CHAPTER 1

The Biological Baseline

THE DIET of most mammals is limited to one category—either animal or plant food—and often to only a few items within that category. Cattle eat grass, chipmunks eat seeds, and hyenas eat mostly carrion. Monkeys and apes, the human's primate relatives, are usually given both animal and plant foods in zoos, but few of them eat much in the way of animal foods under natural conditions. Humans, on the other hand, are distinguished anatomically and physiologically by the wide range of foods they can utilize. Their teeth include the cutting incisors of a rodent, the grinding molars and premolars of a herbivore, and the pointed canines of a carnivore. The human digestive system includes an extremely long gut that can digest green food, gastric juices that convert complex starches to simple sugars, pepsin that metabolizes proteins, and a pancreatic bile that emulsifies fats. No other mammals, with the possible exception of the rats and mice that live in human settlements, possess the same ability to adapt themselves to a variety of conditions—and consequently the capacity to evolve an enormous range of behavior connected with eating.

Thanks to omnivorous eating, humans are not dependent on particular foods and are therefore better able to find food despite plant blights, insect depredations, droughts, and other calamities. This enormous adaptability allows humans to move readily into new environments containing different food sources. Why, then, did not all mammals evolve as omnivores? One reason is that although omnivores do well at obtaining a wide range of foods, they may lose out to the specialized mammals that have become adapted to a specific diet. Omnivorous baboons, for example, cannot equal the efficiency of warthogs in digging out roots. Another reason is that being omnivorous demands a certain kind of intelligence. The world is filled with plants and animals that have little nutritive value, are difficult to obtain or to digest, or may actually be toxic; knowing what is edible and what is not requires both intelligence and memory. Whereas the specialized mammals have food-recognition programmed into their genes, an omnivore must be able to evaluate whatever potential foods the environment offers to make judgments about the relative merits of one food over another, and about the hazards of obtaining it. No wonder that only a few other mammals besides humans and certain other primates have evolved as omnivores—among them the garbage-feeding domestic rat whose fare includes lasagna in Italy, crêpes in France, and moo goo gai pan in China.

The human digestive system deals in essentially the same way with every cuisine. No matter how elegant the meal, whatever is eaten consists in the end of chemicals to be metabolized—that is, combined with oxygen, thereby releasing the heat that provides energy. This heat represents the calories about which so much confusion exists. A calorie (technically, a kilocalorie) is the amount of heat required to raise the temperature of one kilogram of water (about 2.2 pounds, a little more than half a gallon) by one degree Celsius (about 1.8 degrees Fahrenheit). Different kinds of food provide differing numbers of calories: Fats, for example, have two and a quarter times more calories than equal amounts of proteins or carbohydrates. Calories are needed to sustain the body even while it is lying completely at rest—about 1400 each day for an average North American woman weighing 121 pounds. Merely sitting up requires about seventy additional calories per hour, slow walking about two hundred, bicycling on a level road nearly three hundred, chopping wood more than four hundred, swimming as many as six hundred—and sexual intercourse about one hundred and fifty per orgasm. (To get an approximation of the number of calories needed for moderate activity each day, multiply your body weight in pounds by sixteen; active people should multiply it by twenty and those whose work is strenuous by twenty-four.)

Calories are essential for stoking the body's furnace; they become unwanted only when an excess of them is not burned up and instead turns to fat. North Americans are in general overweight, and those excess calories in the form of stored fat total about 2,300,000,000 pounds for all the adults in the United States alone. Recent calculations show that if these adults were to eliminate the excessive calories they have stored as fat, the slimming-down process would produce, in terms of fossil-fuel energy, 160 trillion BTUs—enough to run

about 900,000 automobiles for 12,000 miles a year. And if all of these same adults were to maintain their ideal weights, they would consume 97 trillion fewer BTUs each year, more than enough to supply electricity for a year to the residents of Boston, Chicago, Washington, and San Francisco combined.

For many North Americans, a dinner consisting of shrimp cocktail, T-bone steak, baked potato with sour cream, tossed salad with French dressing, hot rolls and butter, and apple pie à la mode, accompanied by wine and coffee, represents a special treat. To the digestive system, however, it is intrinsically just a collection of nutrients, forty-four kinds altogether, that go into the process of growth and the replacement of dead cells. Virtually all of the nutritional elements in this meal can be found on the shelves of a supermarket and a pharmacy—such as six and a half ounces of liquid protein, half an ounce of salt, about six ounces of sugar, somewhat less than three ounces of lard, thirty ounces of mineral water, and so on. These could be purchased at a considerably lower cost than would go into purchasing the foods on the menu. At 1979 prices, the cost of these equivalents in standard portions, as measured by nutritionists, was $4.25. (Technical data on the nutritional elements in this meal are in the Reference Notes on pages 224–25.) In other words, the cultural appetite for a tasty and varied meal, prepared in interesting ways, is irrelevant to the digestive process—so long as the preferred items continue to supply the calories and nutrients essential for sustenance.

What happens when the items in the dinner menu itself are eaten and digested? Contrary to the usual assumption, the digestive system is, in a sense, not inside the body, for all that it is sometimes referred to as "innards." It consists of a single convoluted tube, some twenty-eight feet long, with openings at each end—the mouth and the anus—which is enlarged at intervals for holding food and mixing it with glandular secretions. Foods in various stages of digestion are propelled along the length of this tube by muscular contractions. It is only after being mechanically and chemically reduced to particles simple enough to be absorbed that the nutrients enter the blood and the lymphatic system and are carried to the cells of the body. The digestive system is therefore an exterior part of the body in the same sense that the hole is exterior to the doughnut. Indeed, after being taken into the mouth, some food particles, such as the cellulose in bread and vegetables, travel the entire length of the digestive tract without ever entering the body itself.

