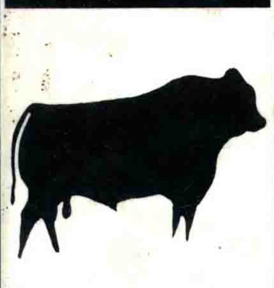
# Feeds & Nutrition Digest

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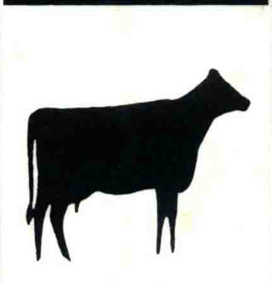

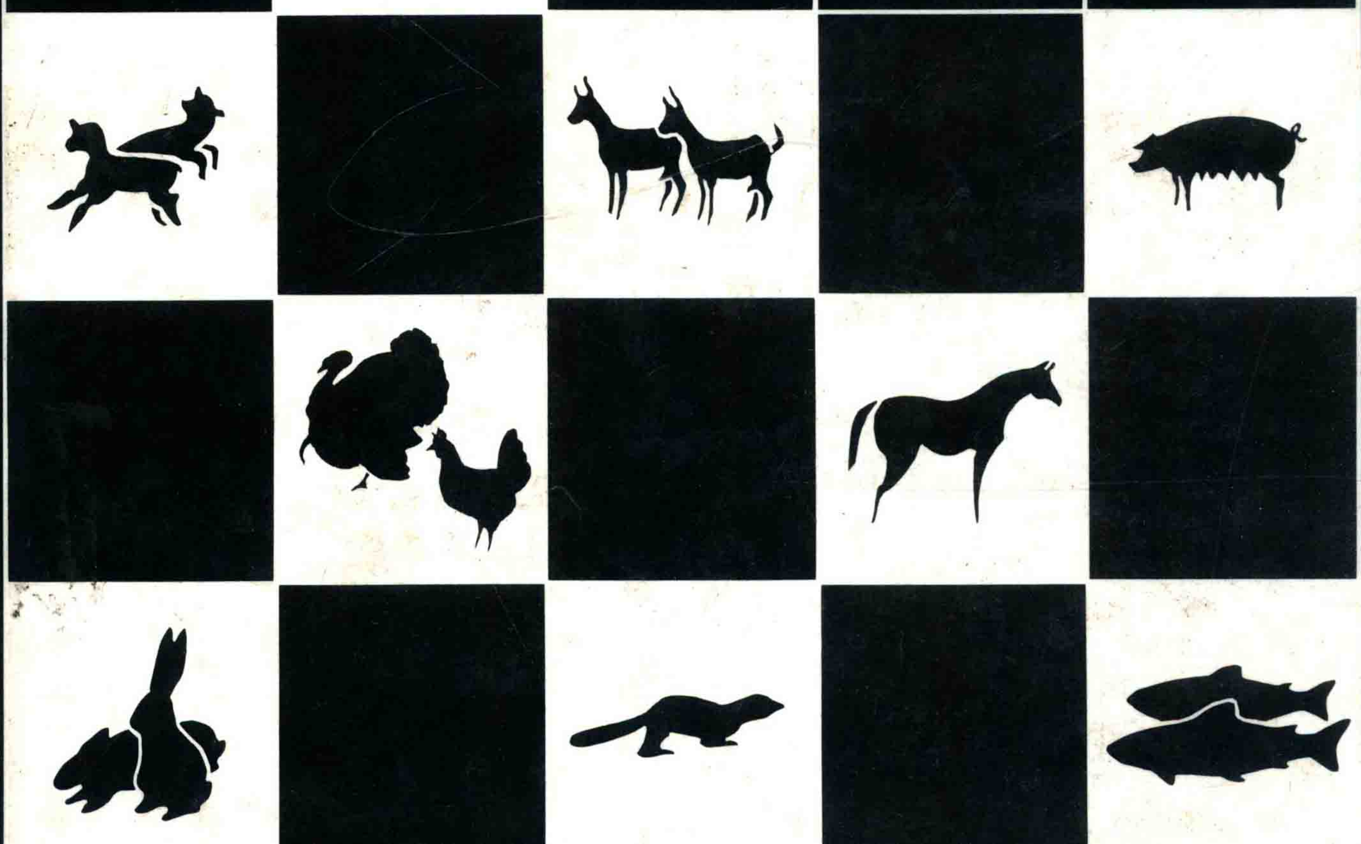

# FEEDS & NUTRITION DIGEST

(Formerly, FEEDS & NUTRITION—abridged)

by

**M. E. ENSMINGER, PH.D.**
**J. E. OLDFIELD, PH.D.**
**W. W. HEINEMANN, PH.D.**

SECOND EDITION



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*Lest we forget!*

Dedicated to the memory of two immortals

W. A. Henry
(1850–1932)

F. B. Morrison
(1887–1958)

authors of

*Feeds and Feeding*

1898, 1st edition—1956, 22nd edition

(From 1898 to 1910, Henry was sole author;
from 1910 to 1929, Henry and Morrison were coauthors;
from 1929 to 1956, Morrison was sole author.)


## ABOUT THE AUTHORS

The three authors are shown seated in the library of the senior author, Dr. M. E. Ensminger. *Left to right:* Dr. James E. Oldfield, Dr. M. E. Ensminger, and Dr. Wilton W. Heinemann.

• ***About Dr. M. E. Ensminger*** **(Center)**—Dr. M. E. Ensminger is President of Agriservices Foundation, Clovis, California, a nonprofit foundation serving world agriculture in the area of World Food, Hunger and Malnutrition. Also, he is Adjunct Professor, California State University—Fresno; Adjunct Professor, The University of Arizona—Tucson; Distinguished Professor, University of Wisconsin—River Falls; Honorary Professor, Huazhong Agricultural College—Wuhan, People's Republic of China; and collaborator, U.S. Department of Agriculture.

Dr. Ensminger grew up on a Missouri Farm; completed B.S. and M.S. degrees at the University of Missouri, and the Ph.D. at the University of Minnesota; served on the staffs of the University of Massachusetts, the University of Minnesota, and Washington State University; served as Consultant, General Electric Company, Nucleonics Department; and served as the first President of the American Society of Agricultural Consultants.

