Should We Eat Meat?

EVOLUTION AND CONSEQUENCES OF MODERN CARNIVORY

Vaclav Smil

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A John Wiley & Sons, Ltd., Publication

This edition first published 2013 © 2013 by John Wiley & Sons, Ltd

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered Office
John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
2121 State Avenue, Ames, Iowa 50014-8300, USA

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Library of Congress Cataloging-in-Publication Data

Smil, Vaclav.
Should we eat meat? : evolution and consequences of modern carnivory / Vaclav Smil.
pages cm
Includes bibliographical references and index.
ISBN 978-1-118-27872-7 (softback : alk. paper) – ISBN 978-1-118-27868-0 (emobi) – ISBN 978-1-118-27869-7 (epub) – ISBN 978-1-118-27870-3 (epdf) – ISBN 978-1-118-27871-0 1. Meat–Health aspects. 2. Meat industry and trade. 3. Vegetarianism. I. Title.
QP144.M43S65 2013
641.3′6–dc23
2013001800

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover images: Meat image: © iStockphoto/mnicholas; Dear image © iStockphoto/DamianKuzdak; Cow image © iStockphoto/meadowmouse
Cover design by Meaden Creative

Set in 10/12.5pt Galliard by SPi Publisher Services, Pondicherry, India

1 2013

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Vaclav Smil conducts interdisciplinary research in the fields of energy, environmental and population change, food production and nutrition, technical innovation, risk assessment and public policy. He has published more than 30 books and close to 500 papers on these topics. He is a Distinguished Professor Emeritus at the University of Manitoba, a Fellow of the Royal Society of Canada (Science Academy), the first non-American to receive the American Association for the Advancement of Science Award for Public Understanding of Science and Technology, and in 2010 he was listed by *Foreign Policy* among the top 50 global thinkers.

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Pieter Brueghel the Elder filled his rich kitchen with obese diners devouring suckling pigs, hams and sausages. Detail of the engraving produced by Hans Liefrinck in 1563.

Preface

Carnivory of modern Western societies is constantly on display. Supermarkets have meat counters that are sometimes tens of meters long, full of scores of different cuts (or entire eviscerated carcasses) of at least half a dozen mammalian and avian species (cattle, pig, sheep, chicken, turkey, duck). Some of them, and many specialty shops, also carry bison, goat and ostrich meat, as well as pheasants, rabbit and venison. Then there are extensive delicatessen sections with an enormous variety of processed meat products. Fast-food outlets – dominated by ubiquitous burger chains – were built on meat, and despite their recent diversification into seafood and vegetarian offerings, they remain based on beef and chicken. Consumption statistics confirm this all too obvious extent of carnivory, with annual per capita supply of meat at retail level (including bones and trimmable fat) surpassing typical adult body weights (65–80 kg) not only in the US and Canada and in the richer northern EU nations but now also in Spain. In fact, Spanish per capita meat supply has been recently the Europe's highest.

What all but a few typical (i.e., urban) carnivores do not realize is the extent to which the modern Western agriculture turns around (a better way to express this would be to say: is subservient to) animals: both in terms of the total cultivated area and overall crop output, it produces mostly animal feed (dominated by corn and soybeans) rather than food for direct human consumption (staple grains dominated by wheat, tubers, oilseeds, vegetables). But, if they are so inclined, modern Western urbanites can find plenty of information about the obverse of their carnivory, about poor treatment of animals, about environmental degradation and pollution attributable to meat production, and about possible health impacts. Vegetarianism has been an increasingly common (but in absolute terms it is still very restricted) choice among the Western populations, and vegetarian publications and websites have been a leading source of

information on the negatives of carnivory. Vegans in particular enumerate the assorted sins of meat eating in an often strident manner on many Internet sites. These contrasting attitudes have been reflected in the published record.

On one hand, there are hundreds of meat cookbooks – unabashed and colorfully illustrated celebrations of meat eating ranging from several "bibles" that are devoted to meat in general (Lobel et al. 2009; Clark and Spaull 2010) and to meatballs and ribs in particular (Brown 2009; Raichlen 2012) or to *Grilling Gone Wild* (Couch 2012) – all promising the best-ever, classic, succulent, complete meat repasts. The middle ground of meaty examinations is occupied by what I would call mission books of many gradations, the mildest ones imploring their readers to eat less meat (Boyle 2012) or arguing the benefits of becoming a flexitarian, that is, only an occasional meat eater (Berley and Singer 2007). The more ambitious ones are trying to convert meat eaters into vegetarians, even vegans, in ways ranging from straightforward (de Rossi et al. 2012) to enticing (O'Donnel 2010). And the same contrasts and arguments have been replayed in yet another genre of books that examine meat's roles in national and global history (Rimas and Fraser 2008; Ogle 2011).

