

From ancient times, health, public health and medicine have been intertwined, becoming more closely, and then more distantly associated. Rene Dubos in *Mirage of Health* asserted that, “freedom from disease and from struggle is almost incompatible with the process of living.”⁷¹ He felt that there is a dynamic process of adaptation; that every living organism is constantly changing to meet its environment; neither science nor technology can alter this entangling relationship. One can view the role of public health and medicine to make the adaptation as comfortable as possible. This conflict of the living has roots in the history of medicine and public health, both serving to promote the health of the population as well as the health of the individual.

This is the medicine version of the classic biology paradigm of nature versus nurture, genes versus environment. In biology, sometimes one dominates sometimes the other but both are simply halves of a unified whole. The same is true with health of the population and the medicine of the individual. One may be predominant but both are simply halves of a unified whole. In this Part I, we show through striking significant examples that both halves must be in balance for individuals to prosper within populations. When medicine dominates and the view is bodies only, major failures occur. When health dominates and the view is societies only, major failures occur. Personal Medicine and Public Health must be in balance for the maximum quality at the minimum cost of healthcare infrastructure.

When public health and medicine work together, great progress can be made. Their energy and effects can be additive. But if their respective definitions and their target activities are changing, progress can be slow and science of the practitioners suffers along with the lives of the individuals within their environments.

2.1

Measuring Individuals and Populations via Personal Medicine and Public Health

The frequent conflict between medicine and health has roots in the history of medicine and public health, both serving to promote the health of the population as well as the health of the individual. In this chapter, the history of health determinants is surveyed, to show how the paradigms and the technologies change over time, yet stay much the same. In the nineteenth century, the pendulum was on the public health side, in the twentieth century the great success of modern medicine swung it to the personal medicine side, with the rise of

the modern hospital system.²³⁸ This book explains the point of view that the twenty-first century must go back to the balance of the Greeks, before the knowledge of anatomy and physiology moved from health to medicine, to consider public health and personal medicine as equal partners.

The classical distinction of health and medicine is closely related to the similar classical distinction of yin and yang discussed below in this Part I on the problems of healthcare infrastructure. In turn, the same distinction is closely related to the infrastructure distinction of volume scaling with variation handling. This distinction was introduced in Chap. 1; its implementation with information technologies will be discussed in the next Part II on the solutions of healthcare infrastructure.

Yin and Yang is the Chinese distinction, originating from the shadows on the mountain across the day and across the year. As the position of the sun changes, the sun becomes shade and vice versa. Although Yin is traditionally female, representing the dark of the shade, while Yang is traditionally male, representing the light of the sun, they are only each halves of the moving shadows. Neither can exist without the other, and they periodically switch roles over time. The traditional symbol shows this duality.²⁵⁶

Yin is diffuse; it is global in nature touching the distributed population. Yang is direct; it is local in nature touching the centralized individual. When the pendulum swings completely to the public health side it emphasizes global changes that affect everyone to some degree, such as sanitation. For example, the Romans draining the swamps prevented malaria. When the pendulum swings towards the middle, public health begins to fade into personal medicine. For example, the localization of contaminated water to a specific water pump prevented cholera by identifying the individuals who should be given a new water supply. When the pendulum swings completely to the personal medicine it emphasizes local changes that affect only a few individuals given a particular drug for a particular disease.

In ancient historical terms, the global is Hygeia, the Greek goddess of sanitation and health, whose living the good life insures health. She gives us the word “hygiene.” In contrast, the local is Panakeia, the Greek goddess of healing and medicine, whose cures overcome disease. She gives us the word “panacea.” Hygeia assumes the normal state is ease, so supports balance to maintain this state of health. Panakeia assumes the normal state is disease, so modifies the current balance to return to a state of health. The discussion goes through the history of defining the humours for general categories and the determinants for specific concepts.

We will use Five Rings to model Human Health, similar to the classical structures. This is our attempt to bring the measurement of health back into balance by insuring that the new infrastructure supports all the rings effectively to consider all the features affecting healthcare. As with the systems of diseases discussed historically, the rings are modeled after the humours: the yin of earth and water combined with the yang of fire and wind. The humours form the fundamental categories that drive the classifications of diseases in every culture, as discussed below in historical progression from India to China to Greece to Rome.

The classical book on the strategy of war by Miyamoto Musashi (1645) was in fact entitled *The Book of Five Rings (Go Rin no Sho)*; Musashi was the unbeatable samurai who could balance all the rings. His first four rings are the humours, with the fifth ring is the void. He was undefeated since he had no fixed system but fought a reactive style for each opponent. So Five Rings are a good metaphor for health measurement that seeks to balance features for each situation, rather than fixed treatments for fixed diagnoses.

In modern scientific terms, the global deals with the Society, while the local deals with the Body. Society is all the persons and their external interactions, constituting the determinants of health of populations. Body is single persons and their internal interactions, constituting the determinants of the health of individuals. Thus Society is dominated by Public Health, while Body is dominated by Personal Medicine. Generally, the global effects are stronger but slower. If everyone is poor and hungry due to a disaster, health suffers for all, but as this improves, individual variation begins to dominate once again.

This strength effect can best be understood by a series of rings, with the Outer being stronger and the Inner being weaker. Thus Public Health information dominates the Outer Rings, while Personal Medicine information dominates the Inner Rings. The viability of healthcare is determined by the balance across the rings of information, health and disease. Thus the rings are a spectrum rather than a dichotomy. In this book, we have integrated the best models of health determinants to demonstrate what the major factors are for successful healthcare infrastructure. These models include those of, Dahlgren and Whitehead⁶², Evans and Stoddart⁷⁴, Berkman and Ichiwara¹⁷, among others (Fig. 2.1).