Among Dr. Ensminger's honors and awards are: Distinguished Teacher Award, American Society of Animal Science; Washington State University named and dedicated the *Ensminger Beef Cattle Research Center,* in recognition of his contributions to the University; and an oil portrait of him was placed in the 300-year-old gallery of the famed Saddle and Sirloin Club, which is recognized as the highest honor that can be bestowed on anyone in the livestock industry.

Dr. Ensminger founded the International Stockmen's School, which he directed for 40 years. He has lectured and/or conducted seminars in more than 60 countries, including giving 5 invitational lectures before the Chinese Academy of Science and conducting the largest Seminar in China since the revolution. Dr. Ensminger is the author of more than 500 scientific and popular articles, bulletins and columns; and the author or co-author of 19 books, which are in several languages and used all over the world. The whole world is his classroom!

• ***About Dr. James E. Oldfield*** **(Left)**—Dr. James E. Oldfield is Director, Nutrition Research Institute, and Professor Emeritus of Animal Science, Oregon State University—Corvallis.

Dr. Oldfield was born in Victoria, B.C., Canada. He received the B.S.A. and M.S.A. degrees from the University of British Columbia; and the Ph.D. from Oregon State University. During World War II, he served in the Canadian Army, and was decorated with the Military Cross.

Dr. Oldfield has conducted nutrition research and/or been involved in nutrition problems pertaining to all animal species, including fur and laboratory animals. He has served in numerous scientific capacities, including: member of the Committee on Animal Nutrition, National Research Council; member, National Technical Advisory Committee on Agricultural Uses of Water, U.S. Department of Interior; member, Animal Nutrition Research Council; Director, Council of Agricultural Science and Technology (CAST); member, Nutrition Study Section, Division of Research Grants, National Institutes of Health; and Consultant to the Office of Economic Cooperation and Development, Ankara, Turkey. Dr. Oldfield is a world-renowned authority on selenium, on which subject he has given invitational lectures, participated in symposia, and/or served on committees throughout the United States, and in Canada, New Zealand, Australia, and China.

Among Dr. Oldfield's numerous professional recognitions are the Morrison Award, American Society of Animal Science; Fulbright Research Scholar, Massey University, New Zealand; and President, American Society of Animal Science.

Dr. Oldfield has published 142 technical papers and journal articles, and 92 reports and popular articles.

• ***About Dr. Wilton W. Heinemann*** **(Right)**—Dr. Wilton W. Heinemann, whose expertise is animal nutrition and pasture/range management, is Professor Emeritus, Washington State University, where he had a long and distinguished career. He completed B.S. and M.S. degrees at Washington State University, and the Ph.D. degree at Oregon State University. Dr. Heinemann is a Fellow in both the American Association for the Advancement of Science and the American Society of Animal Science.

Dr. Heinemann has served as Consultant/Nutritionist to the Bureau of Fisheries and Wildlife, U.S. Department of the Interior; the National Hay Association; the U.S. Feed Grains Council; Battelle Northwest; and to farmers, ranchers and agribusinesses, worldwide.

Dr. Heinemann has presented invitational papers in the U.K., Brazil, Finland, Australia, and the USSR; participated in the Nordic Congress of Agricultural Scientists, Helsinki, and in the Symposium on Ruminant Nutrition, Cambridge University, England; and has twice given invitational lectures before the Polish Academy of Science.

Dr. Heinemann has conducted research and/or been involved in problems pertaining to all animal species, including fish and wildlife. He is the author of 151 technical papers and journal articles, 158 popular articles and reports, and the co-author of a textbook. Dr. Heinemann is an international authority on animal nutrition, and on pasture and range management.

## PREFACE TO THE SECOND EDITION

### *Feeds & Nutrition Digest*

Genetic wizardry by gene splicing is giving rise to a major scientific revolution called biotechnology and spawning many new developments exceeding our fondest dreams. Biotechnology will involve every facet of animal production from breeding and feeding to the finished product, including the genetic makeup of animals and the feeds they eat; the digestion, physiology, stress tolerance, disease resistance, and efficiency of production of animals; the composition, quality, and quantity of products produced; along with the production of large quantities of drugs and chemicals. While some aspects of biotechnology are decades away from commercial production, others are near, and still others are here now.