Finally, there is a venerable tradition of books as instruments of indictment. This genre began in 1906 with Upton Sinclair's novel uncovering the grim realities of Chicago's stockyards and meatpacking (Sinclair 1906). A reader entirely unfamiliar with the revolting nature of Sinclair's descriptions will find an extended quote in a section about meat processing. More than a century later, critics of anything associated with meat include such disparate groups as activists agitating for animal rights, environmental scientists worried about cattle taking over the planet and nutritionists convinced (not quite in accord with the complete evidence) that eating meat undermines health and hastens the arrival of death.

Some of these writings portray modern meat industry in truly gruesome terms, and many have unsubtle titles or subtitles that make it clear that meat production and animal slaughtering are components of a despicable, if not outright criminal, enterprise and that meat eating is a reprehensible habit, a deplorable ride that must end: meat is madness (Britton 1999); meat animals are devouring a hungry planet (Tansey and D'Silva 1999); meat production is a matter of crimes unseen (Jones 2004); and eating meat is our society's greatest addiction (Ford 2012). Others, including books by Schlosser (2001) and Pollan (2006), are more measured in their condemnation. But in terms of extreme positions and incendiary language, few texts can beat *The Sexual Politics of Meat* by Carol Adams first published in 1990: the book's subtitle claims to offer a feminist-vegetarian

critical theory; it abounds in such deliberately provocative phrases as "the rape of animals" and "the butchering of women."

And this is how it ends: "Eat Rice Have Faith in Women. Our dietary choices reflect and reinforce our cosmology, our politics. It is as though we could say, 'Eating rice *is* faith in women.' On this grace may we all feed" (Adams 2010, 202). Of course, the nation where rice had a more prominent place in social identity, self-perception and culture than anywhere else – and where the plant has been a cherished symbol of wealth, power and beauty (Ohnuki-Tierney 1993) – would be left entirely unmoved by that argument: average per capita consumption of rice in Japan is now, in mass terms, lower than the intake of dairy products (less than 65 vs. more than 80 kg/year), and the country's accurate food balance sheets show the per capita supply of meat and seafood at nearly 100 kg/year, or 50% higher than rice (Smil and Kobayashi 2012). And Japan has been a model followed by other traditionally rice-eating Asian nations whose rice consumption appears to fall by about a third with every doubling of income (Smil 2005a).

What are we to make of these contending and contradictory conclusions? Should we eat meat – or should we try to minimize its consumption and aim at its eventual eliminations from human diets? My answers will be based on long-term perspectives and on complex and multidisciplinary considerations: my appraisals of the evolution of meat eating, historical changes and modern modalities of this practice and its benefits as well as its undesirable consequences are based on findings from disciplines ranging from archaeology to animal science and from evolutionary biology to environmental and economic studies. This is a book rooted in facts and realities, not in predetermined posturing and sermonizing, a book that looks at benefits of meat eating as well as at the failures and drawbacks, and that does not aspire to fit into any pre-cast categories, pro or contra, positively programmatic or aggressively negative. I do not approach the reality of modern large-scale carnivory with any pre-conceived notions, and I did not write this book in order to advocate any particular practice or point of view but merely in order to follow the best evidence to its logical conclusions. At its end, a reader will know quite clearly where I stand – but I thought that at its beginning it might be interesting to explain where I come from, that is, to make my full meat-eating disclosure.

As a child, adolescent and a young man I ate a wide variety of meat, but never in large individual portions or in large cumulative quantities: realities of post-WW II Europe (in some countries food rationing was in place until 1954), my mother's cooking and my food preferences (I have always disliked large and thick pieces of meat and all fatty cuts) explain

that. But this moderation went along with a great variety, and before I left Europe for North America at the age of 25, I had eaten pork, beef, veal, mutton, lamb, goat, horse, rabbit, chicken, duck, pigeon, goose, turkey and pearl hen, and as a boy the meat I loved best came from the animals my father shot during the hunting season, pheasants, wild hares and, above all, deer.

