the width of the non-zero part of $C(k)$) and the number of such actions $N/q$ (the hight of the nonzero part of $C(k)$), which gives the universal value $N$. The organizational structure therefore selects a trade-off in capability at different scales. This means that, fixing the number of individuals, an organization with the ability to respond at a larger scale is not able to respond at a fine scale, and vice versa.

From the above discussion, it should be apparent that different types of industries should be organized in different ways. For example, mass production is a large scale task and organizations that are designed for mass production should be quite different than an organization that provides individualized care, as is generally understood to be the role of the existing healthcare system. Different parts of a system can also be analyzed in this way. Of particular relevance is an analysis of the financial flows of the healthcare system (larger scale) and the system of physicians that are performing the care (higher complexity at a smaller scale of action).

**Discussion: Turbulence**

The multiscale formalism can describe the coupling of a large scale flow with a fine scale flow as is present in the financial flows of the health care system. An analogy to the phenomenon of fluid turbulence helps explain why this structure, when used for healthcare, is ineffective. Our conclusions follow from the multiscale framework even without a fine tuned quantitative application because in this language the current situation is far from subtle. This should not be surprising as the system failures are not subtle either. Turbulence occurs when a simple coherent flow is broken up into many smaller flows. It can be observed in the swirls and eddies in a fast-flowing river, or in the way the column of smoke rises from a camp fire. Although one can identify situations where turbulence will occur, it is very difficult to predict the resulting motions, which are irregular and can change rapidly.

In the healthcare system, we have an analogous situation. The large scale financial flows that drive the system eventually have to be allocated as small payments to individual doctors treating individual patients for individual problems. The transition from the large- to the fine-scale is turbulent for financial flows just as it is for fluid motion. The idea that turbulence is the analogy to what occurs in the healthcare system will not come as a surprise to those who work in it, as they have experienced the turmoil over the past 20-30 years. The unpredictable rapid changes have not been in the relationships between doctors and patients, or in the relationships between employers and insurers (though sometimes they feel involved, at least as interested spectators), the main changes have been between the insurers and the physicians. The growth of managed care,

physician cooperatives, reporting and billing systems, and hospital mergers, are all part of the interface between the insurers and physicians. These changes in organizational structure and particularly the consolidation (aggregation) of medical services are a response to the flows that are disaggregating from large scale to fine scale. Many of the changes at the large scale that have occurred or are being considered, including changes in the number of self-insured employers, or degree of government involvement, do not significantly change the driving force or the structure of the turbulence.

What does this turbulence look like in human terms? The problem of large flows connected to highly complex flows is abstract, but the reality is quite easy to recognize. Eventually the issue is related to the problem of controlling the flow, specifically: Who is making the decisions that control the flow of money in this system? Increasingly, since the 1970s, or perhaps earlier since the founding of Medicare in 1965, an effort has been made to control the flow at the large scale end. Both government agencies, and private insurers, frequently with the intervention of state and federal government organizations, negotiate the rate of flow of the money. They decide on changes in the rate from one year to the next. Ultimately, the way these rate changes affect the system impacts the character of the behavior and organization of the system.

Consider the effects of a simple action like changing the flow at the source, by increasing (or decreasing, though practically speaking the former is more likely) the amount by a certain percentage (e.g. 3%). The amount of increase reflects a decision about how much should be spent on health care. How does the healthcare industry implement this decision? At the opposite end of this flow, individual doctors treat individual patients with specific highly specialized care based upon high complexity choices, whose ultimate decisions are based upon years of training and experience. The costs of individual treatments range widely—from tens of dollars to millions of dollars. The consequence of this increase (so much and no more) must manifest itself in the decisions individual doctors make regarding the care of individual patients. They must decide what amount of time and attention to devote to a particular patient, as well as what medical tests and treatments are needed. Ultimately these decisions must be based upon tradeoffs in health and care that compare diverse treatments. Physicians faced with restrictions on expensive procedures and treatments, or incentives to lower their own expenses, would have to make judgments about whether the amount of time and effort devoted to a particular appointment or individual, or a particular diagnostic test or therapy is “worth it,” where “worth it” refers not only to the likelihood of a successful outcome but also to its cost-effectiveness. Since this kind of judgment includes considerable uncertainties and it is largely incompatible with their medical training, different organizations—and individual physicians—would make this judgment in different ways, resulting in extremely unstable and variable quality of care overall.