The Five Rings of Human Health Information have Public Health on the Outside and Personal Medicine on the Inside, with transition bridge in-between. In present Healthcare Infrastructure, Health and Medicine are out of balance and quite separate. In future Healthcare Infrastructure, Health and Medicine will be in balance and quite together. The Outer Two Rings are Societal conditions and Social networks, dominated by Public Health. For example, the health features include sanitation and environment. The Inner Two Rings are Body supports and Biology systems, dominated by Personal Medicine.

There is a Bridge Ring that explicitly shows the transition between Public Health on the outside with Stress and Personal Medicine on the inside with Behavior. In this middle transition ring can be seen the duality of health and medicine, where some features are usually considered public health, such as smoking and alcohol while other features are usually considered personal medicine, such as diet and exercise. This Part I will introduce these risk factors as problems to be dealt with, whereas Part II will introduce the present and future technologies that measure these factors to improve health management.



Fig.2.1 The (5) rings of health determinants. Inside two are Body (1, 2) of individuals, Outside two are Society of populations (4, 5), Middle is the bridge for individuals within populations (3). Simplified diagram to show balance between Health and Medicine. Later use “Ring diagram” with concentric rings in this order inner-outer 1–5 getting larger

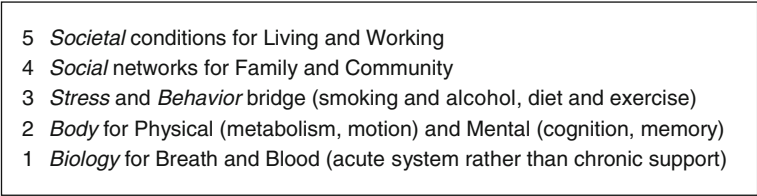


Fig. 2.2 Rings where numbers reflect influence power and inversely reflect change speed

The Five Rings of Health Determinants are the merger between Public Health and Personal Medicine, when these are one in the future instead of separate as in the present. The contribution of Public Health is the demographics, the variation across populations for each type of individual, including age and sex and geographic region. The contribution of Personal Medicine is the features, the diseases and the symptoms that influence individual health; these can vary from differences in organ function to differences in living condition (Fig. 2.2). The history below explains that the features for human disease are always the same order of magnitude in every culture. There are about 1,000 features for individuals (based on ten major organ systems and ten major diseases for each organ) just as there are about 100 types of persons for populations (based on the demographics of age and race).

2.2
India and the Rise of Systems: Concepts and Categories

The oldest system of medicine is that of India, the Ayurveda (4500–1500 BC). Although mostly a system of hymns, prayers to deities and chants, the Ayurveda also described problems of health in terms of humours of the body, movements and sensations, metabolism and physical cohesiveness.

The Ayurveda was able to adapt over 3,000 years, in part because so much of its beliefs centered on the application of prayers and incantations to perceived illnesses and in part because some of its practices, especially in surgery, were founded on careful practice and refined results over generations of practitioners. It was a “healing art” with the foundation as a science which included knowledge from all of life, not just of diseases and therapies.¹³⁴

For this period that the Ayurveda was practiced, its knowledge was passed on orally. About 600 BC, the era of more rational practice began; from this period comes the Ayurvedic text which comprised tens of thousands of hymns in 1,000 chapters. The Charaka text is the encyclopedic work for medical knowledge, as distinct from the Sushruta Samhita, the surgical section.^{111,134}

At the center of the Ayurvedic practice regarding medicine was the interplay of elements of the body, diet, time and season, and through the earlier years of the practice, therapy consisted of correcting the disturbance among the elements, defined as humours of the body, and returning balance to the individual. Medicine and health were a balance of internal and external elements, the individual and the world.

To address a medical problem, Ayurveda describes the body in terms of five elements: water, light/fire/heat, air/motive force, earth, and space/vacuum. These basic elements combine to form the seven basic tissues: plasma, blood, fat, flesh, bone, marrow, semen. Any change in the balance of these elements or in the composition of the basic tissues would result in changes in a person's vitality or power.^{134,189}

In addition to the basic elements and tissues, the Ayurvedic theory describes three humours, on which pathology and physiology are based. One humour, Pitta, was involved in the control of metabolism, digestion and thermogenesis; another, Kapha, oversaw cooling, preservation, thermotaxis and heat regulation. The third was Vata, air. Imbalances among these humours, taking into account disturbances of the basic elements and tissues, would lead to disease, illness and require treatments to restore the proper balance. When out of balance, the condition could be recognized by the trained physician and the proper means to return balance prescribed. But in contemporary terms, there was no means to quantify Pitta or Kapha, these humours could not be measured, nor could they be modeled or tracked over time. Any concern for population management based on the humours would have been impossible.¹³⁴

A practitioner would examine an individual and come to a determination of the imbalance among the humours and then would prescribe corrective measures. There was no way to assure that the determination of an imbalance was accurate or that corrective measures would likely be successful. Nevertheless, the Ayurvedic theory did have many insights into human physiology, noting the flow and exchange of tissue elements, describing vessels and ducts, mentioning something close to nerve impulses. Although primitive, the theory did realize that food resulted in metabolism and sustenance and that the remainder was excreted; there was a balance in intake into the body and output as energy or excretion.