Also as a child I attended with my parents a number of village winter pig killings at the houses of my father's acquaintances. In many traditional European societies, these used to be (and in some places still remain) festive social and culinary events: *Schlachtfest* in Germany, *maialata* in Italy, *matanza* in Spain and *zabíjačka* in Bohemia. They are crowned by eating a remarkable variety of foodstuffs prepared expertly from the killed animal – including blood soup, blood sausages, white sausages and headcheese – and the attendants then take home assorted lean and fat cuts to be roasted or boiled or processed into lard. Other meat-related memories of my childhood include: my grandmother force-feeding geese (a practice I disliked); my father placing fragrant evergreen boughs into the cavity of deer carcass before hanging it to age in cold air (so learning as a child that fresh meat is not really fresh); my mother cooking beef *rouladen* stuffed with carrots, onions, boiled eggs and gherkins (yielding a colorful combination of fillings that is beautifully revealed on cooked cross-cut).

And as in any traditional society, when I was a child we also ate organ meats, albeit much less frequently than pork or chicken. Except for tripe (a preference I share with all those who like *trippa alla romana*) they were never my favorites, but I had eaten brains, lungs, heart, kidneys, cow's udder and calf, pig and poultry livers, the latter both cooked and prepared as *pâtés*. Quantifying those childhood and adolescent meat intakes is impossible with accuracy, but my best estimate is that as a teenager my annual meat consumption was on the order of 15 kg, with a few more kilograms of processed meats (mainly ham and sausages). Liver was the only organ meat whose eating had temporarily survived our move across the Atlantic: for a time during the 1970s, I used to make fairly regularly a chicken liver *pâté* with cognac.

But our trans-Atlantic move and the access to much cheaper meat in general, and to inexpensive beef in particular, did not change my dislike of large or fatty pieces of meat: as a result, in more than four decades of living (and almost daily cooking) in North America, I have never eaten, bought or cooked a steak – and, a fact many readers might find even harder to believe, I have never eaten a hamburger in McDonald's or in any of America's other burger chains. Virtually all cooking with meat I did during the years when our son was growing up was Chinese and Indian food,

with small pieces of meat in sauces and with vegetables served with rice; the only exceptions were some holiday roasts and an occasional *Wiener Schnitzel*. During that period (in order to understand better the difficulties involved in performing representative food intake surveys), I had repeatedly monitored our actual food intakes for a few days at a time, and so I can state with certainty that our average annual per capita meat consumption had never surpassed 25 kg.

When our son left for graduate school in 1996, we continued to eat all animal foods (especially fish, cheeses and yogurt) but cooked red meat and poultry only a few times a year for traditional holiday dinners. According to an inaccurate, cumbersome but often used current dietary parlance, we became the longest-definition vegetarians (lacto-ovo-pisci-vegetarians). There were no sudden specific reasons behind this shift, just a naturally evolving preference. During that time, our per capita meat intake was well below 5 kg/year, but after a dozen years of these virtually meatless diets I began cooking again occasional meat dishes, including my favorite Indian curries and *Schnitzel*, and occasionally buying some good-quality *prosciutto* or *jamón Serrano* – and a few days before these introductory lines were written, I ate in Firenze a small dish of *trippa alla fiorentina*, a cook's natural curiosity to try once again an ancient local favorite.

During the most recent years, our total per capita meat consumption (actually consumed servings, not retail weight, although with the lean meat and boneless cuts I buy these two categories are pretty close) has been thus less than 5 kg/year. As with most people in the West, I should thus be classified as a life-long omnivore – but one with an increasing tendency toward very low meat consumption. After finishing this book, some readers may find that my dietary preferences had some effects on its tenor and on its conclusions; as a scientist, I would like to think that has not been the case, but others may conclude differently.

With this confession out of the way, I am ready to plunge into the realities, complexities and consequences of modern meat production and consumption. In Chapter 1, I must lay out first assorted meat basics, many essential facts and observations about meat in nutrition and health: about its properties, composition, quality and variety; about its role in human diets, above all as a source of high-quality protein and some key micronutrients, and its association with fat; and about its demonstrated and suspected roles in the genesis of major civilizational diseases and in human longevity. Some of these fascinating, but often inconclusive, links between meat and health and longevity have received a great deal of research attention, but they are also subject to an even greater amount of false beliefs and misinformation, and I will try to sort out this complex relationship by

referring to the best available evidence. A separate section will be devoted to diseased meat and impacts and risks of meat-borne pathogens.

In Chapter 2, I will explain the evolutionary basis of human diets and their historical development extending from domestication of animals to typical meat intakes in traditional societies and including dietary taboos and proscriptions as well as meat's common position as a prestige food. Chapter 3 opens with a brief review of modern dietary transition, a process that has transformed traditional diets and whose two main components have been reduced consumption of carbohydrate staples and higher intakes of animal foodstuffs in general and meat in particular. This will be followed by an introduction to modern meat production and consumption that will trace the meat chain from the reproduction and growth imperatives through slaughtering of animals and processing of meat to meat consumption and waste, and that will systematically sort out the statistical categories used to quantify and compare these processes in historical and international terms.