In the mouth, the entranceway to the tube, food is chewed and broken into small pieces, which are mixed with the saliva that begins to break them down further. Just the sight of food will stimulate the glands to produce saliva—which is, of course, where the expression "mouth-watering" comes from. Whether or not food is actually accepted depends not only on whether it falls within the category of those foods considered to be edible by the society, but also to some extent upon sensory perceptions: appearance, aroma, taste, texture, and even sound. Color can be important, which is why a steak colored bright green would automatically be rejected. Food technologists add orange coloring to synthetic orange juice because marketing surveys have shown that people will not believe it tastes right unless it has the familiar color. Similarly, grape-flavored drinks are colored purple, cherry drinks red, and lemonade yellow (even though natural lemon juice is colorless). Texture and sound also have much to do with the acceptibility of food: The expectations are that an apple or celery will crunch in the mouth, whereas milk whose texture is curdled will usually be rejected.

Often, in fact, the sensory properties of food play a greater role in the choice of food than does nutritional value. The senses react to an almost unlimited number of chemical compounds that have odor, flavor, or taste. Odors do not spur us to eat until they have been evaluated by the brain; for example, the odors of milk and of after-shave lotion are both usually acceptable, but milk is associated with nutrition and after-shave lotion is not. Certain foods have been prized since ancient times because of their flavors rather than because of their nutritional value. During the wanderings of the Israelites in the Sinai Desert, they were provided as though by a miracle with a food they called "manna." (Considerable dispute has taken place about what this manna might have been; most probably it was the secretions of certain scale insects that feed at night on the tamarisk thickets of the Sinai.) The Israelites complained to Moses that manna had no flavor compared to the leeks, onions, and garlic (foods that are valued chiefly because of their flavor) and the fish, cucumbers, and melons (which offer strong and distinctive odors in addition to their nutritional benefits) they had left behind in Egypt.

A further example of the influence of aroma is hot chicken soup, sometimes called "Jewish penicillin" because of its reputed powers in curing colds and fevers. Its efficacy in speeding the flow of mucus through nasal passages has now been demonstrated. Volunteers who drank hot chicken soup showed a thirty-three percent increase in the velocity of the mucus; those who drank plain hot water also showed an increase in velocity, but at a much lesser rate, while those who drank cold water showed a markedly decreased flow of mucus. Drinking any hot liquid, either plain water or chicken soup, obviously increases mucus velocity, but chicken soup seems to provide some additional benefits in clearing the nasal passages, probably because of its aroma. Presumably other soups with distinctive aromas would produce the same effect.

The tongue samples the taste, texture, and temperature of food and then signals the body either to accept or to reject it. The surface of the tongue is covered with about ten thousand taste buds, which are clusters of sensitive nerve endings. These decline in both number and sensitivity with increasing age—people by the age of seventy-five have lost two-thirds of the taste buds they had at thirty, thus accounting for the common complaint by the elderly that food nowadays does not have the flavor it did in their childhood. Ever since Aristotle sensations of taste have traditionally been divided into four categories—sweet, salty, bitter, and sour—but scientists have long debated whether only four basic taste sensations exist or whether the tongue detects a spectrum of almost countless tastes, each somewhat different from all the others. Nineteenth-century researchers believed that the perception of taste was similar to color vision, in that several tastes could be mixed to produce a new one, just as mixing blue and yellow produces green. Taste, though, has been shown to be quite different. When foods with different taste qualities are mixed, these qualities do not fuse to produce a new taste but rather suppress or enhance one another: A salty substance added to a sweet one enhances the latter, whereas acid suppresses sweetness.

It is now known that the taste of water—which people often describe as being sweet, sour, bitter, salty, flat, or even having no taste —often depends on what food has just been eaten. Most people after eating an artichoke, for example, find that water tastes sweet. Although the artichoke has served as a food for humans for at least 2750 years, this phenomenon went unnoticed by scientists until about half a century ago, and it was not until recently that two substances in the artichoke that account for the transformation in the taste of water were isolated. These substances do not mix with the water; rather, they temporarily alter the taste buds of the tongue so that nonsweet substances appear to have been sweetened. For this reason the chemicals in the artichoke are now being investigated as possibly offering a substitute for sugar.

Taste and smell are quite different sensations; it is impossible, for example, to smell the sweetness of ice cream or the saltiness of fish. Cane sugar, maple sugar, and honey have the same sweet taste; they vary only in their aroma. Some people believe they detect a metallic taste in foods that have been canned or stored in metal pots; gastronomes accordingly recommend storing meat in wooden containers and stewed fruit in glass ones. North Americans have gotten so used to the metallic character of canned orange juice that according to marketing surveys they even prefer it to that of the freshly squeezed juice. What the metal adds, though, is not a taste but a smell, probably the effect of oxides. The more subtle flavors of foods are detected as aromas in the nasal cavity adjacent to the mouth. Sensory cells with this function are much more discerning than the tongue. The tongue can detect sweetness at a dilution of one part in 200, saltiness at one in 400, sourness at one in 130,000, and bitterness at one in 2,000,000—but odors can be detected at a dilution of one part in 1,000,000,000.