To reach a diagnosis of disease, the individual was examined for a cause, indications of illness, symptoms, therapeutic tests and history of the illness. Because the knowledge of physiology was so limited, the three humours, five basic elements and seven basic tissues had to be stretched and expanded in depth and breadth to explain a wealth of diseases and causations. As there were few medical treatments of value, the system of humours, elements and tissues was adequate to describe the illnesses that the Ayurvedic medicine confronted.¹³⁴

Using the system of humours as a description of health and disease means that the primary internal bodily functions of circulation and respiration are not described. The humours and elements of the Ayurveda did not have any way to associate circulation and respiration with states of health or with manifestations of disease. Consequently, the humours were a better representation of the relationship between the body and the outside world, whether the environment or the world of social interactions. This was appropriate as illness was often conceived as divine intervention, a reason that hymns and incantations were so integral a part of the Ayurveda system. Medications and medical treatments in the more modern sense were unusual if effective and commonly unconfirmed.

From the text, one can extract descriptions of 1,120 diseases, or different imbalances among the humours, each of which would require a different description, evaluation and treatment. But without a comprehensive view of health and disease, one could not verify a particular one of these imbalances versus another. Particular diseases such as epilepsy were described as disturbances in movement (Vatika) or in sensations of Heat (Pattika), but the quantification of such disturbed movement was not possible and it was impossible to collect a series of these descriptions except as isolated histories to be passed on orally.¹³⁴

The Ayurveda does contain lists of herbs which were used to treat many common ailments – so many current medications are derived from natural products one can accept that drugs such as belladonna and aloe vera, rauwolfia and strychnos had real uses and acceptable effects; with the proper Ayurvedic description of humours and elements, some of these herbs were prescribed and confirmatory results obtained. Since record keeping and the quantification of patient response was nearly impossible, there remained no certainty that either a diagnosis or a treatment was effective, except in one's memory. Population response, to a disease or a treatment, was also possible only in the memory of a practitioner with the vagaries of time understood.¹³⁴

The surgical section by Sushruta, which is called the Sushruta Samhita, claims expertise with 120 surgical instruments and 300 different surgical procedures. From the descriptions and skill, it is assumed that the practitioner had studied anatomy, both human and animals; that he had gained more practical experience performing procedures on the dead such that a description of the human skeleton is included in the text. Certainly, his understanding of surgical problems and treatment was vast to accommodate such a wide variety of technical knowledge to differentiate a large number of different procedures, presumably for different conditions and different indications.^{134,193}

However, there was no practical means to record individual case histories, to analyze series of patients, to test theories of disease and outcomes. As the Samhita is in Sanskrit and few copies were available, any practical surgical knowledge needed to be obtained through experience and passed on orally and by memory. Additionally, there was no way to examine a larger picture of the surgical problems of a population or to track particular disease and treatments over time.

Yet Sushruta, despite being a skilled surgeon describing surgical techniques such as nasal reconstruction and intestinal repair, was concerned with prevention of disease. Uppermost was exercise, daily and in moderation, to stay fit and in proper balance. The Sushruta Samhita mentions the syndrome of sedentary life-style, obesity and diabetes. Diabetes was recognized through the urinary manifestations of high glucose and high urine output. This syndrome was noted to be deadly if the proper balance of the humours was not restored, so that there was some understanding that life-style and personal habits could have a profound effect on health.^{43,254}

In Babylonia, about 1700 BC, the Codex Hammurabi was written – a lengthy document which concerned laws and the rules of government. It also included the regulation of physicians and an overview of medical practice.

At the time, Babylonian society summoned Baru (Diviners) and Ashipu (Exorcists) along with the Azu (Physicians) when their health was threatened. The Baru and the Ashipu used physical examination of the patient to search for clues and omens as to which demon or ghost was responsible for a particular affliction. The Azu (Physician), on the other hand, limited his examination of the patient to listening to the history.⁵

The Codex recommended that objective measurements be established regarding a physician's treatment of disease, that means to collect data to document quality of care and the outcomes of such treatment be evaluated. Medical records were kept on hundreds of clay tablets describing illness including abscesses, apoplexy, colic, constipation, cough, and heart symptoms, which recorded the illnesses of population. There were even 40 tablets concerning nightmares.^{5,48}

In this way, the Azu (Physician) of the time were able to keep some records of individual problems, for evaluation, for comparison, for gaining a view of the more general health problems of the population, to learn to identify new problems and presentations, and to pass such case history information along to future generations. Though primitive, these are among the very first attempts to record the case histories of individuals and populations. Such tablets allowed the records to remain frozen, for review and reconsideration and future reference.

The Azu recognized many diseases and health problems at the same time that they learned to use more than 250 different surgical instruments and many drugs. They were familiar with 250 plants and 120 minerals, all of which were boiled, stirred, ground or mixed and were prescribed for the particular problem that an individual had. But there was scant understanding of the primary functions of the body so that disease and treatment was left to the discretion of the physician. The Codex maintained quality of care and was applied primarily to surgery and not usually to non-surgical treatments. It was believed that the Baru or the Ashipu (Diviners or Exorcists) should not be held responsible for outcomes or results of treatment when demons or evil spirits were involved. There was a poor foundation for much of the medical practice of illness.⁵

On the other hand, when the skill of a surgeon to make a diagnosis and apply a surgical treatment was involved, the surgeon was held responsible. There were severe penalties if the treatment of a surgeon was not successful. There was a clear connection between the indications for surgery, the surgical procedure to be performed, and an outcome from performance. Unlike medicine where medical physicians had only the broadest knowledge of a patient and not the information about circulation, respiration and the major body systems to make an accurate medical diagnosis. When a physician faced a particularly difficult problem in diagnosis, he/she might place the afflicted in a town square and ask passers-by for diagnostic help and opinions, hoping that someone had seen a similar case in the past and had experience with treatment and recovery.⁵

2.3

China and the Structure of Humours: Yin and Yang (Volume and Variation)