Chapter 4 will explain what it takes to produce meat: it will first survey the modalities of modern animal husbandry (grazing, mixed farming and centralized "landless" industrial systems) before turning to long-term changes and current best practices of efficient meat production using balanced feed rations and to (humane as well as abusive) treatment of meat animals. The chapter's second part will focus on the environmental consequences of modern mass-scale carnivory. This is not a new concern but one that has gained a much higher prominence as the attention to environmental degradation and pollution and the concerns about the state of the biosphere and the sustainability of modern civilization have become increasingly common subjects of scientific inquiry, public discourse and governmental policy.

Animal Agriculture and Global Food Supply, a comprehensive report prepared by the US Council for Agricultural Science and Technology, was the first notable contribution to these new, environmentally centered, perspectives on livestock and meat production (Bradford et al. 1999). While it detailed many concerns, it concluded that livestock have both positive and negative environmental effects. Seven years later, an even more substantial interdisciplinary report prepared by the FAO had a different message, giving away its concerns by its very title: *Livestock's Long Shadow* (Steinfeld et al. 2006).

Its basic conclusion made many headlines:

> The livestock sector emerges as one of the top two or three most significant contributors to the most serious environmental problems, at every scale

> from local to global. The findings of this report suggest that it should be a major policy focus when dealing with problems of land degradation, climate change and air pollution, water shortage and water pollution and loss of biodiversity.

The report's most often cited findings were that 26% of the Earth's surface is devoted to grazing land, 33% of all arable land is used to grow feed for animals, 18% of all greenhouse gas emissions are attributable to livestock as is 8% of the total use of freshwater.

Two years after FAO's report came a study that had a narrower focus but whose conclusions were even more worrisome: the goal of the Pew Commission on Industrial Farm Animal Production (IFAP) was "to sound the alarms" as it determined that "the negative effects of the IFAP system are too great and the scientific evidence is too strong to ignore. Significant changes must be implemented and must start now. And while some areas of animal agriculture have recognized these threats and have taken action, it is clear that the industry has a long way to go" (PCIFAP 2008). All of these three reports are readily available on the Web, and I will refer to them only when I will need to make, or stress, some specific points that are well developed in these studies. Rather than repeating much they have to offer, I will question some of their approaches and conclusions in an effort to demonstrate many uncertainties that make some of the published conclusions much less definitive than they may appear when they are cited as absolute findings.

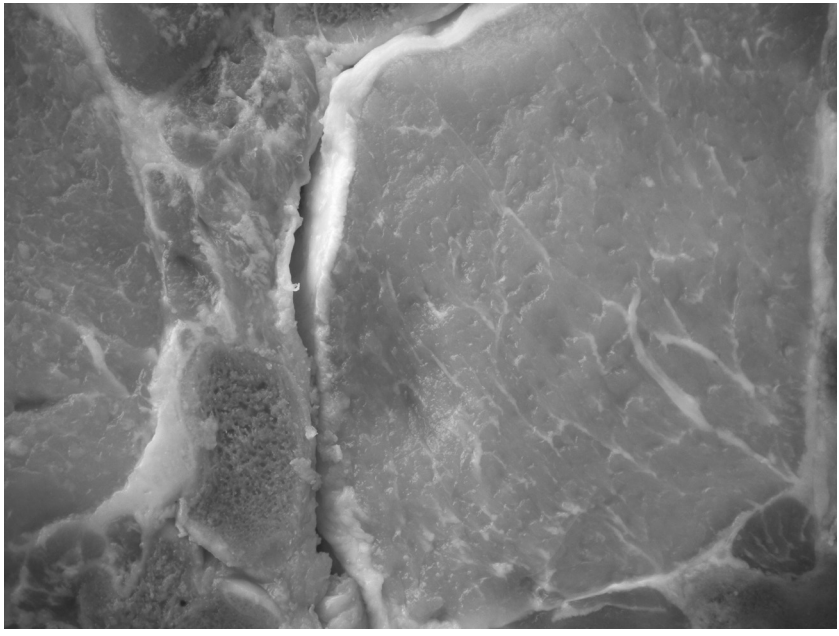
I will do this by surveying five major categories of impact. The first one is the 20th century's rapid rise of domesticated zoomass and its densities, a topic that has not been addressed by the three reports. The second concerns changing animal landscapes, with the effects on land cover and land use dominated by deforestation, deliberately set fires, grazing and overgrazing. Intensive production of feedstuffs is the main reason why meat is an expensive food in virtual energy terms, with indirect energy costs due to intensive cultivation of feedstuffs being far more important than direct energy costs of feeding, housing and killing animals and processing, distributing and cooking meat.