The detection of tastes has, throughout the evolution of mammals, undoubtedly been essential to survival. The evolutionary path from sea-dwelling creatures to modern humans has given us salty body fluids, the exact salinity of which must be maintained. The human desire for salt appears to be inborn, but it is also influenced by individual physiology. People who do not produce enough of certain adrenal hormones excrete salt in unusual amounts; consequently, their craving for salt leads them to douse even grapefruit with it. The tongue's ability to detect bitterness must have had great survival value throughout human evolution, since natural toxins usually taste bitter. A "sweet tooth" is inborn in all mammals, humans included, and it too is adaptive because sugars are a source of energy. Sugar became maladaptive—for the teeth, for the cardiovascular system, and for the entire metabolism of potential diabetics—only after humans learned to grow sugar cane and beet sugar in quantities much larger than had ever occurred naturally. If the assumption is correct that early human food habits were similar to those of modern apes and monkeys, then a marked craving for sweet foods such as fruit is part of the human evolutionary heritage. This heritage is reinforced in each generation by the sweetness of mother's milk and by even a bottle-fed infant's preference for sweet solutions over water.

The humans' very remote ancestors—those that some four hundred million years ago left the sea and took up life on land—were presented with a problem in swallowing that does not exist under water, where the liquid helps ease the passage of food through the mouth toward the gut. For land mammals, therefore, the salivary glands came to be of great importance, and so did the tongue for manipulating saliva-moistened food. Human culture has also contributed such means of aiding the passage of food through the mouth as lubricating dry bread with butter, margarine, lard, oil, or gravy. The chewed food is swallowed when the tongue catapults it into the esophagus, where muscular contractions squeeze it downward into the stomach. There, the semi-liquid mass is mixed with gastric juices. Among these is hydrochloric acid, which kills bacteria in food and drink, softens fibrous foods, promotes the formation of the digestive enzyme pepsin—and is also one of the most corrosive acids known. At the concentration secreted by the stomach lining, it is deadly to living cells and powerful enough to dissolve zinc.

Why, then, does not the hydrochloric acid cause the stomach to digest itself? Sometimes, of course, it does, as when emotional upsets, caffeine, or cigarette smoke markedly increase the amount of acid in the stomach, and ulcers are the result. For most people, though, a complex physical–chemical barrier that is not yet fully understood prevents the acid from corroding the stomach wall. During the digestion of a meal, which stimulates the secretion of hydrochloric acid, many tiny hemorrhages do occur in the lining of the stomach; these are usually superficial, and heal quickly. Alcohol and aspirin are common substances that can penetrate this barrier. A single aspirin tablet causes the loss of only about a thimbleful of blood, but in combination with alcohol it can lead to extensive bleeding.

After anywhere from half an hour to five hours in the stomach, the kneaded mass of the meal is flushed by muscular contractions into the small intestine, which is about twenty feet long in adults, and from which the bulk of the food is absorbed by the body. The small intestine is the place where many of the complex starches in the potato, roll, and dessert are reduced to the simplest sugars, which can be absorbed into the blood within about half an hour. The enzymes in the small intestine divide the proteins from the shrimp, steak, butter, sour cream, and ice cream into the amino acids that are found in all living things. The amino acids and the simple sugars, together with vitamins, are absorbed rapidly by the huge number of fingerlike cells that line the small intestine and extend into the liquid mixture of nutrients and digestive juices; the total surface area of these absorbing cells is about two-thirds that of a basketball court.

By this time, all that is left of the dinner this chapter started with are minerals, fluids, and the fats (triglycerides) in the steak, butter, salad dressing, and dessert. Fat takes some hours longer to digest than protein or carbohydrates; the more fat in a meal, the more slowly the stomach empties and the longer a person has the feeling of satiety. Alcohol takes longer to affect the person who eats fatty hors d'oeuvres such as cheese before drinking than the person who eats non-fatty ones such as carrot and celery sticks. That cheese eaten before drinking serves to "coat the stomach" (in other words, to protect it against the mechanical irritation of alcohol) is not the only reason for this. In addition, alcohol takes longer to reach the intestines, where the major part of it is absorbed into the body, when the accompanying fats cause the stomach and upper intestine to slow down the process of absorption. The minerals and fluids from a meal generally do not enter the body until they reach the large intestine, anywhere from twelve to seventy-two hours after being eaten. The large intestine also receives the undigested remnants of the meal, which represent about five percent of the total intake. Contractions in the colon push this soggy mass toward the rectum, absorbing water from it along the way.

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An understanding of the process of digestion does not, however, explain why humans every few hours halt their work, put aside their obligations, and seek out food. Until several decades ago, questions about this would hardly have seemed necessary. Since hunger was regarded as merely unpleasant churnings and spasms ("hunger pangs") of a stomach that had been empty for too long, filling it presumably stopped the pangs and the hunger as well. The same notion persists to this day, even though a moment's thought will show it to be an incomplete explanation of why people eat when they do. An empty stomach does not lead inevitably to eating. A sick person, for example, may not experience any desire to eat even when the body is in need of food. Scientists and dieters alike have observed that tobacco, caffeine, and alcohol can suppress the pangs of an empty stomach, as can a number of drugs. Various emotional states as well as vigorous exercise can reduce or eliminate the pangs of appetite. On the other

hand, a person whose stomach has been surgically removed may still experience feelings of hunger and satiety.

The motivation to begin eating now appears less dependent on hunger than on such psychological influences as the arrival of the usual mealtime or the sight and smell of food. Few humans in modern societies go without food long enough to know what real hunger is like; and research indicates that humans cannot gauge accurately the difference between slight and moderate hunger, so as then to make the appropriate adjustments in the amount of food they consume. Experimental animals have been shown to respond promptly and accurately to the need for calories, but humans possess no innate mechanism for distinguishing between meals with high calories and those with low. Instead, they rely on cultural knowledge and on trial and error. In one recent experiment, humans who were given meals in which the caloric content was disguised in gruel could not distinguish between one providing 3000 calories and another providing only 400.