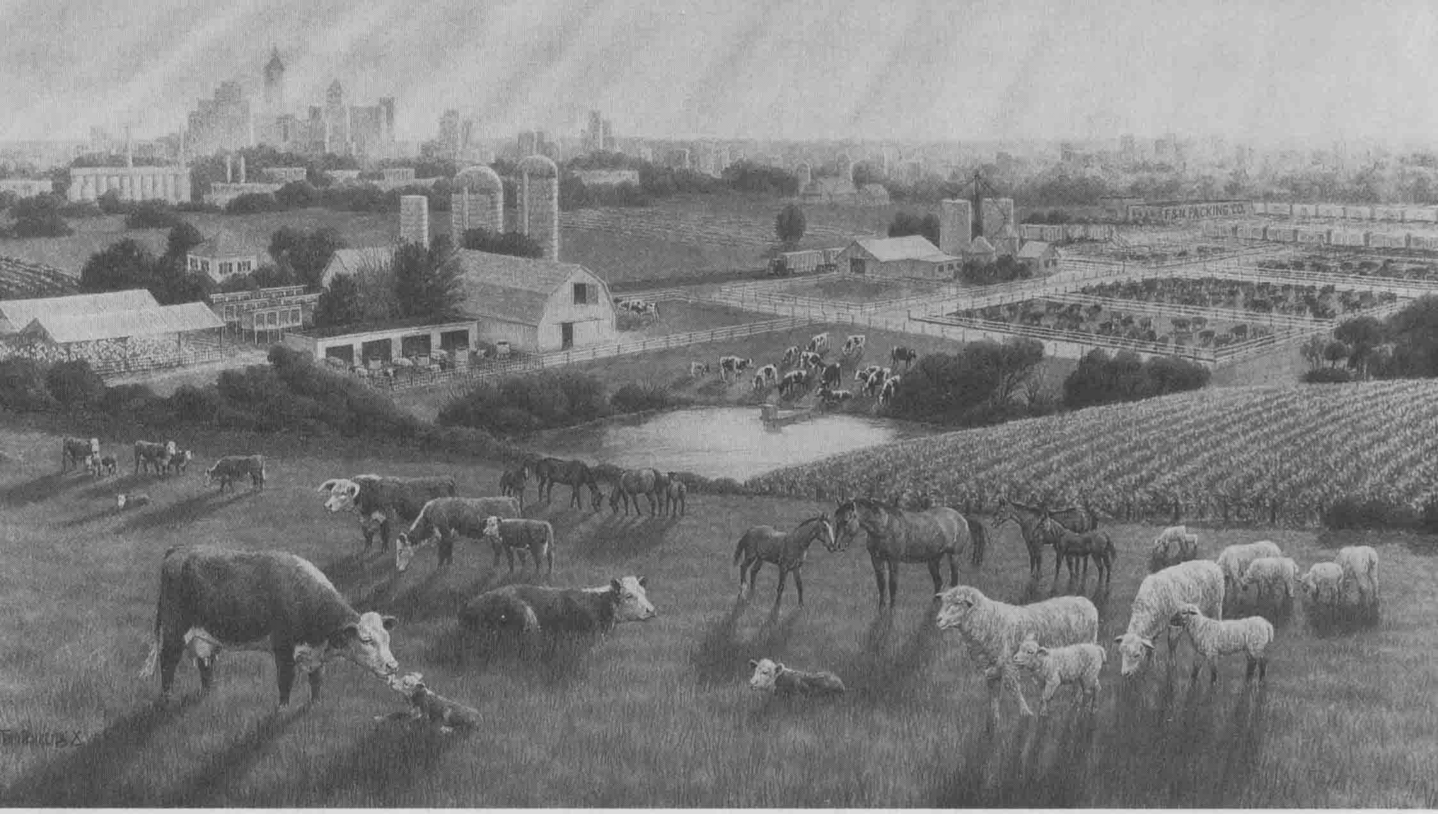
But advanced technology calls for advanced animal adaptation, welfare, and environmental control. We need to breed and select animals adapted to an artificially-made environment—animals that not only survive, but thrive, under the conditions in which they are kept. We need to heed the warnings of endangered animals, endangered people, and an endangered planet—presaged by increased pollution, the greenhouse effect, acid rain, depletion of the ozone layer, and destruction of rain forests.

As the senior author of this book, I wish to acknowledge the great contribution of my two co-authors, Dr. James E. Oldfield and Dr. Wilton W. Heinemann, along with their patience with, and understanding of, my idiosyncracies. Audrey Ensminger shepherded the manuscript from beginning to end; Joan Wright deciphered my hieroglyphics and typed the manuscript; Lynn Wright set the type and paged up the copy; Ran Guang Liang prepared the cover design; and Margo Williams did the traditional art work and prepared the camera-ready copy. Also, I am grateful to Verla Rape, Program Analyst, Office of the Administrator, Economic Research Service, U.S. Department of Agriculture, who gave liberally of her time and talents in providing much of the recent source material for updating. Additionally, at appropriate places in the book, due acknowledgment and appreciation is expressed to all those who reviewed portions of the manuscript or responded so liberally to my call for illustrations and information. Without the help of all these fine folks, the task could not have been completed.

All authors are dreamers and doers. They visualize a need, then set out to fill it through the written word. These were the motivating forces back of *Feeds & Nutrition*. The need: to bring together in one book both the art and the science of livestock feeding; to narrow the gap between nutrition research and application—to speed the process; and to assure more and better animals in the future, followed by conversion of more feeds to palatable and nutritious foods for human consumption. If invoking my nocturnal habit and spending night after night in my lexicon garden alone doing my thing—writing this book—makes these dreams come true faster and more abundantly, throughout the world, I shall feel amply rewarded.

Clovis, California
1990

*M. E. Ensminger*



This is an original painting by the noted artist, Tom Phillips (3333 17th Street, San Francisco, California 94110), prepared especially for this book. It portrays the artist's conception of what is in all five chapters of Section I, *Nutrition*.

# SECTION I

# NUTRITION

Feeding had its beginning as an art, the foundations of which were animal instinct and a blend of the caretaker's fads, foibles, and trade secrets. Then came science, founded on chemistry, physics, physiology, and bacteriology.

For many years, the keepers of the herds and flocks were responsible for the very considerable progress made in the art of feeding. They were intensely practical, never overlooking the utility value or the market requirements. No animal met with their favor unless it was earned by meat upon the back, milk in the pail, weight and quality of wool, pounds gained for pounds of feed consumed, draft or speed ability, or some other performance of practical value. In time, scientists teamed up with caretakers to improve the feeding of animals, slowly, but surely, evolving with the science called *nutrition*.

The successful merger of the art and the science of feeding—the joining of feeds and nutrition—ushered in a new era in animal agriculture. In the process, it also stimulated increased interest in human nutrition, where the requirements are similar. This gave rise to the statement that, "We are gradually learning to feed our children as well as our animals." Many maladies which had long plagued both humankind and beast were traced to dietary deficiencies, imbalances, and toxicities. Rectifying these nutritional problems improved the health and performance of all creatures, including humans.

But the past is prologue! The final chapter of the 20th century, which is now being written, may well be the most revolutionary and dramatic of all in animal nutrition.

Section I covers the fundamentals of nutrition, with separate chapters devoted to each of the following:

Chapter 1, Food and Animals—a global perspective
Chapter 2, Principles of Nutrition
Chapter 3, Digestion/Absorption
Chapter 4, Nutrients/Metabolism
Chapter 5, Nutritional Disorders/Toxins

# *FEEDS & NUTRITION DIGEST*

## CONTENTS

*Original painting by Tom Phillips*

# 1

# FOOD AND ANIMALS— a global perspective

Contents



Back of animals are feeds; and back of the feeds are soil resources, spring rains, and the energy of the sun. With the aid of science, technology, and animals, farmers and ranchers combine these to produce a tasty platter of meat and eggs for the table, cream for the peaches, butter for the biscuits, and cheese for the macaroni—all derived from the sun through the process known as photosynthesis.