And the last two categories of environmental concern will deal with the aquatic and atmospheric impacts of meat production. Large volumes of virtual water are needed to grow animal feeds, and the nutrients lost during that process as well as copious metabolic by-products of meat production are major water pollutants that contribute to undesirably high nutrient loadings and eutrophication of both fresh and coastal ocean waters, while gases released during the cultivation of feed crops and by metabolizing animals are significant factors in local, regional and global atmospheric

changes (the last instance being due to emissions of methane and nitrous oxide, two major greenhouse gases). Some of the published claims appear less dire when seen in a proper context, but there is no doubt that when compared with burdens imposed by other foodstuffs, meat has a high environmental cost.

I will conclude the book with an appeal for what I call rational meat eating. I will first assess the extent to which non-meat options – vegetarianism or diets enriched with other animal foodstuffs (including the promise of *in vitro* meat) – can displace current meat eating, and then I will outline a path of desirable meat production. Advocacy of such a path will anger vegans and it will disappoint vegetarians – while its insistence on moderation will not satisfy the proponents of unrestrained, vigorous carnivory. But I believe that such a choice offers the best way to preserve social, economic and nutritional benefits of meat eating while minimizing many unavoidable and undesirable environmental impacts of mass-scale meat production.

Should We Eat Meat?



Pork loin center chops. A close-up shows what most meat cuts are composed of: muscle fascicles, collagen sheaths, tendons, intra- and extramuscular fat, and bones. Photo by V. Smil.

1

Meat in Nutrition

First things first: no energy conversion is more fundamental for the survival of our species than photosynthesis (primary productivity), the source – directly in raw or processed plants and indirectly in (usually cooked or processed) animal tissues – of all of our food. Eating (setting aside food smells, taste, visual appeal and all those cultural and historical connotations subsumed in the act of ingestion) can be defined in the most reductionist biophysical fashion as a process that supplies macronutrients (carbohydrates, proteins, lipids) and micronutrients (vitamins and minerals) that are required to sustain our metabolism needed for growth, maintenance and activity and hence to perpetuate life of this most advanced of all heterotrophic organisms that cannot (as all autotrophs can) synthesize their own complex nutrients from simple inorganic inputs. Foodstuffs could be then seen as nothing but more or less complex assemblages of nutrients, and meat stands out among them for many reasons.

A small definitional detour is called for first because, as is often the case when dealing with seemingly straightforward subjects, everyday usage of the word "meat" does not coincide with biophysical realities. Meat, from a *sensu stricto* structural and functional point of view, refers only to the muscular tissue of animals, and the narrowest traditional definition would limit it to skeletal muscles of wild and domesticated mammals. Horowitz (2006) documents how even during the 1950s many American housewives did not consider chicken to be a meat and how the chicken industry was encouraged to run advertising campaigns that would confer on poultry a full meat

Should We Eat Meat?: Evolution and Consequences of Modern Carnivory,
First Edition. Vaclav Smil.

status. There are also some national rules that make explicit definition. According to the Food Standards Code of Australia and New Zealand, meat is "the whole or part of the carcass of any buffalo, camel, cattle, deer, goat, hare, pig, poultry, rabbit or sheep, slaughtered other than in a wild state," a definition that pointedly excludes all wild species, including kangaroos whose meat is now readily available in Australia (Williams 2007).

In contrast, a common, *sensu lato*, usage extends the noun's coverage not only to muscles of all mammals and birds (much like the understanding of our pre-industrial ancestors for whom meat was everything from squirrels to bison and from thrushes to herons) but also to muscles of amphibians and reptiles (frogs, snakes, turtles) and to all other tissues that are often integrally or proximally associated with meat, above all to embedded or surrounding fat, sometimes also to skin and to internal organs (organ meats, innards, offal – *abats* in French, *frattaglie* in Italian, *Innereien* in German), most of which are not hard-working muscles. But even this liberal definition still leaves out all seafood although few skeletal muscles are as powerful and as efficient as those propelling fast cruising bluefin tunas that can (unlike all other ectothermic fish) raise their temperature above that of the surrounding water (Block 1994).