People eat a lot or a little for reasons that obviously do not have much to do with their awareness of the food's energy value, but those reasons are subject to at least four internal controls that regulate the body's intake of calories and thus keep the weight of most adults nearly constant. First, the brain acts as a monitor of the store of body fat and the rate at which sugar in the blood is being consumed, collecting this information in a small organ at its base, the hypothalamus. Second, the body monitors the process of eating: The mere filling of the stomach and gut produces a signal to stop eating, even before sufficient time has passed for the nutrients to be absorbed into the bloodstream. Third, like all warm-blooded animals, humans possess internal regulators that adjust the body temperature within certain narrow limits in relation to the environment. Because eating increases body temperature, the familiar loss of appetite in hot weather is biologically adaptive, and so is the desire to eat more when air temperatures are low. Finally, from very early childhood through life, the learning of those food preferences and avoidances that become part of the personality has its effect on what and how much is eaten.

Scientific interest in the regulation of eating has shifted in recent decades from the stomach to the brain, which is nowadays considered to be in effect the first part of the digestive system. This function seems to be centered in the hypothalamus and in the associated pituitary gland. One part of the hypothalamus is a "stop-eating" center; when a laboratory rat is electrically stimulated there, it will not eat even though it has been deprived of food for a long time. Another part is a "start-eating" center; stimulation here will cause a rat that has just finished feeding to begin again. By operating alternately, the two parts of the hypothalamus initiate periods of feeding followed by periods of fasting, in that way maintaining approximately the same body weight day after day. A rat from which one of the two centers is surgically removed will either die of starvation in the midst of food or literally eat itself to death.

Such experiments show that animals do maintain their weight as a response to settings on their internal scale—and the same thing seems to be true for humans as well. Human patients with damage to the hypothalamus may display similar symptoms. Normally, though, humans exercise a much greater extent of conscious control over eating and drinking than do laboratory rats. When the hypothalamus signals hunger, a human may respond in any number of ways that are not possible to the rat exploring a laboratory cage for food. A rat cannot go to the refrigerator, or shop at a supermarket, or panhandle for a coin to buy a cup of coffee, or draw a picture of something delectable to eat—or restrain itself out of a resolve to lose weight. The internal regulators in the brain that tell humans to eat every few hours can be overridden by cultural attitudes, as a result of which people may be in the habit of eating anywhere from one to six meals a day, or none at all because they are fasting. Feelings of revulsion about certain foods may also cause people to starve themselves rather than eat a food their culture has labeled inedible—as happened during World War II, when United States pilots in the Pacific went hungry because of cultural inhibitions against strange sea creatures, lizards, toads, and insects, even though they had been taught that these could safely be eaten.

The reason humans eat or do not eat is explicable neither in terms of a full or empty stomach nor as a result of any mechanism operating in isolation—such as the level of sugar in the blood, the emptiness or fullness of fat cells, or a need for caloric energy. Moreover, even if a combination of mechanisms does send humans in search of food, no single part of the brain dictates that they will eat the food once it has been found, since it might turn out to have been labeled as inedible by the particular society. In the final analysis, whether or not humans eat depends upon the interactions among numerous physiological and environmental variables.

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Why humans eat is one thing, and another is what they eat. The chemical compounds obtained from food by the human body are classified as proteins, carbohydrates, fats, vitamins, and minerals. Proteins make up part of every living cell, and would in fact account for half of the weight of the entire body if all its fluid content were drawn off. Muscle, bone and cartilage, skin, membrane tissue, hair, and just about everything else are composed at least partly of protein. The protein content of food is resynthesized by the digestive process into new forms of protein that the body can use for its growth and maintenance. A North American male between eighteen and twenty-two years of age who consumes about two ounces of protein a day—the equivalent to that in three hamburger patties—is getting all he needs, including a slight surplus to draw upon in the event of injury or disease. The body can tolerate as much as five or six times that amount of protein a day—so long as sufficient water is drunk to help the kidneys dispose of their accumulated nitrogen—but no benefit from an excessive intake of protein has ever been demonstrated beyond its caloric energy.

Carbohydrates are occasionally scorned, especially by some proponents of miracle ways to lose weight, as providing only empty calories (that is, energy without much nutritional value). The accusation is justifiably made, however, only against refined carbohydrates such as honey (refined by bees) and table sugar (refined by humans from beets or cane), which are indeed lacking in such nutrients as are found in the raw carbohydrates provided by maize, wheat, and potatoes. A shortage of carbohydrates in the diet can bring about harmful biochemical changes. For example, glucose, which is one of the carbohydrate molecules, is being continually absorbed by the brain at a rate of some five hundred calories every twenty-four hours. To supply this glucose to the brain alone—quite aside from the needs of the rest of the body—a 125-pound woman requires about four and a half ounces of carbohydrates a day. Any reducing diet that reduces calories at the expense of the carbohydrates necessary for the brain to function must obviously be dangerous to health. If not enough carbohydrates are eaten at least every twelve hours—as they are not in some reducing diets—the liver must draw upon the protein stored in the muscles to supply glucose to the brain. If the liver cannot do this, the metabolic changes associated with starvation begin to appear. A rapid drop of ten percent in the amount of glucose available to the brain can cause mental confusion; a twenty-five percent drop leads to coma and cell damage; a drop even slightly greater can be fatal.