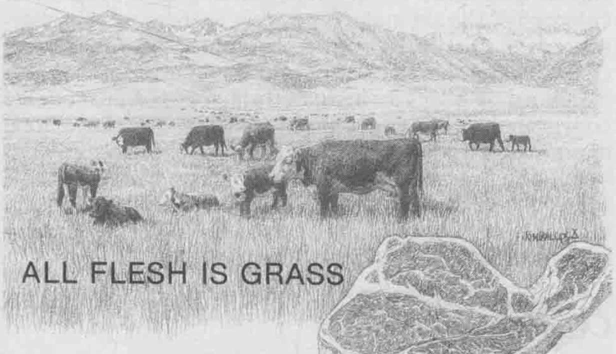



Fig. 1-1. Without photosynthesis, there would be no oxygen, no plants, no food, no animals, and no people.

But animal products are far more than just very tempting and delicious foods! From a nutrition standpoint, foods of animal origin contribute certain essentials to the American diet; they supply 35% of the energy, 70% of the protein—along with the essential amino acids, 80% of the calcium, 60% of the phosphorus, and significant amounts of the other minerals and vitamins needed in the human diet. It is noteworthy, too, that animal products contain vitamin B–12, which does not occur in plant foods, and that they are a rich source of iron, the availability of which is twice as high as in plants.

## *ALL FLESH IS GRASS!*

Life on earth is dependent upon photosynthesis. Without it, there would be no oxygen, no plants, no feed, no food, no animals, and no people.

As fossil fuels (coal, oil, shale, and petroleum)—the stored photosynthates of previous millennia—become exhausted, the biblical statement, "all flesh is grass" (Isaiah 40:6), comes alive again. The focus is on photosynthesis. Plants, using solar energy, are by far the most important, and the only renewable, energy-producing method,[1] the only basic food-manufacturing process in the world; and the only major source of oxygen in the earth's atmosphere. Even the chemical and electrical energy used in the brain cells of man is the product of sunlight and the chlorophyll of green plants. Thus, in an era of world food shortages, it is inevitable that the entrapment of solar energy through photosynthesis will, in the long run, prove more valuable than all the underground fossil fuels—for when the latter are gone, they are gone forever.

## *PHOTOSYNTHESIS AND RUMINANTS*

*Photosynthesis is the process by which the chlorophyll-containing cells in green plants capture the energy of the sun and convert it into chemical energy; it's the process through which plants synthesize and store organic compounds, especially carbohydrates, from inorganic compounds—carbon dioxide, water, and minerals, with the simultaneous release of oxygen.*

*Ruminants, which include cattle, sheep, goats, and water buffalo, are even-toed, hoofed animals that ruminate (regurgitate and chew a cud) and have a complex four-compartment stomach characterized by much storage space and microbial fermentation and adapted to the effective use of high-fiber feeds and the manufacture of B-complex vitamins and essential amino acids.*

Photosynthesis and ruminants team up to provide every ounce of food that we eat, every breath of oxygen that we inhale, and a very large portion of all the B-complex vitamins and all the essential amino acids that we require. Without photosynthesis and ruminants, there would be no plant and animal life on earth—and no human race.

[1]Certain types of microorganisms, termed chemoautotrophs, get their energy from inorganic compounds, but aside from this minor exception, the energy that runs the life support systems of the biosphere comes from photosynthesis.

Photosynthesis is dependent upon the presence of chlorophyll, a green pigment which develops in plants soon after they emerge from the soil. Chlorophyll is a chemical catalyst—it stimulates and makes possible certain chemical reactions without becoming involved in the reaction itself. By drawing upon the energy of the sun, it can convert inorganic molecules, carbon dioxide ($CO_2$) and water ($H_2O$), into an energy-rich organic molecule such as glucose ($C_6H_{12}O_6$), and at the same time release free oxygen ($O_2$). It transforms solar energy into a form that can be used by plants, animals, and humans. Because of this capability, chlorophyll has been referred to as the link between nonliving and living matter, or the pathway through which nonliving elements may become part of living matter.

Through the photosynthetic process, it is estimated that more than a billion tons of carbon per day are converted from inorganic carbon dioxide ($CO_2$) to organic sugars ($C_6H_{12}O_6$— glucose), which can then be converted into other carbohydrates, fats, and proteins—the three main groups of organic materials of living matter.

Photosynthesis is a series of many complex chemical reactions, involving the following two stages (see Fig. 1–2):

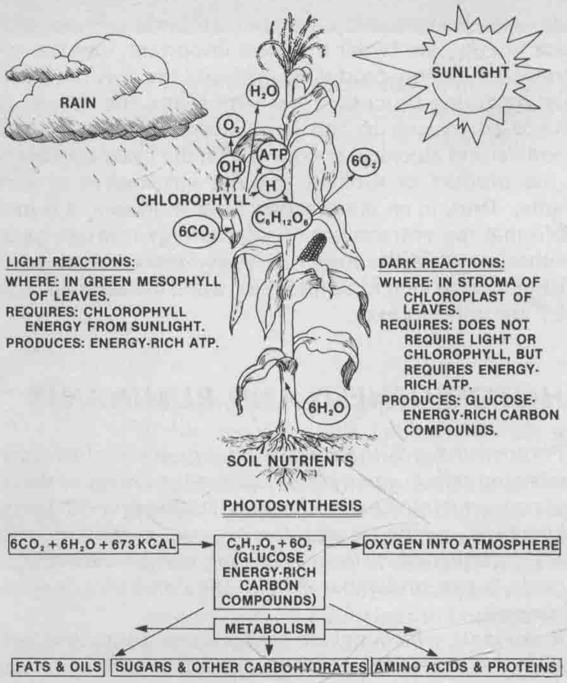



Fig. 1–2. Photosynthesis fixes energy. Diagrammatic summary of (1) photosynthesis, and (2) the metabolic formation of organic compounds from the simple sugars. This diagram shows the following:

1. Carbon dioxide gas from the air enters the green mesophyll cells of plant leaves.
2. Plants take up oxygen from the air for some of their metabolic processes and release oxygen back to the air from other metabolic processes.
3. Plants take up water and essential elements from the soil.
4. The energy essential to photosynthesis is absorbed by chlorophyll and supplied by sunlight.
5. For a net input of 6 molecules of carbon dioxide and 6 molecules of water, there is a net output of 1 molecule of sugar and 6 molecules of oxygen.
6. The process is divided into light and dark reactions, with the light reactions building up the energy-rich ATP required for the dark reactions.
7. In the process, 673 Calories (kcal) of energy are used.
8. The sugar (glucose) manufactured in photosynthesis may be converted into fats and oils, sugars and other carbohydrates, and amino acids and proteins.