Nor is there any clear, universal divide between "red" and "white" meat. The distinction obviously owes to the amount of myoglobin in muscles (just 0.05% in chicken, up to 2% in beef), but because all mammalian meats have higher concentrations than poultry or fish, the USDA puts all large livestock meat into the red category. In contrast, the Australian definition of red meat refers to beef, veal, lamb, mutton and goat meat, but it excludes pork as well as all game meats, including buffalo whose meat is largely indistinguishable from beef. And then there is a common culinary usage that draws the line by age: veal, lamb and piglets are white; beef, mutton and pork are red, but so are duck and goose; and (to bring yet another color into the mix) in France, all game meat is labeled *viandes noires*. But lack of strict logic is common in classifying foodstuffs: tomato is, of course, a fruit that is always classified as a vegetable, to say nothing about counting tomato paste on pizzas as a vegetable.

Meat Eating and Health: Benefits and Concerns

In this introductory chapter, I will deal first with the functional and structural properties and the basic composition of muscles and other

animal tissues before I turn to specific surveys of meat as a source of energy that comes (given the virtual absence of carbohydrates in muscles) only from two macronutrients, lipids and high-quality proteins. Most societies could always secure abundant, or at least adequate, amounts of carbohydrates from plants, but lipids, and even more so high-quality proteins, were relatively scarce in all traditional agricultures, as well as in the early stages of post-1500 modernization. That is why the role of animal protein in early human growth deserves particular attention.

Eating relatively large amounts of meat must have a variety of health and longevity consequences, but, as with all long-term effects of specific components of human diet, it is not easy to tease them out in an unequivocal manner from often inadequate and sometimes questionable epidemiological evidence. There is no doubt about the benefits of high-quality protein for young children in general and for their growing brains in particular, and there is also a high degree of consensus regarding the undesirability of consuming large amounts of fatty meat (although even here there are some intriguing caveats). More recently, a consensus has been emerging about the undesirability of frequent consumption of processed meat products ranging from bacon to wieners.

In contrast, solid generalizations regarding the contribution made by low to moderate meat consumption to the prevalence of the two leading causes of death in modern societies, that is, to cardiovascular and cancer mortality, are much more elusive – and hence it is difficult to say what might be the exact role of meat consumption in extending or reducing average human life expectancy. And, finally, when looking at links between meat and health, it is unavoidable to address the concerns about diseased meat, about meat-borne pathogens whose effects can range from mild individual discomfort to viral pandemics.

These risks have always been present in terms of bacterial contamination arising during the growth, killing of animals and post-slaughter treatment of carcasses and retail cuts, and several animal diseases with potential for epizootic outbreaks have always made their episodic appearance. But there have been two new developments during the past two decades: the emergence of contagious avian viruses with a strong potential for viral pandemics, and beef infected with a variant Creutzfeld–Jacob disease (vCJD) (human form of bovine spongiform encelopathy [BSE], commonly known as mad cow disease). Individual risks of the latter infection have always been minimal, but the avian

influenza is a cause for legitimate worries as its future virulent manifestation can cause large global death toll.

Meat and its nutrients

Evolution has left us with no shortage of specialized organs to admire because of their intricate structures and amazing functions: brains and eyes are commonly cited as the pinnacles of evolution, but such rankings are meaningless as in living organisms only the synergy of all organs matters, and hence skins or intestines or bones or muscles are no less important. Muscles – the prime movers of heterotrophic locomotion that make all walking, running, jumping, swimming and flying possible – look macroscopically fairly simple, but viewing their structure sequentially upward from molecular level is a different matter (Aberle et al. 2001; Lawrie and Ledward 2006; Myhrvold et al. 2011).

Molecules of specialized proteins, actin and myosin, are organized in myofilaments that form sarcomeres whose contraction and relaxation generates all muscle motion. In turn, sarcomeres are grouped into myofibrils that are bundled into muscle fibers sheathed by a collagen matrix (endomysium); muscle fibers are bundled into fascicles that are contained within another collagen mesh (perimysium), and the entire muscle is covered by yet another collagen sheath (epimysium, or silverskin). The ends of these connective tissues merge into tendons that are attached to bones (but there are also some muscles that are not attached to skeleton). Tenderness of meat is determined by the size of fascicles (muscle grain) and by the strength and thickness of collagen sheaths. Coarser grain of more powerful muscles covered with stronger collagen results in less tender meat.

The division between light and dark meat reflects the muscle functions: rapidly twitching muscles, reserved for sudden, fast movements and brief exertion at maximum power, are lighter-colored, while the muscles for continuous but relatively low power exertions (breathing, standing, masticating) are composed of darker, slow-twitching fibers – they have more myoglobin, another specialized protein that moves oxygen from the blood to muscle cells. But there is no stark color difference in muscle color among those domesticated animals whose ancestors had large home territories or migrated over long distances: intermediate fibers of muscles in cattle or aquatic birds are all colored

by myoglobin which accounts for 0.5% of muscle mass in cattle but for less than 0.1% in pigs.

