
An Evolutionary Foundation for Health Promotion

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From a strategic standpoint, contemporary health promotion research appears illcoordinated, duplicative, and underproductive, suggesting that scarce resources, including personnel, facilities and financial support, might be utilized more economically and effectively. Furthermore, the field's current disarray makes it difficult to accommodate inconsistent investigative findings, thereby promoting public confusion and skepticism. For example, in 1994 the *New England Journal of Medicine* [1] declared that health-conscious Americans '...increasingly find themselves beset by contradictory advice. No sooner do they learn the results of one research study than they hear of one with the opposite message.'

In his highly regarded essay, *The Structure of Scientific Revolutions*, Thomas Kuhn argues that mature sciences operate under the aegis of a governing paradigm, an underlying thesis that serves as the foundation for a particular research tradition and which is essential for selection of appropriate, potentially fruitful investigative efforts [2]. Proponents of Darwinian medicine maintain that a fundamental weakness of prevention research to date has been its lack of just such an integrated theoretical basis, a Kuhnian paradigm, and that this deficiency might be remedied by adopting an evolutionary perspective. For this approach, a proposed axiom would be that the genetic basis of current human metabolism and physiology was established during the evolutionary experience of our remote forebears. Over millions of years alterations in ancestral lifeways occurred slowly, in

concert with appropriate genetic selection. However, subsequent to agriculture, and especially with industrialization, genetic adaptation has been unable to keep pace with cultural change so that our genetically determined biology and the circumstances of our lives are out of alignment. A logical extension, that the resulting mismatch fosters chronic degenerative diseases, could serve as the unifying hypothesis for prevention research in multiple disciplines, including those related to diet and exercise. After sufficient investigative testing an ultimate corollary may emerge: health promotion recommendations should aim at recreating the essential features of ancestral human existence, especially as experienced throughout the Paleolithic, that evolutionary segment during which the defining characteristics of our species were selected.

Adoption of a foundational paradigm for any field alters the gestalt through which investigators view natural phenomena, affects both the acquisition and interpretation of data, and profoundly influences research agendas. These considerations impact evolution-oriented health promotion research in two related spheres:

- First, accurately characterizing conditions which refined the current human genome, including dietary and physical activity patterns, should become a vital focus, generally recognized as central to disease prevention research. Subject to modification as our picture of the past becomes clearer, current understanding is that: (1) physical activity, a component of total energy expenditure, was typically four times that of affluent Westerners [3] and (2) Stone Age diets generally provided abundant protein, fiber, and micronutrients, but little sodium. Intake of carbohydrate (fruits and vegetables, not grains) and fat varied reciprocally with latitude, but rarely afforded high levels of serum-cholesterol-raising saturated fatty acids and usually yielded an ω -6: ω -3 ratio approximating unity (vs. ~ 16:1 for Americans) [5]. This current overview will undoubtedly be modified and expanded as its paradigmatic significance becomes better appreciated leading to more intensive investigation.
- The second sphere involves generation of novel, potentially fruitful lines of investigative endeavor. The experimental methods themselves would continue practices and techniques previously established by epidemiologists and other prevention researchers. However, the hypotheses to be tested would be logical extensions of a basic proposition. As contemporary human experience comes to differ from that of our ancestors, health is adversely affected and the greater the difference, the more detrimental the impact. Conversely, interventions designed to bring contemporary life into accord with ancestral patterns should improve health. Many projects in keeping with this line of reasoning might be proposed, but for this paper, only three examples will be discussed: (1) fruits, vegetables, grains and cancer; (2) dietary factors, physical activity, and age-related fractures, and (3) body composition, physical activity and insulin resistance.

Fruits, Vegetables, Grains and Cancer

For 50 million years the main energy source for humanity's primate ancestors was naturally occurring fruits and vegetation. No free-living primates except humans regularly consume cereal grains. However, since the emergence of agriculture, corn, wheat, rice and their like have provided from 40 to 90% of our caloric requirements. Epidemiological studies indicate that fruits and vegetables have substantially more cancer-preventive activity than do grains [6, 7]. In one meta-analysis, vegetables exhibited preventive effects against 16 different cancers (of 18 studied); fruits were similarly active against 12, but cereals appeared to have (modest) preventive effect against only one [7]. This striking difference may reflect the intrinsic phytochemical content of these food categories. The phytochemicals of fruits and vegetables are ones to which current human biology became adapted over a many million-year subsistence relationship, but cereal phytochemicals have routinely interacted with our physiology for only 10,000 years (or less). Epidemiological findings that fruits and vegetables have more cancer preventive potential than cereals are thus supported, and partially explained, by evolutionary understanding.

Further insights arising from such awareness are that (1) the partial replacement of fruits and vegetables – as a proportion of total energy intake – by cereals which occurred after the emergence of agriculture probably reduced overall human resistance to cancer, and (2) an increased intake of vegetables and fruit, to approximately preagricultural levels, should reduce cancer incidence. These propositions could form the basis for predictions amenable to testing in lower animals.