Ancient China took a holistic approach to health and disease. Physicians and patients favored good health over curing disease, paying less attention to anatomy and more attention to balance and harmony. Yin and Yang, the conception of the universe, produced illness when they were not in balance and they affected the Five Elements, fire, earth, metal, wood, and water. Any attempt to diagnose a disease or to recommend a treatment would describe an imbalance and suggest a return to harmony. This approach places more emphasis on natural ingredients and energy to return to a healthy state than on the identification of disease.⁵

The ancient text, the Yellow Emperor's Classic of Internal Medicine,²⁶² describes illnesses in terms of five colors, five viscera and six bowels – a classification system which was not concerned with particular internal organ pathologies but rather with a holistic view of the individual or organism a broader universal view of the cosmos, hence the concern for balance and harmony. With the use of Yin and Yang for balance, the five elements and

the multiple colors, viscera and bowels, a recommendation of balance and harmony might be accepted, but there was no means to record a decision regarding a specific set of descriptions and no way to review past decisions and their outcomes.^{5,262}

Certainly, records of populations treated in this manner were best left to the memory of the physician involved, trusting that his memory would be correct. The Yellow Emperor's Classic of Internal Medicine, written between 700–221 BCE, helped to separate the increasing knowledge, experience and skill of the physician from the activities of witchcraft.²⁶²

Since little was known of the physiology and diagnosis of the human body, physicians gained what they could from external examination and a key part of the examination of the ill in ancient China was taking the pulse; the Chinese recognized 50 different pulses with greater than 200 variations. Without a scientific description of physiology, it is difficult to conceive how to describe 50 pulses with analyses, recommendations and outcomes. The presumed fineness of detail using pulse palpation prohibited the collection of meaningful longer term information as so much interpretation was left to the examiner.^{131,258}

In addition to traditional physicians who favored harmony and balance, China also has a long history of folk medicine. Such practitioners traveled from place to place and were often quacks, managing through force of personality rather than results. As results from the more traditional approach might be difficult to verify, one might be easily persuaded by a passing folk medicine practitioner to try most any recommended treatment. Once again, records of such activity rest in stories and tales.⁵

Chinese medicine entered the era of Confucius after 150 AD which brought some order. Recommendations were made of four methods of medical examination – observation, auscultation/olfaction, interrogation, and pulse/palpation, but few means on which to base practice and little science for training, learning or measuring the outcomes of health and disease. Rather than assigning one of many diagnoses to an individual, Chinese medicine developed a feeling for particular situations and how they might be improved. With the passage of time, the situation might well have changed and another means to achieve harmony recommended.⁵

Like the problem with the Ayurveda and the Babylonians, there was no practical method to collect population data or to survey a population for health and disease. Records were sparse and primarily kept through the experience of a physician; for the times therefore, a system based on humours, which could be readily remembered and recalled, was a practical way to organize medical thought, in an era where true treatments for medical problems were few. In this world the physician was able to determine the basic physiological functioning of an individual: whether they were breathing, whether they had a pulse and whether their thought processes were clear. An individual's personal situation would likely be known to the Chinese physician so that, despite the limited physiological model with which a physician worked, the Chinese physician would have a fair knowledge of the individual.

2.4

The Greeks and the Humours Defined: Hygeia Versus Panakeia

Two cities in the Mediterranean, Cos and Cnidus, were the homes of the ancient western medical school tradition. Much of the inspiration for these schools of thought arose from Asklepios, a demi-god, son of Apollo. Innumerable temples dedicated to Asklepios were

built throughout Greece; they were temples where the ill could seek refuge and guidance, often staying overnight awaiting the presence of a god to heal their wounds or cure their ailments. Many travelers inscribed their stories, noting their cures, on the walls of the temples where their treatments occurred. These inscriptions became a record of disease and treatment, perception and instruction.^{171,188}

Asklepios had two daughters, one Panacea, associated with treatment, and the other Hygeia, associated with Hygiene and preventive health and medicine. To those afflicted and seeking aid at a temple, Panacea would be the daughter whose spirit one might invoke; to those hoping never to visit a temple of Asklepios, the spirit of Hygeia would be summoned.⁷¹

One of the earliest Greek physicians, Empedocles, described the world in terms of four cosmic elements: air, fire, earth, and water. He believed that the entire world was composed of these elements in different proportions and that there were four qualities of opposing pairs: hot/cold, wet/dry. The concept of four medical humours, indirectly from the four elements, defined medical properties in terms of opposing pairs and remained a medical explanation of health and disease for thousands of years.^{8,171}

In the Greek ideal, health was equilibrium. In this world of order and beauty, the physician's role was to define and help attain that equilibrium for a given patient. The four humours for the Greeks was a way to define a balance among the internal functions of the body, where the medical science was primitive and complex physiology was far in the future. Combinations of four humours represented an optimum number of elements that a physician could analyze and decipher. This elementary conception of human physiology was combined with the broader knowledge of a patient in his environment and society.¹⁷¹

The more commonly known tradition of medicine was known as the Coan school, from the island of Cos, the island of Hippocrates. In contrast to the Cnidians from Cnidus who concentrated on bodily organs and organ centered disorders, the physicians from Cos emphasized the identification of factors to prevent or to treat a disease. Cos concentrated on the individual and the environment, the population and geography, to determine those common characteristics and behaviors that would best explain and improve health.¹⁸⁸