What can those who want to control costs do? It is clearly impossible for those who "manage care" to make decisions about care changes on an individual by individual basis in a way that will altogether correspond to the change in total flow specified from year to year. The only thing they can do is stipulate overall policies that act across the board. These policies typically restrict the set of options that are available for patients or physicians. Patients are restricted to certain physicians, hospitals or other care providers. Physicians are restricted in what diagnostic tests or medications they can provide. The

amount of time spent in hospitals might be limited, or incentives to reduce the amount of time or attention to individual patients may be implemented. It is not surprising that limiting the options that a patient or physician can choose will have a negative impact on the quality of care that could be provided. Examples of detailed studies illustrating this include: limitations on postpartum stays correlating with readmissions,[25] and drug formularies (restrictive lists of prescription drugs) leading to increased costs and decreased quality of care.[26,27] The effectiveness of cost control strategies to achieve their objectives has been questioned based upon historical experience.[28] The more detailed studies challenge the idea that such actions actually save costs even when implemented according to plan, as indirect effects may ultimately lead to increased costs. Our discussion based upon multiscale analysis provides a more general understanding based upon the functional behaviors of complex systems and does not require a specific mechanism in order to arrive at the same conclusion. We have shown that fundamentally, it is not a good idea to use across the board (large scale) rules to try to control a highly complex system that is making careful (highly complex) decisions.

This discussion clarifies why recent efforts to increase efficiency have led to organizational turbulence and the current need for and difficulties with quality improvement. As the necessary treatment of individual patients has become progressively more complex and individualized, HMOs, managed care, Medicare and Medicaid and other health insurance solutions have been acting in a way that makes the structure of healthcare more large scale and undifferentiated. Due to the complexity of the resulting allocation problem, unexpected "indirect" effects have resulted from these efficiency methods. According to the analysis, these indirect effects arise from the reduction of fine scale complexity of the organizations performing the tasks. When an organization becomes less effective overall at many different tasks, it is not necessarily less effective at the particular tasks or measures that management or regulators are focusing on. Indeed, one can expect that for those tasks or measures the organization will improve, while for others its effectiveness will decline. This explains why problems appear as indirect effects. Moreover, the more problems arise with quality, the greater are the efforts to regulate the actions of doctors, nurses, and other medical professionals. Uniform regulation, whether for cost containment or for quality, has the same effect on a system performing high complexity tasks—diminishing overall effectiveness. It may seem that imposing uniform care in some context may be constructive, however, in the context of complex organizations uniformity is in itself a limitation (exceptions do exist but must be understood within this framework rather than just assumed to exist). Since the resulting problems show up as indirect effects, it is difficult to discover their origins.

The problem is that the healthcare system is expected to behave efficiently with respect to financial flows at the large scale, but to exhibit high complexity of individual patient care at the fine scale. If all patients were in roughly the same condition, requiring roughly the same treatment, an efficiency approach would be fine, as this approach works well for streamlining low-complexity procedures. However, the medical treatment of patients is an extremely high-complexity fine-scale task. One-size-fits-all does not work in this case. Applying such methods can only result in poor quality care. Although the above discussion of the current state of the healthcare system is grim, a fundamental approach to a solution to the problem does exist, and will be discussed below.

**Matching scales**

Multiscale analysis suggests that a key to effectiveness is the matching of the scale of organizational processes to the task. The current structure of the healthcare system inherently fails to do so. An important aspect of the solution to this problem comes from recognizing that there are large scale aspects of health care. These are tasks that are repeated many times. Large scale tasks *can* be met by efficient processes, reducing expenses and improving the overall effectiveness of the system. Recognizing them as large scale, we can use these tasks to improve the matching of tasks and financial flows. In this way, the current difficulties of financial control can also be relieved. The approach of identifying which tasks are large scale can be extended to identifying tasks that have intermediate scales. The development of organizations that perform tasks at various intermediate scales as appropriate would result in substantial additional efficiency. Here we will focus on the largest-scale parts of the healthcare system, those that should be addressed at a population level and are often identified with public health.