Although many athletes believe that they need large steaks at the training table to build up muscles, beef is really no better as a source of protein than pork, poultry, cheese, or even vegetables in balanced combinations. Instead of building up an excess of protein, athletes should concentrate on building up a reserve of stored glucose, which comes from carbohydrates, as fuel for prolonged physical exertion. This can be brought about by a temporary change in the usual patterns of eating. For several days before the particular event, the athlete consumes a diet consisting mainly of protein and fat, with a minimum of carbohydrates, and exercises to exhaustion the muscles that will be used. The day before the event, large portions of carbohydrates are added at each meal with the result that glucose will be preferentially stored in the muscles at a level almost double what it is normally, where it will be drawn upon for the needed energy.

The high esteem in which fats were once held is clear from many references in the Old Testament. In the book of Genesis, for example, Abel offers Yahweh "the firstling of his flock and of the fat thereof" (4:4); and Pharaoh promises Joseph that if he and his brothers settle in Egypt they "shall eat of the fat of the land" (45:18). Although nowadays fats have a poor reputation, they are important nutritionally for a number of reasons. They are essential for the absorption of fat-soluble vitamins from the digestive tract. Certain fatty acids (such as those in oil made from maize, peanuts, and soybeans) are necessary for the growth of very young children, and in smaller amounts are needed also by adults. Fats remain in the stomach longer than almost any other kind of food, and thus produce a feeling of satiety. A meal in a Chinese restaurant—which often consists mostly of fish, chicken, rice, bean curd, and vegetables—is low in fat, and this is the reason why people complain of being hungry again only a few hours afterward.

Evidence of the role played by vitamins—or at any rate by one of them, vitamin C (ascorbic acid)—was available as long ago as the time of Columbus. Some of his sailors who showed symptoms of what is now known to have been scurvy—pain in the joints, hemor-

rhages of the blood-vessel walls, and a loss of weight—were left behind on a Caribbean island, where they lived on fruit and recovered. Later they were picked up by a Portuguese ship, and so miraculous did their recovery seem that the Portuguese word for "cure"—Curaçao—was given to the island, a name it bears to this day. Despite the experiences of these and later seamen, the causes of scurvy were not established until the eighteenth century, when James Lind, a physician for the Royal Navy, carried out an experiment. When he divided seamen suffering from scurvy into six groups, and fed each group on a different diet, the only men to show rapid recovery were those who every day had been given the juice from oranges and lemons (which are, of course, rich in vitamin C). Although he published his results in 1753, it was not until 1795 that the Admiralty made a citrus ration compulsory, thereby freeing the fleet from scurvy by the time of the sea battle against the French at Trafalgar in 1805. The British at that time used the word "limes" for what are known as lemons today; the warehouse district around the London waterfront where the fruit was stored got the name of "Limehouse" as a consequence, and the British sailors were nicknamed "Limeys."

Vitamins consist of two large groups: those that are fat-soluble (A, D, E, and K) and those that are water-soluble (notably C and the nine B vitamins). Fat-soluble vitamins, as their name indicates, occur in fatty foods such as oils and meats, water-soluble vitamins mostly in fruits and vegetables. The latter tend to leach out into the water they are cooked in. This vitamin-laden "pot likker" was eaten by the black population of the southern United States—with the result that they were generally better nourished than whites at the same economic level, who regarded drinking it or even using it in soup as socially unacceptable. Of the four fat-soluble vitamins that are stored in the liver, where they form a valuable reserve, vitamin D is a natural constituent of only a few foods. Small amounts are found in eggs, cream, and butter, and somewhat larger amounts in fish. Otherwise vitamin D must be manufactured in the outer surfaces of the skin by the action of sunlight. Since vitamin D is necessary for depositing calcium and phosphorus in the bones, children who are largely deprived of sunlight—such as those who are brought up in the narrow, smog-darkened streets of northern slums—often suffer from the crippling disease known as rickets. Over the past several decades, pasteurized milk has been fortified with vitamin D as a means to prevent it.

No disease resulting from a deficiency of the fat-soluble vitamin E has ever been found, although experiments with rats indicate that it is necessary for reproduction. Vitamin A is usually associated with carrots, with other yellow vegetables such as sweet potatoes and squash, and with fruits such as peaches and cantaloupes, though what they contain is the hydrocarbon pigment carotene, which is converted into vitamin A by the liver. Some dark green vegetables (for example, spinach, turnip greens, asparagus, and broccoli) are also rich in carotene, the yellow of the pigment being masked by the green of chlorophyll. Animal livers are the richest source of vitamin A; the older the animal, the greater the concentration of the nutrient, making beef liver a better source than calf liver. A folk belief that eating quantities of carrots allows a person to see in the dark has no basis in fact, other than that one symptom of vitamin A deficiency is an inability to adapt quickly to changes in the intensity of light. Nevertheless, the belief is so ingrained that during World War II the Royal Air Force was able to keep the invention of radar secret by declaring the great accuracy of British fighter pilots at night to be the result of superior vision achieved by eating enormous quantities of carrots. Since the Germans subscribed to the same folk notion, they believed the story.

About fourteen minerals (among them calcium, phosphorus, iron, copper, iodine, and fluorine) are found in the human body, and with one exception—iron—these are easily obtained from the normal diet. Particularly for a woman who is menstruating, pregnant, or nursing an infant, sufficient quantities of iron are extremely difficult to obtain except by eating large amounts of certain foods—notably liver, beef tongue, certain leafy vegetables, dried fruits, and nuts. Since even inorganic iron can be absorbed by the body, a soup or a stew simmered in a cast-iron pot will usually be enriched by the leaching of mineral traces from the pot into the food. The problem of obtaining sufficient iron is further compounded by the fact that only about ten percent of the amount eaten is absorbed by the body. A deficiency of iron can lead to a form of anemia that has been common at various times and places. The "greensickness" mentioned by Shakespeare and other Elizabethans as a disease of women—as when Juliet is berated by her father for having fallen in love with Romeo: "Out, you greensickness carrion!"—was almost certainly anemia.