Using the logic and deductive reasoning of the philosophers of his time, Hippocrates from Cos introduced rational thought in medical science. Hippocrates rejected the belief that disease came from supernatural causes. Plato and Aristotle had demonstrated how to approach a given problem – information was collected about the entire world, then one studied the problem and came logically to a conclusion. Aristotle urged intellectual debate and the use of scientific information where it was available, even undertaking dissection and describing his findings in a rational, logical manner. With this approach applied to medicine, Hippocrates urged the observation of everything that he could about an individual. He came to a conclusion based on this analysis, balancing bodily humours to explain an individual's physiological changes. Nevertheless, Hippocrates believed, "It is stressed that medicine is not an exact science."^{8,145}

For Hippocrates, observation and the maintenance of a record were crucial. But most records had to be kept in the mind as there were few practical means to keep vast amounts of individual related information in a retrievable fashion. Hippocrates, a keen observer, left records of different diseases, their circumstances and outcomes. Unfortunately, many of his detailed descriptions ended in the death of the patient as there was little that the medicine of the time could offer. Recorded as the Epidemics, several careful descriptions show

in great detail the deterioration that occurred with particular patients as they succumbed rapidly over a number of days to a deadly illness. Hippocrates included records of patients who had slept in temples and left writings of their suffering and pleadings to recover. The records were his observations, without significant input from others; poor methods existed to transmit records across generations and there was no practical way to collate vast amounts of data about a population for comparison.¹⁰⁹

Among the most important contributions of Hippocrates was his recommendation to observe any and all factors that might influence a particular individual. In *Airs, Waters, Places*, Hippocrates writes about observation and description, expressing deep concern for the environment, climate and way of life of the individual. He realized that disease changed the body within and that the physician needed to understand how and why from the outside. Observation was most important, observation of the patient, surroundings, and the circumstances of ill health. *Airs, Waters and Places*, pays particular attention to the seasons of the year, the winds and the quality of the waters when considering health and disease. This understanding that factors beyond the individual being are vital to an accurate description of health, public health and medicine was profound. Hippocrates adds, "From these things he must proceed to investigate everything else." The "everything else" was comprehensive in scope but dependent on his abilities; he talks of the conditions of the cities, their inhabitants and locations, and how important such data could be when studying health.^{5,109,145}

When he traveled to distant lands, Hippocrates maintained his powers of observation and noted differences in populations and circumstances. Writing of people near the Sea of Azov, Hippocrates states that, "I will leave out the minor distinctions of the various races."¹⁰⁹ He states, "First the Macrocephali; no other race has heads like theirs." "The chief cause of the length of their heads was at first found to be in their customs, but nowadays nature collaborates...."¹⁰⁹ These comments suggest that life experiences can affect physical appearance and may be of great importance. But Hippocrates goes on to say, "If therefore bald parents usually have bald children, grey-eyed parents grey-eyed children...." These passages suggest a fundamental knowledge of genetics and what would later become genomic studies and proteomics.¹⁰⁹

He writes of the Phasians, "The ground is often covered with mist. As a result of this the Phasians have peculiar constitutions. They are big and stout and their joints and veins are obscured by flesh."¹⁰⁹ Hippocrates understands that genetics has effects across populations, but might not affect every detail of an individual. There is a difference between genetics and developmental biology.

Hippocrates, both a physician and a surgeon, followed the school of Asklepios and the tradition to heal the sick but adhered more closely to the path of the daughter Hygeia, recommending health, diet and exercise. He emphasized athletics, often using athletes as examples for training, discipline and health, and felt that the physician should allow nature to heal the problem. Clearly, these thoughts refer to more chronic conditions since surgical problems would have been treated more urgently with the surgical methods and procedures of the time.^{5,188}

Hippocrates placed his observations of individuals and environments within a framework of physiologic elements. These elements were the four bodily humours: blood, black bile, yellow bile, and phlegm. The humours existed within the body and the external environment consisted of four cosmic elements: fire (hot and dry) earth (cold and dry) air (hot

and moist) water (cold and moist). Because the humours were limited to four, there were a restricted possible number of combinations ($4 \times 3 \times 2 \times 1$). This physiologic framework reduced the needed logical analysis to a small number of internal and external features. The framework left logical analysis to the individual and physician to find the path needed in order to balance the humours and the environment, the road to health. An individual was able to maintain a state of health through managing the humours in the proper proportion and controlling the body's heat and pneuma (breath) through food and breathing. An imbalance of these factors leads to distortions and the loss of health. Nevertheless, the data ingredients needed for analyses were few and could be determined by a single observer.^{8,188}

Consequently, treatments related to the balances among the humours. Although many recommendations were possible, the most common recommendation for severe disorders was bloodletting. The era of Hippocrates was known for removing blood from a vein to right an imbalance of the bodily humours. However, there are few records of the results of bloodletting and no large computations of successes and failures. The amount of blood to be removed depended on the degree of imbalance.^{56,189}

A larger number of humours would have made the number of combinations so large that no individual could have managed humoral imbalance without a more rigid and clear logical system. Through the use of logic and analysis, the physician would observe and deduce a conclusion.⁸

The four humours, their nature and balance, were at the center of analysis. There were few means to describe the observations, little opportunity to quantify signs and symptoms and nearly no way to trace a particular deductive process. Nevertheless, for the first time a formal rational method was applied to issues of health and disease and the making of medical decisions but there remained no way to retrace the process.¹⁸⁸

Beyond the powers of observation, there were few tools for Hippocrates to aid the measurement and tracking of the environmental factors. Individuals could be observed and the surroundings described but there was little that could be achieved except for recalling the observations at a later time. They did not have means to accurately compare observations, and fewer means to store the information recorded for later. Standardization relied on the individual practitioner. Brilliant physicians such as Hippocrates might recall individual cases, particular circumstances and may have been able to perform his own comparisons; the standardization of observation was impossible making broader descriptions unlikely; timely application of data also suffered as did the ability to observe changes over time, in different populations and different locations. Although he wrote descriptions of individual patients, the format did not lend itself to tracking similar diseases or comparing outcomes of treatments.