How can we create a healthcare organization that is effective at large-scale tasks? The existing approach to healthcare organizations already has some separation of tasks, particularly in hospitals. Nevertheless, the patient-physician interaction continues to be used as an essential part of most healthcare tasks. The issue of a tradeoff is manifest when we consider whether an individual (e.g. physician) is able to perform rapid repetitive tasks when they are needed, and take enough time to perform careful complex tasks when these are needed. Is this possible, or does the speed become compromised in some cases while the need for time become compromised in others? Even more critical is the problem of coordination, since when there is a change in protocol of large scale tasks, all individuals must change behavior. However, individuals must act independently for complex tasks. This creates a need for management structures that control when it is necessary, but do not control when it is not advisable. Thus there are key demands on individuals and on organizational structures that must be met. We can compare this to a strategy of separating the large scale tasks from the fine scale tasks, creating mostly separate organizations involving different people for doing them. Let's call the separation a heterogeneous organization, and the single organizational structure for all tasks a homogeneous organization. We can think of the task requirements as a complexity profile, $C(k)$, of things to do, and the objective is to cover this area with the complexity profiles of individual people. Stacking individual profiles vertically means having them work independently, and stacking them horizontally means having them work in a coordinated way. In a heterogeneous organization some individuals stack vertically and others stack horizontally, while in a homogeneous organization all individuals contribute equally to tasks at all scales (so that each individual has the profile $C(k)/N$). The idea of using a heterogeneous organization is supported by the following observations: (1) The use of a homogeneous organization is a severe restriction on the types of organization that are possible. Heterogeneity opens many more possible organizational forms. (2) Not all organizations can achieve all forms of coordination. For example, it has been proven that hierarchical organizations cannot achieve high complexity at intermediate scales.[9] (3) Organizational structures that are designed for a restricted set of scales are both known and more transparent than organizational structures requiring various levels of coordination of individuals at multiple scales. Thus where task separation can be made, a

heterogeneous organization can be more easily understood, planned and designed than a homogeneous structure. (4) Individuals may be quite different from each other in their individual scale and complexity tradeoff. Thus a person who intrinsically performs simple tasks repetitively is distinct from a person who intrinsically performs careful decision making about high complexity tasks. A heterogeneous organization allows different individuals to perform individually appropriate roles. (5) Organizational specialization, ie. The formation of a heterogeneous organization, is a larger version of individual specialization, a well established concept.

There are many examples of organizations, both biological and social, that separate distinct kinds of tasks providing phenomenological support for these formal conclusions. Human physiology has several illustrations: legs for walking are designed differently than hands that can manipulate finer scale entities. The immune system is designed differently than muscles, the former for more complex finer scale challenges than the latter. Similarly, the military is separated into a variety of forces: tank divisions, infantry, marines, and Special Forces for different tradeoffs in scale and complexity. Even supermarkets have different sections for purchasing cheese: e.g. the dairy and the deli, one for larger scale and the other for more complex products. These examples illustrate the fundamental principles revealed by the multiscale analysis and the theorem that implies a trade-off in system effectiveness based upon organizational structure. They also illustrate how by creating distinct parts of the system to address different types of tasks it is possible to effectively perform these different tasks.

**Separating large scale / complex care**

Intuitively we can recognize that preventive care and population health services are frequently large scale tasks. Indeed, we can consider the concept of large scale as defined by the multiscale analysis to provide a possible formal framework for understanding the domain of public health as an organizational imperative. The public health system works through many channels to achieve improved prevention and population health. Moreover, it also frequently serves as a palliative to the failings of the healthcare system by providing healthcare services. Still, one of the main channels for action is the healthcare system. Our analysis suggests that a public health system that promotes private and/or public supported organizations that are effective at large scale prevention and population care will be more effective in the long term. The role of such organizations should include performing a variety of tasks that are intrinsically large scale. The aspects of healthcare that can be treated as large scale include: wellness services, such as nutrition programs, management of some widespread chronic problems, prenatal care, and the treatment of common minor health issues (allergies, stress, the common cold), and preventive procedures, such as immunizations and screening through diagnostic tests. Many of these services can be performed on populations as highly efficient processes, as they do not require decision-making on an individual basis. They can be separated from those aspects of health care that require decision-making on an individual-by-individual basis. While the general principle is clear, the specific services that should be separated should be determined by a more detailed quantitative analysis of complexity and scale as well as pilot programs that are properly focused on the issue of efficiency and