Actin, myosin, collagen and myoglobin are all proteins (collagen is the most abundant protein in animal bodies), and hence muscles can be best thought of as intricate assemblies of wet proteins: on the average, living muscles contain about 75% water (extremes range from 65% to 80%), and their protein content is, at nearly 19%, the least variable major component; embedded lipids average about 3%, non-protein nitrogen (including nitrogen in adenosine triphosphate) is less than 2% and the small remainder are traces of carbohydrates (mainly glycogen) and inorganic matter (particularly iron and zinc). Because of their higher fat content, there is less water in animal carcasses (about 55% in beef and just over 40% in pork), but the protein content of their separable lean meat varies within a very narrow range, from 19% to 23%.

But most muscles also contain fat that is embedded in the sheathing collagen in order to supply long-acting aerobic fibers with a readily available and highly dense source of energy. This embedded fat also plays an essential role in meat's gustatory quality as it weakens collagen structures and makes meat more succulent, particularly once it degrades to gelatin during moist heat cooking once meat reaches 65°C. In contrast, no external application of fat can make a very lean meat as succulent as a more fatty cut, a reality that engendered a partial help through an ancient practice of larding lean cuts of meat. In some mammalian and avian species (particularly in such highly mobile wild animals as hares, deer or pheasants), there is only a small quantity of fat beyond the limited amount that is present in embedded stores, while in others there are substantial subcutaneous fat deposits as well as rich deposits surrounding internal organs.

Shares of separable lean and separable fat range widely among both beef and pork cuts. The extreme for beef are top round steak with almost 90% separable lean, just 8% of separable fat and about 2% of refuse when all fat is trimmed away, and short ribs with only about 40% of separable lean, 32% of separable fat and 27% of refuse (USDA 1992). Depending on taste preferences and health concerns, separable fat may be almost completely removed during butchering, preparation of retail cuts or final trimming before cooking, or it may be left in copious amounts on retail meat cuts and eaten as part of stews, roasts, barbecues or processed meats.

The heart is, of course, the only constantly working muscle in the human body, but among all other organ meats only tongue and gizzard are peculiar muscles (in the first instance, a complex network of muscles of

great agility and omnidirectional mobility, in the second case an involuntary smooth muscle), while liver and sweetbreads (thymus) are enzyme-rich glands, tripe is a lining of ruminant stomach, and brain and kidneys are each *sui generis* organs. The composition of raw mammalian livers is very similar to that of skeletal muscles (about 70% moisture and 20–21% of protein), and tripe has about 19% of protein, but other innards are slightly to substantially less proteinaceous: kidneys and tongues have about 16% protein, hearts between 15% and 17%, sweetbreads 15% and brains only about 10% (and 80% moisture). Skin, contrary to common perception, has very high moisture content, and in some species (including pigs, chicken, ducks and geese), it is eaten as a part of broadly defined meat, either as crisply cooked part of meat in roasts or as a separate preparation.

Finally, all meat eaters also ingest some blood. Between 40% and 60% of all blood is lost by exsanguination and all but a small share of the rest is retained in viscera; as a result, the residual blood content amounts only to 2–9 mL/kg of muscle, and this minuscule rate does not appear to be affected by different ways of slaughter (Warriss 1984). When assuming mean blood content of 5 mL/kg, an annual consumption of 80 kg of boneless meat (recent US average) would imply annual intake of some 400 mL of residual blood. For comparison, the pastoral Maasai tribe in Kenya, who used to tap regularly the jugular veins of their cattle to drink blood or to collect it for mixing with milk, would draw at a time 4–5 L from a steer or a bull and half that volume from a cow or a heifer and consume several liters in a single month (Århem 1989). Maasai blood drinking has been in decline for decades, but in many societies blood is still consumed (albeit irregularly and in small amounts) in traditional dishes ranging from soups and stews to stir-fries and sausages. But a habit from the late 19th century is no longer with us: young Parisian women do not visit slaughterhouses to drink the blood of freshly killed animals in order to redden their cheeks (Gratzer 2005).

Although meat has been an important component of food energy supply during the long period of hominin evolution and a major contributor to energy intake in Paleolithic and Neolithic societies, its prime role was qualitative rather than quantitative: foods that are equally, or much more, energy-dense could be secured by gathering, but before animals were domesticated, and in societies that had limited access to aquatic foods, meat was the only source of the highest-quality protein. And while most wild animals have low, or even very low, deposits of fat, high energy density made animal lipids much sought-after, and only modern nutritional science discovered meat's value as an outstanding source of a key vitamin and of several essential minerals.