Bone Mass and Age-Related Fractures

During the Paleolithic, before the advent of agriculture and animal husbandry, humans consumed no milk or other dairy products after weaning. Still, Stone Age diets generally provided more calcium than do those of contemporary Europeans and Americans because wild plant foods often contain considerable calcium. For 181 uncultivated fruits and vegetables consumed by hunter-gatherers in various parts of the world, mean calcium content is 110 mg/100 g, a value which approximates that for whole milk (~ 120 mg/100 g) [5]. However, in far northern latitudes, plant foods sometimes made up such a small proportion of total subsistence (<5% total energy intake) that low bone mineral density, osteoporosis, was common among Stone Agers (e.g. Inuit) living in such regions. Nevertheless, fractures were infrequent in these populations because a bone's strength reflects not just its mineral density, but also its size and structural geometry, especially its diameter and cross-sectional conformation [8]. Structural geometry is

influenced by habitual physical activity, which tends to increase bone diameter and create cross-sections more oval than round. Bones with such configuration resist mechanical stresses effectively, even when their mineral density is deficient. These considerations help explain why Melanesians and black South Africans, both of whom consume relatively little dietary calcium, have markedly fewer age-related fractures than do white and black Americans, for whom average calcium intake is greater [9, 10].

National and/or regional hip fracture rates correlate positively with dietary protein intake [11] an association that at least partially reflects the tendency of dietary protein to promote urinary calcium loss. This pathophysiology operates through endogenous acid production. Renal acid excretion is accompanied by urinary calcium loss so those factors, like dietary protein, which increase acid production tend to accelerate calcium loss in the urine. On the other hand, dietary potassium has a net alkalinizing effect, countering protein's influence. Despite the many other factors involved, a surprisingly accurate estimate of net endogenous acid formation, which largely determines net renal acid excretion, can be predicted simply by determining the dietary protein (g/day)/potassium (mg/day) ratio [12]. Higher values are associated with greater urinary calcium loss. The extremely high potassium content of typical Paleolithic diets [e.g. 10,500 mg/day for a 3,000-kcal. 35:65 animal:plant subsistence pattern (vs. ~ 2,500 mg/day for average Americans)] [4] thus offset the commonly higher Stone Age protein intake. A representative Paleolithic protein/potassium ratio might have been 0.84, which would actually have been calcium retentive in comparison with the average (1.24) determined for 20 different contemporary American diets [12].

Furthermore, dietary sodium also increases urinary calcium loss, an effect roughly comparable in magnitude to protein's influence [13]. Stone Agers are retrojected to have consumed less than a fourth the sodium that average Americans do each day (~ 750 vs. ~ 4,000 mg) [4] so this factor would have been an additional influence acting to preserve skeletal calcium retention for our human ancestors.

These variables, dietary protein, potassium and sodium intake relative to urinary calcium loss might easily be used for predicting the impact of Paleolithic and contemporary affluent diets. Such predictions would be appropriate for testing in short- or intermediate-term human experiments.

Sarcopenia and Insulin Resistance

The central importance of insulin resistance and hyperinsulinemia have become increasingly apparent, not only with regard to type 2 diabetes, but also in relation to the whole spectrum of syndrome X conditions from dyslipidemia to

hypertension. Clearly nutrition, habitual physical exertion and genetic influences must all figure in the development of insulin resistance, but just how the interaction operates is uncertain as are the factors underlying the rapid rise in diabetes prevalence during the past few decades. In the face of these uncertainties evolutionary considerations may provide a scaffold for understanding.

The epidemiological relationship between excess adiposity and insulin resistance has been recognized for some time, but an evolutionary perspective suggests there should be a second, parallel linkage involving relative skeletal muscle deficiency. The average member of affluent society differs from his or her human predecessors not only because of extra adipose tissue, but also by virtue of less skeletal muscle and a lower level of physical fitness. Each person is born with a genetically determined potential for adiposity, muscularity and fitness. Extant conditions: the accessibility of food energy, the ubiquitous availability of labor-saving machinery, and the economic uncoupling of energy expenditure from food acquisition now promote body composition and a sedentary lifestyle unprecedented, on the population level, in human existence. Contemporary males are 30 pounds heavier than were age- and height-matched Civil War recruits in 1863 [14], while soldiers in today's US Army perform very poorly relative to scores achieved on the same physical fitness test administered to their predecessors in 1946 [15]. These altered parameters distort the physiological milieu for insulin action from that obtaining when the genetic bases for carbohydrate metabolic regulation were selected through evolutionary adaptation [16].

An intricate sequence of intracellular events follows insulin binding, but the whole-body physiology of insulin molecule-insulin receptor interactions is less complex. After a pancreatic secretory pulse the number of insulin molecules reacting with skeletal muscle and adipose tissue must be, at some level, proportional to the relative amounts of these tissues in the body. The relationship is a kind of biochemical competition in which identical receptors, located on different organs, compete for a finite number of available stimulatory (insulin) molecules. This interaction differs from the classic model in which two similar, but not identical, molecules compete for receptors on the same organ. The two situations are alike in that both represent a kind of competitive inhibition.