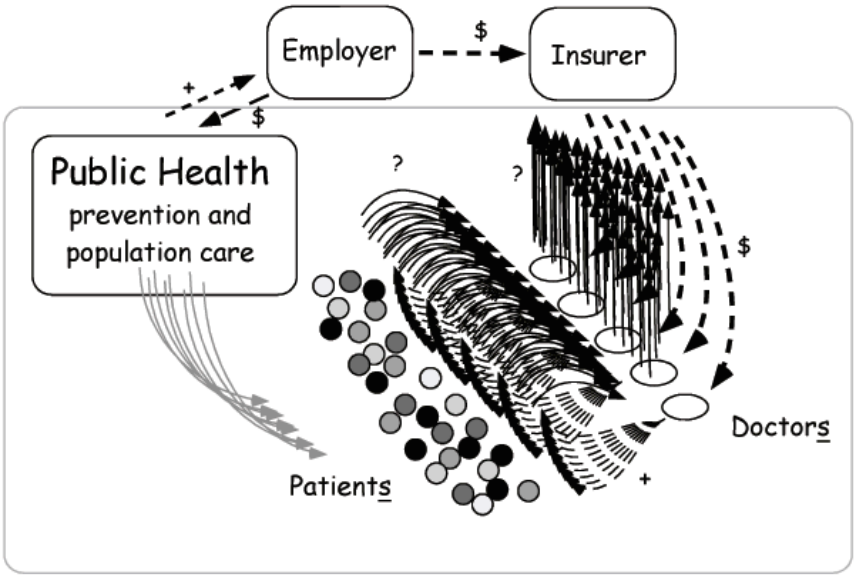


Figure 3: A proposed structure for a new healthcare system. One part is designed for efficient prevention, population based health and wellness programs—the priorities of public health, the other part is designed for complex individualized medical care. Perhaps the most natural customers for the high efficiency system are employers (indicated), but the customers may also be insurers (including government agencies) or individuals, just as individuals are the customers for high efficiency fast food and manufacturing.

effectiveness as articulated by the analysis. The degree of separation may also be explored. Some solutions might place prevention and population services as divisions or units within healthcare organizations, and others might have them associated with other types of organizations such as pharmacies and supermarkets that have more experience with efficient services. While the separation could also be done through government delivery, this is not necessary even if government oversight is desirable.

The high efficiency prevention and population care system pictured in Figure 3 would function in some ways analogously to a traditional mass production factory model, or a mass market service organization like a fast food provider. There are ample precedents for such activities in healthcare in the U.S. and internationally from historical and current public vaccination programs[29,30] to modern supermarket delivery,[31,32] and mass screening programs.[33] Such programs administer vaccinations and diagnostic tests on groups rather than through individual appointment. The purpose is to ensure a high level of health in the population and to identify those who will need individual medical attention. Exceptions are referred to the medical system. The objective is large scale efficiency, but once a problem is identified, individual attention can be personal and effective.

Unbinding the large scale and complex tasks, enables efficient and effective organizations to be formed around these distinct tasks. A system for population health can be made efficient on a large scale. A system designed for the complexities of individual medical care must be error-free in individual tasks. Separating large scale

"prevention and population care" from complex, "individualized care," relieves physicians of tasks that can be addressed with a much higher efficiency, enabling them to focus their attention on the complex tasks for which they are uniquely trained. Overall, this enables the system to be more efficient as well as more effective.

The idea of separate systems reasonably evokes concerns about reciprocal communication. Moreover, the need for communication often suggests the adoption of centralized databases with concerns for privacy. Without engaging in a full discussion, at least one potential solution can be suggested of having individuals carry the information with them in portable storage media that are a simple and relatively inexpensive technology.

The development of an efficient system for prevention and population health also would help to fundamentally address many of the other problems with the healthcare system. Highly efficient services, would make such care much more widely available with the potential of radically reducing disparities, as the ubiquitous television and fast food illustrate.