**Stage 1**—The water molecule ($H_2O$) is split into hydrogen (H) and oxygen (O); and oxygen, the necessary gas for breathing of animals, is released into the atmosphere. Hydrogen is combined with certain organic compounds to keep it available for use in the second step of photosynthesis. Chlorophyll and light are involved in this stage.

**Stage 2**—Carbon dioxide ($CO_2$) combines with released hydrogen to form the simple sugar (glucose) and water. This reaction is energized (powered) by ATP (adenosine triphosphate), a stored source of energy. Neither chlorophyll nor light is involved in this stage.

The chemical reactions through which chlorophyll converts the energy of solar light to energy in organic compounds is one of nature's best-kept secrets. Scientists have not been able to unlock it, as they have so many of life's processes. Moreover, photosynthesis is limited to plants; animals store energy in their products—meat, milk, and eggs—but they must depend upon plants to manufacture it.

Although photosynthesis is vital to life itself, it is very inefficient in capturing the potentially available energy. Of energy that leaves the sun in a path toward the earth, only about half reaches the ground. The other half is absorbed or reflected in the atmosphere. Most of that which reaches the ground is dissipated immediately as heat or is used to evaporate water in another important process for making life possible. Only about 2% of the earthbound energy from the sun actually reaches green plants, and only half of this amount (1%) is transformed by photosynthesis to energy storage in organic compounds. Moreover, only 5% of this plant-captured energy is fixed in a form suitable as food for people.

With such a small portion of the potentially useful solar energy actually being used to form plant tissue, it would appear that some better understanding of the action of chlorophyll should make it possible to increase the effectiveness of the process. Three approaches are suggested: (1) increasing the amount of photosynthesis on earth; (2) manipulating plants for increased efficiency of solar energy conversion; and (3) converting a greater percentage of total energy fixed as chemical energy in plants (the other 95%) into a form available to humans. Ruminants are the solution to the latter approach; they can convert energy from such humanly inedible plant materials as grass, cornstalks, and straw into food for humans. (See Fig. 1–3.)

## *CONSERVE ENERGY*

In addition to production, as such, there are two other important steps in the feed-food line as it moves from the producer to the consumer; namely, processing and marketing, both of which require higher energy inputs than to produce the food on the farm. (See Table 1–1.)

Table 1–1 points up the increasing drain that modern food production is putting on the energy supply. In 1980, U.S. farms put in 2.8 calories of fuel per calorie of food grown, 3.1 times more than the on-farm energy input in 1940.

Table 1–1 also shows that, in the United States in 1980, a total of 12.1 calories were used in the production, food processing, and marketing-cooking for every calorie of food consumed, with a percentage distribution of the total cost of energy at each step from producer to consumer as follows: on the farm, 23%; food processing, 39%; and marketing and home cooking, 38%. In 1940, it took only 5.2 cal-

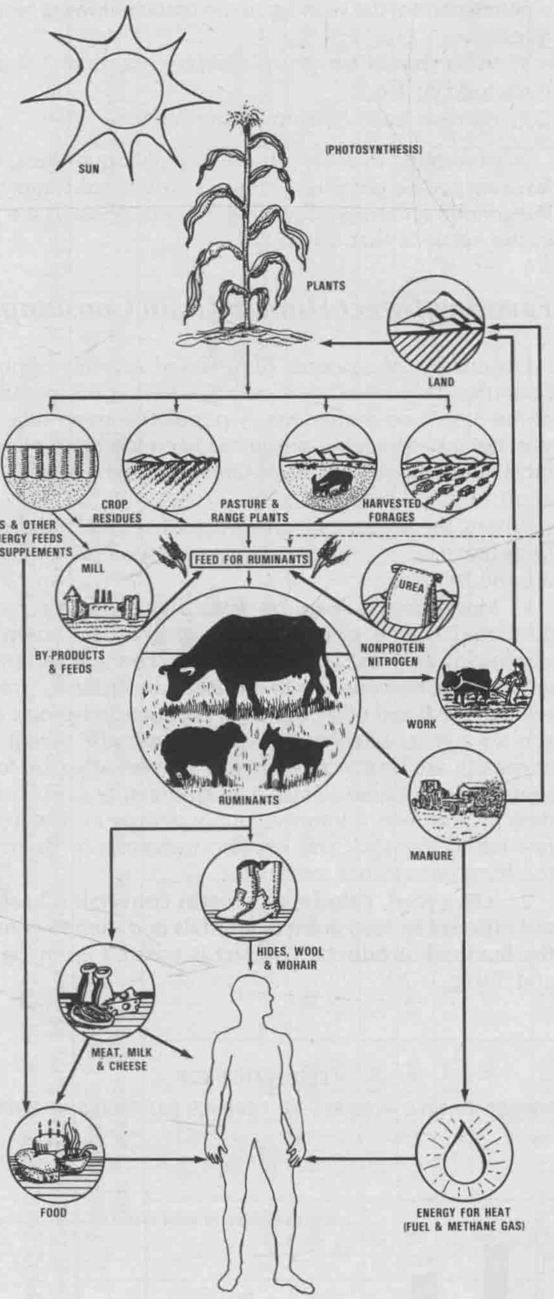



Fig. 1-3. The sun-plant-land-ruminant-human relationship. Ruminants step up energy and manufacture B-vitamins and essential amino acids. Their feed comes from plants which have their tops in the sun and their roots in the soil. Hence, we have the nutrition cycle as a whole—from the sun and the soil, through the plant, thence to the ruminant (and human) and back to the soil again.

ories—slightly less than half the 1980 figure—to get 1 calorie of food on the table. It's noteworthy, too, that more energy is required for food processing and marketing/home cooking than for growing the product; and that, from 1940 to 1980, the on-the-farm energy requirement increased by 3.1 times, in comparison with an increase of 2.1 and 2.2 times for each of the other steps—processing and marketing/home cooking.