The physical and chemical properties of meat obviously determine its taste, ease of cooking, flexibility of preparation and hence the popularity of individual species or specific meat cuts. Nutritional composition is a different matter as the tissues and cuts that may rank low in terms of culinary preference may contain virtually identical shares of essential nutrients. Three kinds of preformed organic macromolecules present in plant and animal foodstuffs – carbohydrates, proteins and lipids – must be digested in relatively large quantities to serve as source of food energy, as well as sources of proteins and fatty acids that are indispensable for the growth and maintenance of human bodies. In modern diets, typical consumption rates of these macronutrients range from 10^1 g/day for proteins and lipids to 10^2 g/day for carbohydrates. In contrast, compounds and elements belonging to two distinct classes of micronutrients – vitamins and minerals – are ingested at low to very low rates, ranging from just a few grams per day for sodium and potassium to just a few micrograms per day for vitamin B11.

Meat contains virtually no carbohydrates, but it is an excellent source of high-quality proteins and fats. In those prehistoric societies that had no milking animals and no, or limited, access to aquatic species, meat was the only source of proteins needed for normal childhood and adolescent growth and adult body maintenance. The importance of meat in diets of hunters and gatherers encountered by the European expansion in the Americas, Africa, Asia and Australia has been abundantly described in the narratives of explorers and colonizers, and in the societies whose traditional way of life persisted into the 20th century, it was eventually studied and analyzed by modern ethnographers and anthropologists.

Some of these studies have included revealing quantitative analyses demonstrating the importance of domesticated pigs in New Guinea (Rappaport 1968), cooperative hunting among Tanzanian Hadza (Marlowe 2010) or dependence on collected and hunted wild animals among Ache of Paraguay (Clastres 1981). As I will show in some detail in Chapter 2, meat consumption declined to low or very low levels in all densely settled traditional agricultural societies, but during those millennia of low intakes, meat never lost its status of a highly desirable food. In the Western world of the 19th and the early 20th centuries, meat was valued both as a source of protein and fat, and its rising consumption was one of the major contributors to enhanced growth, increased adult weight and improved health of rapidly urbanizing populations.

Post-WW II affluence and new nutritional and health awareness changed the perspective: with the abundance of other high-quality protein sources (seafood, eggs, dairy products), meat lost its status of indispensable

supplier of protein, and fatty meat (beef in particular) lost a considerable market share to lean pork and, above all, to chicken. The composition of meat consumption has changed, but in all modern societies, be they affluent Western countries or rapid modernizers of Asia, meat remains the single largest source of high-quality protein, followed by dairy products, fish and eggs (usually, but not necessarily, in that order). Meat also supplies significant shares of essential fatty acids and important micronutrients, above all iron – a mineral whose deficiency has been common in many populations, including women in affluent countries.

Few modern scientific advances have been as consequential as the discoveries of the importance of micronutrients to human health. Deficiencies of common minerals can impede normal human growth; low intakes of vitamins compromise essential metabolic functions ranging from gastrointestinal upsets to epithelial hemorrhaging. Balanced diets supplying adequate amounts of macronutrients in foods originating from a variety of plant and animal sources do supply sufficient quantities of micronutrients, but poor eating habits mean that even in the countries suffused with food and consuming excess of carbohydrates, fats and proteins, micronutrient deficiencies are common.

Iron deficiency is one of the most widespread as well as one of the most damaging problems as it affects as many as 1.6 billion people, or more than a fifth of all humanity (deBenoist et al. 2008), and, even more tragically, in low-income countries, it impairs brain development of roughly half of all children and is associated with every fifth maternal death (Micronutrient Initiative 2009).

Meat is one of the best sources of dietary iron because it supplies this essential mineral as heme iron that is easily absorbed in the upper small intestine and that also helps to absorb non-heme iron present in plant foods, and even modest meat consumption helps to prevent iron deficiency anemia (Bender 1992). Iron content in red meat is mostly between 1 and 2 mg/100 g; it is particularly high in mutton (more than 3 mg/100 g), and it is highest in organ meats (nearly as much as 10 mg/100 g in lamb liver and kidneys). Recommended daily intakes of iron are 8–11 mg/day for children and adolescents, 8 mg/day for adult men, 18 mg/day for pre-menopause women and 27 mg/day during pregnancy (Otten et al. 2006). This means that up to 25% of daily adult male requirements can be supplied by eating a single modest serving of red meat.

Zinc is the other metal present in relatively high concentrations. The element is a part of metalloenzymes (it is actually the most common catalytic metal ion present in cell cytoplasm), and as such it plays several essential roles in the synthesis of nucleic acids, protein and insulin.