Perhaps even more important, the fundamental role of prevention and population health in reducing the need for medical care (this is what prevention is about after all) could be realized. The benefits of the virtuous cycle of prevention reducing the costs of healthcare and freeing resources for more careful medical care where it is needed, as well as more preventive and population care, is precisely the converse of the current vicious cycle of reduced prevention leading to the need for more medical care and less resources for each individual that requires care. The virtuous cycle, as well as the intrinsic value of improved health, are the well recognized reason for the need for prevention, that can only be realized when it is performed efficiently and effectively.

The principle of separation of tasks at different scales can be applied also to many other aspects of healthcare. For example some surgical procedures may be performed as efficient mass production processes if there are many individuals with similar conditions requiring similar procedures. This may be true even if the decision to perform the surgery is highly complex. Still, other forms of surgery are clearly highly complex. Such examples abound within the healthcare system. Understanding the concepts of scale and complexity and how to apply them to specific tasks may be helpful in determining the details of organizational structures. A more detailed discussion is beyond the scope of this paper.

The development of a highly efficient system for administering screening tests may also broaden the utility of many tests, making some that are not cost effective become cost effective due to economies of scale. Moreover, concerns about false positives that are present with infrequent testing, may also be relieved by more frequent testing. The tracking of conditions over time allows the medical response to be based upon following the developments over time for greater certainty in diagnosis. Finally, high efficiency processes widely applied increase dramatically the availability of data that can improve knowledge of how to utilize this information.

## Conclusions

A multiscale analysis of information flows in the healthcare system demonstrates that efforts to lower costs through managed care must lead to ineffectiveness, as is manifest in medical errors and low quality of care. Moreover, while significant debate has surrounded the nature of the payer system, whether it should be public or private, this dichotomy does not address the essential failings of the system, and either choice (public or private) can be well or poorly executed.

A public health system should recognize key distinctions between individual and population care, and develop systems that are well designed for delivering distinct types of services. The need for increased investment in prevention and population based services must be married to a recognition of the organizational needs for such tasks. Among the changes in the healthcare system that can contribute to improvement is a separation of complex tasks from large scale tasks. The current healthcare system is an individualized system, and even when it provides care relevant to populations it typically provides them through a one-to-one physician-patient model. Individualized care should be entrusted to a fine-scale individual care medical system, while a distinct system should be created for large scale and efficient prevention and population health programs. Through such a separation we will no longer expect one organizational structure to provide both financially efficient population and preventative care that can be performed in a repetitive way, and complex medical care that requires careful decision making in each case. Trying to perform both by the same organization creates conflict between the short term response to immediate needs of individual patients, and the longer term benefits of prevention and population care. Just as having physicians doing the laundry at hospitals would be ineffective and inefficient, such a dual purpose system can only be expected to provide mediocre response to both tasks. An efficient prevention and population-based care delivery system will improve this aspect of care and improve healthcare by helping to relieve the stresses on individual care.

A system that delivers effective population based care can demonstrate the effectiveness of such services as part of the overall healthcare system in a manner that cannot occur within the current organizational structure. The result: a relief of financial pressures, a better balance between prevention/population and medical care and systems that are separately effective at both leading to a healthier population.

A full discussion of specific practical transitional steps to achieve such a system is beyond the scope of the current paper. However, it should be understood that the benefit of the multiscale understanding of the healthcare system is the recognition that changes in organization can be of widespread benefit and therefore this understanding should promote the adoption of change. Specifically, a wide range of players should recognize that changes that promote adoption of a prevention and population based care system will serve their goals and interests.

A more complete solution for the healthcare system problems would also require other complex systems concepts that are essential in the development of highly complex organizational structures. These concepts that can be obtained from multiscale analysis include: (1) Recognizing the limitations of centralized control in management of complex medical care; (2) Recognizing both the possible constructive role and limitations on the

role of automation in improving healthcare, (3) Detailed structures of information flows associated with medical errors suggesting organizational processes that eliminate medical errors; (3) The understanding of how to induce organizational change and improvement in highly complex organizations for high complexity medical tasks, including the role of competition and cooperation in systems that may or may not be market driven. Such issues are relevant to the role of payment and reward systems. A discussion of these ideas can be found elsewhere. [10]

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