The ability of insulin-stimulated adipocytes to take up glucose is far less than that of stimulated myocytes [17]. Hence, if a greater fraction of the insulin molecules released by the pancreas during any given time period (e.g. postprandially) bind to adipose tissue rather than to muscle, less lowering of the blood glucose concentration will be achieved and additional, compensatory insulin secretion will be required (fig. 1). Exercise-conditioned muscle can extract more glucose than can unfit muscle [17] so an easily tested hypothesis, incorporating both body composition and fitness, would be: in subjects neither glucose-intolerant nor frankly diabetic, relative insulin sensitivity should vary directly with the propor-

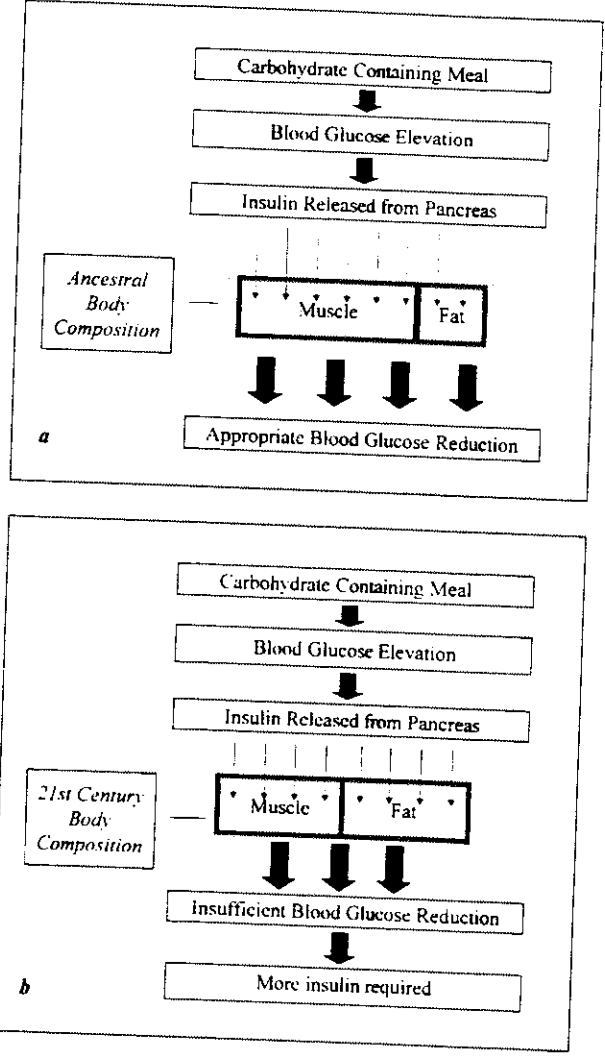


Fig. 1. a Carbohydrate metabolism of paleolithic humans. *b* Carbohydrate metabolism of contemporary humans.

tion and metabolic activity of skeletal muscle and inversely with percent body fat.

With increasing adiposity, decreasing muscle mass and diminishing physical fitness, episodic, transient hyperglycemia and hyperinsulinemia would follow ingestion of carbohydrate-containing meals. In genetically susceptible individuals

further metabolic deterioration could result from secondary downregulation of insulin receptors, glucose transporters, and intracellular enzymatic sequences leading ultimately to glucose intolerance and type 2 diabetes.

Conclusion

The hypotheses and research initiatives put forward in this paper are interesting and heuristically valuable in and of themselves even though the health recommendations – increase exercise, reduce sodium intake, eat more fruit and vegetables – which might be derived from them are not new. However, their primary significance lies in their relationship to an underlying central theme, a Kuhnian paradigm that can serve to link not only these investigational areas, but also many others related to health promotion and disease prevention.

The governing principle is that chronic degenerative disorders arise out of dissonance between the way humans in affluent societies actually live and the lifestyle for which our current genome was originally selected. This hypothesis is as applicable to psychosocial influences, the effects of toxins and allergens, reproductive factors, human-microbial interactions, and auxological (growth/developmental) considerations as it is to nutrition and exercise.

A 1995 *Science* editorial [18] asserted: 'The news about health risks comes fast and furious these days and it seems almost constitutionally contradictory.' Observations of this sort necessarily influence the public's consciousness, undermining confidence in preventive recommendations and fostering a laissez faire attitude. Health promotion deserves better. Almost 30 years ago Kuhn observed that in multiple scientific disciplines acceptance of a founding paradigm allowed order to emerge from a morass of data which had previously appeared contradictory and disconnected. The result was development of what he termed 'normal science' in place of preparadigmatic disarray.

To forestall ongoing, widespread and, in some respects, legitimate criticisms like those cited, to achieve the productive validity of a true science, and to begin actually reducing the incidence of chronic degenerative disease, health promotion needs a solid theoretical foundation. For this purpose genomic-cultural evolutionary dissociation is a more logical, simple, and aesthetically satisfying paradigm than any other which can currently be advanced.

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