**Table 1-1**
**MODERN FOOD PRODUCTION IS INEFFICIENT IN ENERGY UTILIZATION—THE STORY FROM PRODUCER TO CONSUMER[1]**

| Year | On the Farm | Food Processing | Marketing and Home Cooking | Total/Person /Year |
|---|---|---|---|---|
| **1940[2]** | | | | |
| Million kcal ........ | 0.9 | 2.2 | 2.1 | 5.2 |
| Percent ........... | 18.0 | 42.0 | 40.0 | 100.0 |
| **1980[3]** | | | | |
| Million kcal ........ | 2.8 | 4.7 | 4.6 | 12.1[4] |
| Percent ........... | 23.0 | 39.0 | 4.6 | 100.0 |
| **Increase,** times, 1940-1980 .......... | 3.1 | 2.1 | 2.2 | 2.3 |

[1]Energy in million kcal per capita to produce one million kcal of food in the U.S.
[2]Values from Borgstrom, G., "The Price of a Tractor," *Ceres*, FAO of the U.N., Rome, Italy, Nov.-Dec., 1974, p. 18, Table 3.
[3]Authors' estimate based on several reports detailing trends in energy usage.
[4]This means that in 1980 it required 12.1 million kcal to produce 1 million kcal of food for each person, a daily consumption of 2,740 kcal (1,000,000 ÷ 365 = 2,740).

Modern intensive farming has markedly increased crop yields per acre and per man-hour—by as much as 50- to 100-fold. But this has been done at the cost of large inputs of fuel. Today, for a surprising number of cropping systems, a 10- to 50-fold increase in the energy output merely doubles or triples the food energy. Thus, the law of diminishing returns prevails.

Scarce and high-priced fossil fuels have spurred a search for conserving stored energy and for increased energy production through photosynthesis. Higher productivity of the agriculture of tomorrow must be achieved through ingenious approaches in order to reverse the present lopsided energy balance. In obtaining increased feed and food yields, we must consider how many calories of energy are required to produce each calorie of feed or food. We must remember that photosynthesis does not deplete fossil fuels. We must remember, too, that grazing animals do not require fuel outside of their own body use to harvest the energy and other nutrients of grass (solar energy converted into chemical energy by grass), a renewable source. It follows

Fig. 1-4. An Oriental wet rice peasant, using animal power (water buffalo), expends only 1 calorie of energy to produce each 50 calories of food. By comparison, the average U.S. farmer, using mechanical power (tractors), expends 2.5 calories of fuel energy to produce 1 calorie of food. (Courtesy, International Bank for Reconstruction and Development, Washington, D.C.)

that ruminants, which utilize grazing land, offer the best means of stepping up and storing energy for humans.

Energy may also be conserved by lessening waste. Pests cause an estimated 30% annual crop loss in the worldwide potential production of crops, livestock, and forests.[2] Every part of our feed, food, and fiber supply is vulnerable to pest attack, including marine life, wild and domestic animals, field crops, horticultural crops, and wild plants. Obviously, reducing these losses would conserve energy and increase the supply of feed, food, and fiber.

## *FOOD FOR THE 21st CENTURY*

As the ghost of hunger, foretold by the English clergyman Thomas Robert Malthus in 1798, stalks the world, the focus is on animals. During periods of food scarcity, it is inevitable that some will suggest that grain be diverted from livestock and poultry feeding—that they will challenge the efficiency of animals in converting feed to food and the place of animals in the economical production of human food. Animal agriculture will be on trial. Increasingly, the charge will be made that much of the world goes hungry because of the substitution of meat, milk, and eggs for direct grain consumption. A response to this accusation requires that animal agriculturalists substitute knowledge for moral indignation. To this end, the important sections that follow are presented.

### *Who Shall Eat?*

An appalling 500 million people in the world suffer from hunger and malnutrition. More shocking yet, it is estimated that the troubled 21st century will open with 1.3 billion malnourished people. For these starving millions around the globe, life is little more than a heartrending journey to an end which refuses to arrive soon enough to stop their suffering. For the most part, the world's hungry and malnourished are grain eaters.

Cereal grain is the most important single component of the world's food supply, accounting for 50% of the food produced in all the globe. It is the major source of food for many of the world's poorest people, supplying 58% of the total calories in the developing countries (see Fig. 1–5).

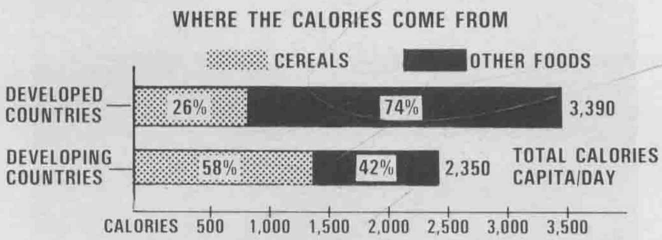



Fig. 1-5. Calories per person per day from cereals vs other foods. In the developed countries, only 26% of the calories comes from direct consumption of cereals, compared with about 58% in developing countries. (*Source:* The Fifth World Food Survey, FAO, United Nations, Rome, Italy, 1985)

However, in many developed countries, more grain is fed to animals than is consumed directly by humans. Under such circumstances, sporadic food shortages and famine in different parts of the world give rise to the following recurring questions:

1. Who should eat grain—people or animals? Shall we have food or feed?
2. Can we have both food and feed?

In attempting to answer these complex questions, those favoring people going on a grain diet often substitute moral indignation for knowledge. The authors' answers are given in the sections that follow.

### *Favoring Direct Human Grain Consumption*

Historically, the people of new and sparsely populated countries have been meat eaters, whereas the population of the older and more densely populated areas have been vegetarians. The latter group has been forced to eliminate most animals and consume plants and grains directly in an effort to avoid famine.

Among the arguments sometimes advanced by those who favor bread alone—the direct human consumption of grain—are the following:

1. **More people can be fed.** More hunger can be alleviated with a given quantity of grain by completely eliminating animals. About 2,000 lb of concentrates (mostly grain) must be supplied to livestock in order to produce enough meat and other livestock products to support a person for a year, whereas 400 lb of grain (corn, wheat, rice, soybeans, etc.) eaten directly will support a person for the same period of time. Thus, a given quantity of grain eaten directly will feed 5 times as many people as it will if it is first fed to livestock and is eaten indirectly by humans in the form of livestock products.