Several attempts have been made to determine the allowances of these nutrients that will satisfy the needs of all human beings. Such are the Recommended Dietary Allowances (RDA), which often appear in abbreviated form on the labels of prepared foods, and which have been established by the United States Food and Nutrition Board and by the British National Committee on Nutritional Sciences. Such recommendations should not be looked upon as requirements; they are, in fact, deliberately calculated in excess of the needs of most people under current living conditions in the United States and Britain, as a way of insuring that the needs of all are met.

That everyone leaves a unique set of fingerprints is a fact readily accepted, yet little attention has been given to the uniqueness of the nutritional blueprint for every human body. Two individuals of the same age, sex, and physical proportions do not have precisely the same metabolism. One of them, in fact, might burn calories ten times faster than the other because of the varying rates at which the chemical reactions involved in metabolism take place. Extensive studies have shown that some healthy people secrete as much as two hundred times the amounts of pepsin and hydrochloric acid secreted by others equally healthy. Even more surprising is the discovery of some women in India who synthesize vitamin C—a feat of which the human body was thought to be incapable.

Another enigma has come to light in New Guinea in a nutritional study of about five hundred children. As many as seventy-four percent of them were subsisting on a diet so extremely deficient in both calories and protein that they could have been expected to exhibit clear signs of malnutrition—yet the only visible effect was that they grew more slowly than white children in North America and Britain. Not only did the children seem to have no ill effects from this diet; the health of young adults also was good, and adult females paid no penalty in decreased fertility. How are these findings to be explained? One possibility is that estimates of food requirements using North America and Europe as the standard may not necesssarily apply to other populations of the world. Some of those who have investigated the problem believe further that New Guineans might have a special kind of nutritional adaptation. For example, one highland group consumed an extremely unbalanced diet: between eighty and ninety percent of their calories from a single food source, the sweet potato, a mere four percent from protein sources, and the remainder from leafy vegetables and beans. Metabolic studies of these people show a number of anomalies that have yet to be explained, but which suggest that they might possess unusual intestinal bacteria that fix nitrogen (an essential component of protein) in the same way as do bacteria in the roots of soybeans and alfalfa—thus becoming what one investigator has labeled "walking legumes," equipped to thrive on carbohydrates and a minimal amount of protein.

No wonder, then, that nutritionists have great difficulty in recommending an appropriate daily intake of various nutrients for people generally. The problem is compounded by the fact that not everyone eats every part of every kind of food. Those, for example, who peel off the skin of a white potato and then boil it or make French-fries have thrown away about twenty percent of the nutrients it contains. Each year an average North American family of four throws out more than a hundred pounds of potato peelings—losing thereby the equivalent of the iron from five hundred eggs, the protein from sixty steaks, and the vitamin C from nearly two hundred glasses of orange juice.

These are not the only problems in the way of standardizing nutritional requirements. Another difficulty is that variations in the chemical form in which a nutrient enters the digestive tract largely determine whether it is absorbed and utilized by the body. Only about ten percent of the form of iron found in red meat is absorbed—and it may be less if the meat has been eaten along with substances that inhibit its absorption, such as the oxalic acid in spinach. (Spinach also binds calcium and prevents its absorption by the body. Well-intentioned parents who provide children with spinach and milk—each in itself a nutritious food—at the same meal are actually preventing the body's utilization of the calcium in the milk.) A second complication has to do with the bacteria that are permanent inhabitants of the large intestine, where they live on organic molecules from food and contribute to the digestive process by manufacturing vitamins, particularly K and some of the B vitamins, which their human hosts absorb. Ill health or an unbalanced diet would tend to inhibit this activity, and in that event some additional nutrients would be needed.

A third major complication is that the absence of just one nutrient may prevent the utilization of others. The human body cannot synthesize protein without amino acids; most of these can be synthesized by the body, but anywhere from eight to ten of them, depending upon a person's age, can be obtained only from the food that is eaten. If just one of these is absent from a meal, then none of the others can be utilized fully by the body. And to the extent that a single one is insufficient, then all become equally insufficient. Animal products—meat, fish, poultry, eggs, milk, cheese—supply all of the essential amino acids in the necessary proportions, but plants usually lack at least one of them. Maize, for example, lacks lysine and tryptophan; beans and peas are good sources of lysine but lack methionine; leafy green vegetables contain the tryptophan that is absent from maize but lack other essential amino acids. Every culture—through a long selective process—has surmounted the deficiency of plant foods in amino acids by developing dishes that combine and balance them. Mexicans eat beans, rice, and leafy vegetables with a maize tortilla; Jamaicans eat rice, wheat, or maize combined with peas; many American Indians ate succotash, a combination of maize and lima beans.