To study and promote health and medicine, Hippocrates saw that one had to gather a comprehensive amount of data, that environmental and personal experiences could have permanent, long lasting influence. Although not able to link such experience with the later development of disease, the thought process on his part was similar to that of public health today; unfortunately for him, the development of the genome and modern science weren't to come for thousands of years. But Hippocrates grasped that health and disease, public health and medicine, required vast amounts of information, in a format to allow comparison and tracking.

Public health and the health of populations were poorly developed at the time of the Greeks. There were epidemics and peoples suffered from waves of infections. Hippocrates knew of epidemics but all he could do was wait to determine when an individual needed help. He could not follow, predict, treat a population or prevent an epidemic. Outside of his observations and four humours, he could not understand or describe an epidemic. There was no model to prevent an epidemic. Because of the informational limitations, tracking the spread of an epidemic could only be achieved through messengers and word of mouth. Thus the concepts of endemic and epidemic disease were difficult to grasp. It was known that epidemics could be spread through populations by way of human contact; but since prediction was so poor, epidemics were often thought to be a form of divine retribution for an evil doing population.²⁰⁷

In contrast to the school of Cos which concentrated on observation, health and well-being, the medical school of Cnidus focused on bodily organs. The Cnidian classification paid less attention to the individual than to the characteristics of a particular disease. For example, 12 types of bladder infection, cystitis, were described. The Cnidian School receded in importance. Although a point of view seemingly correct from a contemporary point of view, there were few means to investigate health and disease to the depth that the Cnidian school required at the time.¹⁸⁸

The Hippocratic school and four humours maintained dominance for centuries until the scientific progress of the late medieval period and the Enlightenment. Advances in the eighteenth and nineteenth centuries allowed the development of pathology, histology, microbiology, and pharmacology so that an emphasis could once again be placed on a Cnidian type classification with concentration on organs and diseases. Despite its initial shortcomings, the Hippocratic view would support public health with societal influences, behaviors and the environment. Concentrating on organ derived illnesses, the Cnidian view would favor medicine and deep medical enquiry.

2.5

The Roman Systemization of Galen: Infrastructure Succeeds

The Greek world was followed by Rome, but medicine seemed to make only slow progress in the Roman era. The Romans were more concerned with maintaining their health, with exercise, with their way of life in a predominantly warm Mediterranean climate, rather than with disease.

Physicians in Rome most often came from Greece and often were not highly considered socially; in a way the Romans practiced what Hippocrates preached, maintaining diet and exercise in strict control and optimum balance. For many years the Romans translated and read the Greek authors in medicine rather than advance the study of disease. It appears that the best medicine of the time would be obtained by summoning a Greek physician to the bedside of someone ill in Rome. It was not until the time of Galen, AD 129–216 that progress was made once again.^{56,207}

Health advances in the Roman world occurred in the area of public health. The Romans concentrated on hygiene, sanitation and public baths, clearing swamps and delivering clean water to a population. As the empire expanded, the Romans understood that among their first obligations was the need for clean water and sanitation. The aqueducts that delivered clean water throughout the empire are still evident.

The Romans were not alone. Trends toward sanitation were widespread: Mohenjo-daro in India had rectangularly laid out towns, with sanitation ditches running alongside the road. The town of Kahun in Egypt was able to build a drainage ditch which ran down the center of the roadways. Clean water was also known to be important for maintaining health and avoiding disease: the Cretan-Mycenean culture built water conduits to maintain a steady flow of clean water; Troy had its own means to bring in needed water resources. The Incas achieved the same separation of clean and contaminated water. Thus, the separation of clean water coming in and sanitation waste going out developed.²⁰⁷

Mankind learned of the benefits of sanitation but the exact origins remain obscure. As there are not many historical observations, trial and error was probably the means to progress. Aside from observation, there were no means to measure health once the water supply system and aqueducts had been built. Clean water and waste disposal were confirmed benefits but disease in the face of such structures was still difficult to separate from the environment or from remediable causes. Epidemics recurred. The Romans kept better records and there was a certain amount of administrative data but it appears less attention was paid to disease.²⁰⁷

While medicine remained in the background, public health commanded massive projects with clear and widespread benefit. Unlike Greece which is blessed with abundant streams and water supply, Rome had to engineer theirs carefully. The Romans learned the association between swamps and disease. But despite the aqueducts and water delivery system, epidemics continued; they could not identify a common vector or agent and had no effective treatments. The epidemics were not well recorded or documented.²⁰⁷

About the second century AD, Rome instituted public physicians, *archiatri*, whose primary duty in each small town was to treat the poor. At this time the concepts of public health were beginning to emerge with individual physicians assigned to treat the poor at the public's expense. The information sources remained weak, largely dependent on individuals, without large scale means of surveillance or measurement. Comparison of several different approaches to individual cases was essentially impossible. The means of communication remained verbal, person to person with the variability that such implies and essentially no means to retain accurate records.²⁰⁷

A census of the baths was undertaken in 33 BC and the number rose gradually from 170 to nearly 1,000 afterwards. Under Augustus, a Water Board was established to oversee the water supply and the related structures of aqueducts and baths. This is among the first references to a consolidated department of public health that might be distantly familiar to what we have today. The primary task of the Water Board was the water supply and not directly the health of the population. A separate department was responsible for the public baths and a third for cleaning the streets. There is no reason to believe that any of these departments could monitor the health of the population; the departments were confined to counting and maintaining their structures. Nevertheless, these public health services under Augustus represent the organization of public health, well defined and executed but without the means to collect or share very much data.²⁰⁷

Through these efforts, the health of populations throughout the empire improved, whether to the north in Britain and France, to west in Spain or towards the east. Stability was the measurement of the benefits of the public work projects, the survival of the empire for so many centuries would support their importance. These enormous public works projects demonstrate that clean water was vital to the maintenance of the empire, although the

Romans might not have determined all of the causes and effects of sanitation in our current terms, through an empiric process they learned that clean water, baths and sanitation maintained health and raised the standards of a region.