2. **On a feed, calorie, or protein conversion basis, it's not efficient to feed grain to animals and then to consume the livestock products.** This fact is pointed up in Fig. 1-6 and Table 1-2.[3]

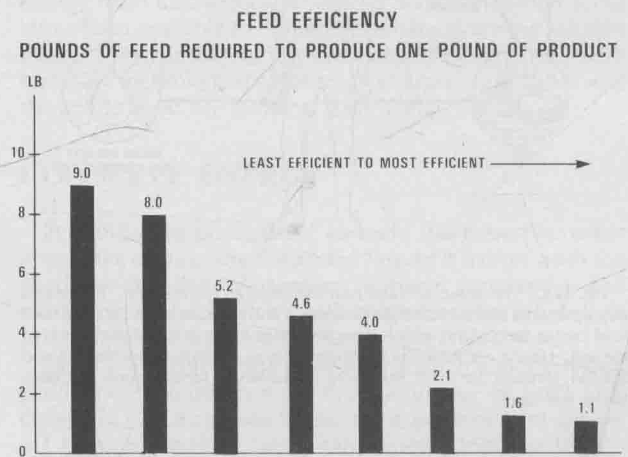



Fig. 1-6. Pounds of feed required to produce 1 lb of product. This shows that it takes 9 lb of feed to produce 1 lb of on-foot beef, whereas it takes only 1.11 lb of feed to produce 1 lb of milk. (Source: Table 1-2 of this chapter)

[2]Ennis, Jr., W. B., W. M. Dowler, and W. Klassen, "Crop Production to Increase Food Supplies," *Science*, Vol. 188, No. 4188, May 9, 1975, pp. 593–598.

[3]See **NOTE WELL** at the bottom of Table 1-2.

## TABLE 1–2
### FEED TO FOOD EFFICIENCY RATING BY SPECIES OF ANIMALS, RANKED BY PROTEIN CONVERSION EFFICIENCY
(Based on Energy as TDN or DE and Crude Protein in Feed Eaten by Various Kinds of Animals Converted into Calories and Protein Content of Ready-to-Eat Human Food)

| | | Feed Required to Produce One Production Unit | | | | Dressing Yield | | Ready-to-Eat; Yield of Edible Product (meat & fish deboned & after cooking) | | | | Feed Efficiency[4] | | Efficiency Rating | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Unit of Production (on foot) | Pounds | TDN[1] | DE[2] | Protein | Percent | Net Left | As % of Raw Product (carcass) | Amount Remaining from One Unit of Production | Cal-orie[3] | Protein[3] | (lb feed to produce one lb product) | | Calorie Efficiency[5] | | Protein Efficiency[6] | |
| | | (lb) | (lb) | (kcal) | (lb) | (%) | (lb) | (%) | (lb) | (kcal) | (lb) | (%) | (ratio) | (%) | (ratio) | (%) | (ratio) |
| **Broiler** | 1 lb chicken | 2.1[7] | 1.7[8] | 3,400 | 0.21[8] | 72[13] | 0.72 | 54[14] | 0.39 | 274 | 0.11 | 47.6 | 2.1:1 | 8.1 | 12.4:1 | 52.4 | 1.9:1 |
| **Fish** | 1 lb fish | 1.6[9] | 0.98 | 1,960 | 0.57 | 65[10] | 0.65 | 57[11] | 0.37 | 285 | 0.27 | 62.5 | 1.6:1 | 14.5 | 6.9:1 | 47.6 | 2.1:1 |
| **Dairy cow** | 1 lb milk | 1.11[7] | 0.9[8] | 1,800 | 0.1[8] | 100 | 1.0 | 100 | 1.0 | 309 | 0.037 | 90.0 | 1.11:1 | 17.2 | 5.8:1 | 37.0 | 2.7:1 |
| **Turkey** | 1 lb turkey | 5.2[7] | 4.21[8] | 8,420 | 0.46[8] | 79.7[13] | 0.797 | 57[15] | 0.45 | 446 | 0.146 | 19.2 | 5.2:1 | 5.3 | 18.9:1 | 31.7 | 3.2:1 |
| **Layer** | 1 lb eggs (8 eggs) | 4.6[7] | 3.73[8] | 7,460 | 0.41[8] | 100 | 1.0 | 100[12] | 1.0[12] | 616 | 0.106 | 21.8 | 4.6:1 | 8.3 | 12.1:1 | 25.9 | 3.9:1 |
| **Hog** (birth to market weight) | 1 lb pork | 4.0[18] | 3.2 | 6,400 | 0.36 | 70[16] | 0.70 | 44[17] | 0.31 | 341 | 0.088 | 0.25 | 4.0:1 | 5.3 | 18.8:1 | 24.4 | 4.1:1 |
| **Rabbit** | 1 lb fryer | 3.0[19] | 2.20 | 4,400 | 0.48 | 55[19] | 0.55 | 79[19] | 0.43 | 301 | 0.08 | 35.7 | 2.8:1 | 6.8 | 14.6:1 | 16.7 | 6.0:1 |
| **Beef steer** (yearling finishing period in feedlot) | 1 lb beef | 9.0[18] | 5.85 | 11,700 | 0.90 | 58[16] | 0.58 | 49[17] | 0.28 | 342 | 0.085 | 11.1 | 9.0:1 | 2.9 | 34.2:1 | 9.4 | 10.6:1 |
| **Lamb** (finishing period in feedlot) | 1 lb lamb | 8.0[18] | 4.96 | 9,920 | 0.86 | 47[16] | 0.47 | 40[17] | 0.19 | 225 | 0.052 | 12.5 | 8.0:1 | 2.3 | 44.1:1 | 6.0 | 16.5:1 |

[1]TDN pounds computed by multiplying pounds feed (column to left) times percent TDN in normal rations. Normal ration percent TDN taken from M. E. Ensminger's books and rations, except for the following: dairy cow, layer, broiler, and turkey from *Agricultural Statistics 1974*, p. 358, Table 518. Fish based on averages recommended by Michigan and Minnesota Stations and U.S. Fish and Wildlife Service.