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Although a proper balance of proteins, carbohydrates, fats, vitamins, and minerals is obtained most readily by eating both animal and plant foods, in some societies the diet seems to consist of either meat or plant food almost exclusively. Certain Eskimo groups, for example, were long thought to subsist solely on meat. When hunting had been good, an adult might eat as much as twelve pounds of it a day. One would think that Eskimos pay a nutritional penalty, but studies reveal that most of those living on a traditional diet suffer from no major nutritional diseases. Several things account for their ability to achieve a balanced diet even though they inhabit an environment where few plants grow. One is that in fact they do eat some plant foods. Many of the more southerly Eskimos gather a variety of wild plants for food, and even the northern Eskimos manage to obtain them in small amounts—mainly roots, berries, and the buds from willow thickets on the tundra, supplemented by the fermented stomach contents of plant-eating mammals such as the caribou they hunt. These stomach contents are in fact regarded as a delicacy and, although meager in quantity as compared to the large amounts of meat that Eskimos consume, they are rich in carbohydrates and in the many vitamins synthesized by bacteria during the process of fermentation.

Another reason Eskimos are well nourished is that they consume nearly all parts of the animals they kill, including the internal organs, which furnish virtually the entire range of vitamins and minerals they need. One comparative study of an Eskimo diet showed ten times more of vitamins A and D, and also more iron and other minerals, than in an average North American diet. A deficiency of vitamin C might be expected to be particularly common among Eskimos, since they lack the vegetables and citrus fruits that are primary sources of this vitamin, yet cases of scurvy are almost never found among them. This is because meat contains small amounts of vitamin C, and these are not lost in cooking, since Eskimos either eat their meat raw or roast it only slightly. Vitamin C also occurs in willow leaves, and some berries that grow on the tundra are exceptionally rich in it; these are preserved for the winter in seal oil, which happens also to be an excellent source of vitamin A. In summary, the traditional adaptation of the Eskimos to the far north requires no arcane knowledge of nutrition to keep them well nourished during most of the year. Only in recent decades, as the Eskimos' way of life has changed and they have begun to consume increasingly large amounts of processed foods bought at trading posts, have nutritional diseases become common.

At the opposite extreme from the meat-eating Eskimos are those peoples who consume plants almost exclusively. Some are vegetarians by necessity, because they have no money to buy meat, or because neither wild nor domesticated animals are abundant where they live; others may abstain from meat as a result of ethical or religious sanctions. Most vegetarians by choice do eat some animal products in the form of milk, butter, cheese, and eggs, which even in small amounts contribute important nutrients to what is basically a plant diet. Some people described as vegetarians, though, do not really fit the category. The Amhara of Ethiopia observe approximately 150 fast days each year during which they eat no flesh from either birds or mammals and no milk products; and especially pious people observe 220 such fast days. They are allowed fish at these times, though, and during the remaining days of the year the Amhara eat enough animal foods to give them a balanced diet.

Some of those who are vegetarians by choice point to the successful adaptation made over a few thousand years by adherents of Buddhism, which preaches vegetarianism because of a moral repugnance toward the killing of animals. Although it is true that a devout Buddhist will not knowingly deprive any creature of life, it is not true that Buddhists in general consume no animal products whatever. Many eat butter and drink milk, and in some countries that are largely Buddhist—among them Tibet, Sri Lanka, Burma, and Thailand—even the priests eat meat. In India, those belonging to the lower castes eat meat whenever they can obtain it, and those belonging to the higher castes often eat eggs, cheese, and butter (while some of the more liberated urban dwellers even eat meat itself). In China, both Buddhist and Taoist influences have discouraged the eating of meat, yet complete vegetarianism has not generally been practiced except by the clergy and a small number of particularly devout people.

Many people in the world are, of course, vegetarians by necessity rather than choice. The typical peasant of Gambia in West Africa consumes various cereals (most commonly rice, but also millet, sorghum, and maize) as well as nuts, beans, green leaves, and fruits. This is not to say that the peasants prefer such a diet; they readily eat meat, dried fish, and eggs on whatever rare occasion any of these can be obtained. As a result of having been forced to subsist on a low-protein, high-carbohydrate diet, many Gambian peasants suffer cirrhosis of the liver, pellagra, beriberi, kwashiorkor, and other deficiency diseases, all of which become particularly evident during the "hungry season"—those months each year after the food from the previous harvest has been used up and before new fields have begun to produce. At such times, energy must be obtained by drawing on the body's store of fat; consequently, adults lose weight and the growth of children comes nearly to a halt. Things would be even worse for the peasants if they were not able to obtain small amounts of protein from insects, rodents, and other small animals that North Americans and Europeans would regard with repugnance as a source of food.

Although little meat is eaten in certain societies simply because it is so rarely available, no society has ever been discovered that is exclusively vegetarian. The reason apparently is that such a society would not be able to produce offspring generation after generation, and it would eventually die out. One reason for this is the obvious fact that diet affects the nutritional quality of a mother's breast milk. Any woman who adhered strictly to a vegetarian diet, one not including even eggs or milk, would lack vitamin B_{12}, which is obtained almost exclusively from meat and animal products and which is essential to avoid anemia. Nevertheless, it is possible to achieve a healthy diet from plant foods alone, so long as they are combined in accordance with current nutritional knowledge and are occasionally bolstered by nutritional supplements. This was demonstrated by a study in Israel of some eighty strictly vegetarian households, who were satisfactorily nourished by consuming a wide variety of plants that complemented one another in providing essential amino acids and vitamins. Dishes made from sesame seeds and soybeans provided calcium, iron, and thiamine; wheat germ and bran were excellent sources of iron and B vitamins; vitamin A was obtained from carrots and leafy vegetables, vitamin C from green peppers and guava.

Before anyone concludes from this study that a strictly vegetarian diet provides adequate nutrition for all people, several facts must be emphasized. First, these Israelis belonged to the urban middle class and therefore both could afford a varied plant diet and were able to purchase it in convenient city markets. Furthermore, as members of the Israeli Vegetarian Association, they made a practice of being well informed about nutrition and the need for vitamin supplements. The same cannot be said of Gambian peasants or of any other peoples who are vegetarians by necessity. Nor were the knowledge of nutrition, the long-distance transportation necessary to import a variety of plant foods, or today's vitamin supplements to be had during the more than 99.99 percent of evolution in which human adaptations to eating took place.