An important feature of the Roman era was the development of “hospitals” for the military. Ever concerned with the health of the soldiers during the numerous battles to expand empire, the Romans made advances in surgery and the care of the wounded and erected facilities for their recovery. Roman surgeons, like the Greeks, learned mostly from the battlefield and animal dissection. As the Greeks had avoided human dissection, much knowledge of human anatomy came from the dissections performed by Egyptian physicians in Alexandria; their work handed down and translated for succeeding generations. Battles and the surgical treatment of wartime wounds allowed the study of anatomy to advance.⁵⁶

Aside from the translated case histories of Hippocrates, perhaps some knowledge of prior recorded patient diaries, there were no patient records from which conclusions could be drawn or collective data on a particular illness organized. Unlike the anatomical studies of Alexandria, where human anatomy was studied and recorded, patient case histories were most commonly preserved in the individual memory of a physician or family member without opportunity for later study or correlation.

Into this world came Galen of Pergamun, in Turkey, who learned from the Greek texts and became the leading medical figure of his time and for the next 1,000 years. Reading the works of Hippocrates, studying all of the literature that might have been available, traveling and observing advancing his own skills in medicine and surgery, Galen studied anatomy and physiology and wrote the texts that would dominate western medicine until the end of the Middle Ages.⁵⁶

His detailed dissections became the basis for study for generations, many of the manuscripts survived in various forms – and he advanced the study of physiology, applying careful analysis and investigation to the workings of the body in a systematic way. Unlike the Egyptians who felt the brain had slight value and was to be discarded upon death, Galen described the brain as the center of the nervous system since all nerve fibers lead in that direction. Similarly, he contradicted the prior Egyptian concept that air filled the blood vessels.¹⁷⁰ This was the beginning of the formal study of physiology; although he made many errors as his was just the beginning of the process to untangle the workings of the human body, in an environment where human dissection was not permitted, although likely secretly practiced. Galen gained knowledge from what he read and experience from battlefield surgery on gladiators and soldiers.^{85,189}

The era of Galen represents the advancement of science and the study of medicine, the method that would continue to the present time. Thus, Hippocrates, with his concern for the entire patient, the circumstances, the history and the observations, combined with Galen. Galen’s precise dissection, his study of anatomy, his attempts at modern human physiology that supported a more accurate picture than just the four humours of how the human body functioned, represent the founding principles of modern medicine. If one realizes the limitations that Galen faced, and accepts that he made many mistakes through investigative inability rather than approach, the tradition of medical study in the twentieth century really represents a continuation of his work. Many details have been added with discoveries over the past 2,000 years, but Galen’s style and method continue today.⁸⁴

So much of what he wrote was accurate, but areas of error remained as so much of human physiology could not be unlocked. Galen searched for a logical explanation of bodily function through the study of anatomy, dissection, and the description of a physiologic model. When an explanation was well founded, as when he traced a hand and arm problem to a point source of the median nerve, he was able to act logically. Nevertheless, when a model was lacking, Galen returned to the four humours and bloodletting as his remaining treatment choice. He approached bloodletting with the same vigor that he did anatomy, describing in great detail when and how much blood to remove and how to monitor an individual so that too much was not taken.²⁹

Galen wrote about the character of categories, the meaning of disease, and the etymology of words to convey the full meaning of particular illnesses. He understood the vagaries of labels and how imprecise some categorization was. He tried to incorporate this variation in his descriptions. As Galen well understood, variation is limited by definitions and the models that are used.¹⁰¹

In addition to Galen, the other dominant source of medical knowledge from the time before the Middle Ages was the Arab world. The Arabs had access to many of the Greek and Roman texts and preserved them; many such texts came later to Europe by way of Arabia in translation, without which many would have been lost. But the Arabs used their own powers of observation and experience and advanced medicine and surgery.

Among the best known works were those of Al-razi, the first illustrated surgical text was by Al-Zahrawi and the Canon on Medicine was written in 1010 by Ibn Sina. The use of the cautery and advances in ophthalmology as well as the addition of many drugs were added to medical science.⁵

Ibn Sina's work became the standard medical text in Europe in the twelfth century and was divided into sections on general principles, simple drugs, diseases of specific organs, diseases of the entire body and drug compounds. Although physiology and pathology were poorly developed, Ibn Sina's important contribution was the organization of disease by organ and those that were systemic in an era when there were nearly no diagnostic tests available.⁵

As was the case in the world of Greece and Rome, the Arabs had no means to retain patient histories or to analyze collective data over time; rather the best that they could do was to maintain the ancient Greek texts and add their own learned techniques. Aside from listening to a patient's story and then examining the patient, inspecting the urine of a patient was the most important diagnostic technique. Urine was analyzed in an extraordinary number of ways and observed for sediment, color, consistency. Attempts were then made to match the urine findings with a particular patient but this process was hindered by the paucity of patient case histories and the minimal knowledge of physiology.⁵ Remarkably, Arab physicians sometimes concentrated on the bodily organs and disease in a way similar to that of the Cnidians.