Such adaptations made over long periods of time can often explain differences among human groups in regard to physique, body dimensions, and the size of the face and skull. Anthropologists used to attribute such differences solely to the genetic makeup of populations, but many physical characteristics are now known to be influenced greatly by diet. Two groups of the Hutu people of Ruanda, for example, subsist on markedly different diets and also exhibit marked differences in their size and physical proportions, even though they are genetically similar.

If a superior nutrition can indeed promote growth, will not an improved diet eventually produce a human species of such gargantuan size that it is destined for extinction, as happened to the Irish elk and the giant dinosaurs? A study of Harvard students published in 1932 did seem to give support to this notion. On the whole these male students were distinctly larger than their fathers had been at the same age; and similar increases in size appeared to have been occurring from one generation to another. A more recent study, though, found that no further increase in stature had occurred among Harvard students. For the United States population as a whole, data from the National Center for Health Statistics show average gains in height for both males and females totaling about four inches over the past hundred years—but, as was true for the Harvard students in recent decades, the trend toward increased size has virtually ceased.

Such increases in stature are a phenomenon that has been observed in many parts of the world during the past few centuries, particularly in modernizing nations. The increase is strikingly evident during a visit to a museum or a historic home; clearly, most humans living nowadays in Europe or North America would have trouble fitting into those small beds or suits of armor. Between 1880 and 1960, the average height of French army conscripts increased by nearly two inches. An increase was also observed among Japanese immigrants into Hawaii and the two subsequent generations of Japanese–Hawaiians born there. The average stature of first-generation males increased by more than four inches over their immigrant male parents; in the second generation, though, no further increase took place. For females the pattern was different: The increase in stature was much slower, but it took place for both generations born in Hawaii, eventually totaling nearly three inches.

No explanation based on genetics can account for all of the observed facts, and neither do most environmental explanations, except where a change in diet is taken into account. The diet of the two generations born in Hawaii included much more protein and calcium than had been commonly eaten in Japan. Why, though, did a difference in patterns of growth occur between males and females? Culture undoubtedly played an important part. Whereas the Japanese immigrants were concerned that their sons should adopt the new Hawaiian ways, including the superior diet, the daughters were frequently kept at home, where they had only the traditional foods available. Furthermore, the preferential treatment given Japanese males meant that they were served first and that the females of the household ate only the leftovers. Being better fed, the males could reach their genetic potential of growth much more rapidly than the females, who required two generations to achieve the same thing. But once an improvement in diet had brought their stature to the genetic potential, further increases for either sex ceased.

Although the phenomenon of increased growth is apparently both genetic and environmental, changes in the latter, especially in regard to nutrition, have obviously been more influential. This may explain why, despite the worldwide increase in the stature of adults, the size of infants at birth has not changed appreciably over the past several centuries. Once the outer limit for growth set by genetics has been reached by an individual who is well nourished, further increase in growth is halted. Increases in stature such as occurred from generation to generation in Hawaii and elsewhere can be explained as beneficial adaptations to an abundance of food: The added size, in well-fed individuals, allows a diet high in calories to be metabolized more easily. Once the genetic limitation on size has been reached, however, an excess of calories results not in more growth but in added fat, leading to circulatory disorders and various diseases associated with obesity.

These changes in stature are an illustration of how eating, culture, and biology cannot be separated from one another—and that indeed, as elemental facts of existence for the human species, they are in constant interaction. Every animal species is unique in the kinds of food it takes from the environment and the ways in which they are metabolized. But human metabolic needs are like those of no other animal, in being continually influenced by culture. The human adaptation thus produced did not develop suddenly or by some accident of history; rather, it emerged by degrees along the unique evolutionary path taken by the ancestors of modern humans.

CHAPTER 2

The Emerging Human Pattern

HUMANS—from the tips of their fingernails to their facial proportions—have been shaped by the ways they acquire and utilize food. The exact details of how humans gradually developed into omnivorous animals with a wide range of cultural associations between eating and social behavior, symbols, status, and sexual relations can never be known for certain. A surprising number of facts about the origins of the human diet can, though, be inferred from observing our living primate relatives among the apes and monkeys, from fossils, and from surviving hunter–gatherer societies. A number of biological and behavioral features that are the foundation for the way humans eat were inherited from the primates, whose living species display them in rudimentary form: adaptability in foraging, the occasional sharing of food, and clear preferences for certain foods and ways of obtaining them. The physical structures inherited by humans from primate ancestors include mobility of the digits, a reduction in the size of the snout and the teeth, and stereoscopic vision.

Most apes and monkeys are adapted to a diet of plant foods, and some—such as the colobus and howler monkeys, and the gorilla—even have specialized digestive tracts whose lengthened intestines can cope with the leaves that are indigestible for almost all other mammals. Many other primates are more omnivorous, and some feed on a wide variety of roots, seeds, fruits, flower buds, nuts, and such animal foods as insects, bird eggs, reptiles, even other primates. In zoos, almost all primates easily adapt to a diet of chow and offal, along with the peanuts and ice cream offered by visitors. Despite the basic orientation of apes and monkeys toward plant food, the need for vitamin B_{12} means that they must eat some food of animal origin to survive—as they all do, either intentionally or unwittingly, in the form of insects that are consumed along with the plants they feed on.