Nevertheless, when there were not surgical choices or specific medications for treatment, the Arabs advised exercise, a restful environment and sleep, especially for mental illnesses. As they also explained illness in terms similar to Hippocrates, they prescribed diets, baths and medications to increase the "wetness" of the body and force the drying up of the predominant black bile, if such was the problem. The Arabs often took the mentally ill into a more protective environment and utilized the physician's role as an educator and

the benefits of psychic healing. Words had a healing power as did music and recitations. Along the same lines of health, they recommended spacious surroundings, fountains and gardens and perhaps flowers for a positive olfactory response. Certainly, the Arabs had empiric understanding of the beneficial effects of the calm and supportive environment that they encouraged for those mentally ill at ease.⁵

2.6

Plague and the Collapse of Society: Infrastructure Fails

The Roman Empire was in decline from the third–fourth century AD onward. By the middle of the sixth century, there were two separate empires, one based in Rome and one in Constantinople in the East. The vast armies had deteriorated, the empire of vassal states stretching across Europe to the Middle East was contracting, the tribute that had flowed from the ends of the empire had ceased and the supply of manpower was declining. In this environment, the system of public health, the aqueducts and clean water that had sustained the empire as it advanced fell into disrepair. Much of the fundamental governmental structures that had made the empire so cohesive and powerful were deteriorating. Rome had one of the first widespread public health infrastructures in the world, but the infrastructure of public health and government had collapsed.^{56,208}

Into this world in disrepair and collapse came the plague. The plague had visited many of the cities of the Roman Empire every 15–20 years for centuries, leaving without inflicting complete devastation as the infrastructure was able to sustain. But with the collapse in the era of Justinian, the remnants of Roman society were no match for the plague infestation that fed on poor sanitation, poverty, filthy water, contaminated food and few means of central management. The plague of 542 AD was the first of many that would leave parts of Europe barren and empty. When the Empire had been strong, the organization of public health intact, the plague had been localized and controlled even though it struck periodically. But with the complete decline of the Empire, the bacteria of the plague found an environment without defense, the physical public health infrastructure in disarray.²⁰⁸

For the next eight centuries, Europe gradually recovered. Populations returned, agriculture improved, towns developed and the basic infrastructure replaced. Some believe, as the infrastructure of Rome had deteriorated in the sixth century through mismanagement and corruption, the infrastructure throughout Europe deteriorated through over farming and leveling the forests. Food and fuel were scarce; people were poverty stricken. Central town facilities had collapsed.

By the mid fourteenth century there were concentrations of population, in dire straits with minimal sanitation and weak economies, just the environment for the plague to flourish and wreak havoc again. Like the Roman Empire without its aqueducts and clean water, Europe in the fourteenth century was without its traditional physical infrastructure, meager though it might have been. The Plague returned. It struck Florence, Venice, crept stepwise fashion moving through the cities of Italy; although people heard of the plague's approach, of populations disappearing, of towns in despair, there was no protection and no defense. Lacking the basic necessities, food, fuel and labor, Italy and Europe were consumed.^{41,76}

Once a town was under attack, there was little to do. The wealthy would leave for the countryside if they could, to return when the terror had past. This was an unusual luxury. Faced with the first few deaths, entire households would be labeled as plague-ridden and isolated until the disease passed or everyone died. It was thought the plague came by caravan from the East. Fleas and black rats moved west; as the rats died out, the fleas which carried the plague bacteria searched for victims, often congregations of people, crowded, poorly nourished, miserable conditions of poverty, filth, carcasses, rotting vegetables and disease.⁴¹

The early physical signs were the swollen lymph nodes, especially of the groin as so many individuals were bitten by fleas on the legs. The fleas injected the *Yersinia* bacteria through the human skin only to have the infection progress to the lymph nodes in the groin for a momentary pause before flooding the entire body. Often the swollen lymph nodes would turn dark, the buboes of history. But this clinical course was not present in every person; there was no means to test each person to confirm a diagnosis. Without laboratories, the infective agent ragged unidentified.

Without treatments, as usual through history, populations turned to isolating an individual assumed to have plague, often sending them out of town or compelling a sign be placed on a home until the disease had moved on. But many people did not have a clinical history or signs suggestive of plague, without confirmation, one was just assumed to be infected when the devastation began.⁴¹

Many individuals might well have had a different disease, perhaps smallpox, perhaps the flu, perhaps a combination of several agents in an at-risk population. Typhus was endemic and often epidemic, and presented with acute delirium, and petechiae. Another possibility, although more rare, was meningococcus, an infection that attacks the central nervous system but can cause systemic and extremity injury and ultimately death. Plague was an all or none phenomenon: either one died or not when the epidemic struck. Prolonged symptoms or long term morbidity were uncommon, in part because so much infrastructure was missing that one had to fend for oneself.⁴¹

Why did plague die out? Populations were lost. The public health lessons of Rome were forgotten, the lessons of clean water, sanitation neglected. The diet and exercise, clean air, thoughts of the environment lost for generations – to return again after the fourteenth/fifteenth centuries. The world of Hippocrates, advanced by Galen, had to be recreated but first populations and economies suffered from losses of 50% of the people. Towns were abandoned, villages devoid of humans. The world of health, medicine and public health would have to be rebuilt – but medicine and public health which had been joined loosely for so many years would maintain an uneasy relationship for the next 500 years.^{76,116}

After the plague of 1348, there was no infrastructure, there was no way to find the source of the contagion, to separate cases of smallpox and typhus from plague, no treatments, no salvation, no information, few records, no data in retrospect of what had been. There remained only separation, isolation, and waiting for the end.¹¹⁶

Some peoples did survive the plague. The Bedouins went back into the desert, carrying their beliefs and behaviors with them. Their infrastructure intact, they lived and avoided the plague that swept through Cairo.¹¹⁶



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