[2]Digestible Energy (DE) in this column given in kcal, which is 1 Calorie (written with a capital C), or 1,000 calories (written with a small c). Kilocalories computed from TDN values in column to immediate left as follows: 1 lb TDN = 2,000 kcal.

[3]From *Lessons on Meat*, National Live Stock and Meat Board, 1965.

[4]Feed efficiency as used herein is based on pounds of feed required to produce 1 lb of product. Given in both percent and ratio.

[5]Kilocalories in ready-to-eat food = kilocalories in feed consumed, converted to percentage. Loss = kcal in feed ÷ kcal in product.

[6]Protein in ready-to-eat food = protein in feed consumed, converted to percentage. Loss = pounds protein in feed ÷ pounds protein in product.

[7]*Agricultural Statistics 1974*, p. 358, Table 518. Pounds feed per unit of production is expressed in equivalent feeding value of corn.

[8]Pounds feed (column No. 2) per unit of production (column No. 1) is expressed in equivalent feeding value of corn. Therefore, the values for corn were used in arriving at these computations. No. 2 corn values are TDN, 81%; protein, 8.9%. Hence, for the dairy cow 81% × 1.11 = 0.9 lb TDN; and 8.9% × 1.11 = 0.1 lb protein.

[9]Data from report by Dr. Phillip J. Schaible, Michigan State University, *Feedstuffs*, April 15, 1967.

[10]*Industrial Fishery Technology*, edited by Maurice E. Stansby, Reinhold Pub. Corp., 1963, Ch. 26, Table 26-1.

[11]*Ibid.* Reports that "Dressed fish averages about 73% flesh, 21% bone, and 6% skin." In limited experiments conducted by A. Ensminger, it was found that there was a 22% cooking loss on filet of sole. Hence, these values—73% flesh from dressed fish, minus 22% cooking losses—give 57% yield of edible fish after cooking, as a percent of the raw, dressed product.

[12]Calories and protein computed basis per egg; hence, the values herein are 100% and 1.0 lb, respectively.

[13]*Marketing Poultry Products*, 5th Ed., by E. W. Benjamin et al., John Wiley & Sons, 1960, p. 147.

[14]*Factors Affecting Poultry Meat Yields*, University of Minnesota Sta. Bull. 476, 1964, p. 29, Table 11 (fricassee).

[15]*Ibid.* Page 28, Table 10.

[16]Ensminger, M. E., *The Stockman's Handbook*, 6th Ed., Sec. XII.

[17]Allowance made for both cutting and cooking losses following dressing. Thus, values are on a cooked, ready-to-eat basis of lean and marbled meat, exclusive of bone, gristle, and fat. Values provided by National Live Stock and Meat Board (personal communication of June 5, 1967, from Dr. Wm. C. Sherman, Director, Nutrition Research, to the senior author), and based on data from *The Nutritive Value of Cooked Meat*, by Ruth M. Leverton and George V. Odell, Misc. Pub. MP-49, Appendix C, March 1958.

[18]Estimates by the authors.

[19]Based on information in *Commercial Rabbit Raising*, Ag. Hdbk. No. 309, USDA, 1966, and *A Handbook on Rabbit Raising*, by H. M. Butterfield, Washington State University Ext. Bull. No. 411.

**NOTE WELL:** It could be argued that Table 1–2 makes no provision for the feed used by the sires and dams of these animals—the animals that gave birth to these producers. Others may be critical of using a yearling steer without making provision to get him to the feedlot stage. Finally, it may be contended that any such comparison should be between animals of like age; for example, between broilers and veal calves. Having raised these questions, the authors submit Table 1–2, which in their judgment is as fair a rating on feed to food efficiency as can be made.

## *Favoring An Animal Agriculture*

Among some social reformists, the charge persists that much of the world goes hungry because of the substitution of meat, milk, and eggs for direct grain consumption. A response to this accusation requires far more than a simple denial.

The following facts are presented in favor of sharing grain with animals, then consuming the animal products:

1. **Animals provide needed power.** In the developing nations, cattle, water buffalo, and horses still provide much of the agricultural power. In this capacity, they contribute to human food supply from plant sources.

2. **Animals provide needed nutrients.** It is estimated that the average American gets the percentages of food nutrients shown in Fig. 1-7 from animal products.

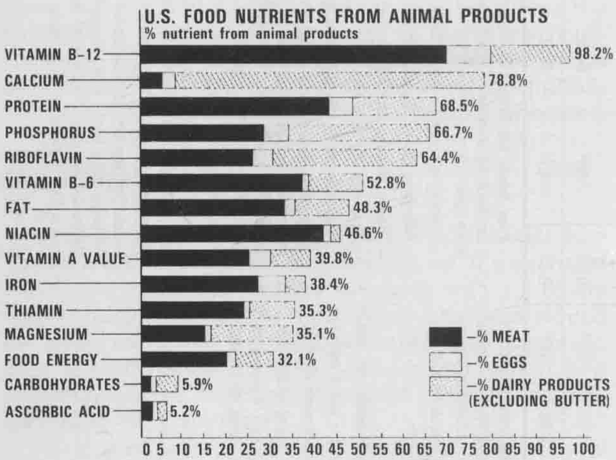



Fig. 1-7. Percentage of food nutrients contributed by animal products of the total nutrient supply in the U.S. (From: *Agricultural Statistics,* USDA)

Foods of animal origin (meat, milk, eggs, and their various by-products) are especially important in the American diet; they provide ⅔ of the total protein, ⅓ of the total energy, ⅘ of the calcium, ⅔ of the phosphorus, and significant amounts of the other minerals, and vitamins needed in the human diet. Note, too, that animal products provide practically all of the Vitamin B-12, which does not occur in plant foods—only in animal sources, and fermentation products. Also, it is noteworthy that the availability of iron in meat is twice as high as in plants.

About ⅔ of the world's protein supply is provided from plant sources, ⅓ from animal sources. (See Fig. 1-8.) The Food and Agriculture Organization of the United Nations reports that the world's diet needs animal protein in amounts equivalent to ⅓ of the total protein requirements. Thus, there should be ample animal protein, *provided* it is equally distributed. But it isn't.

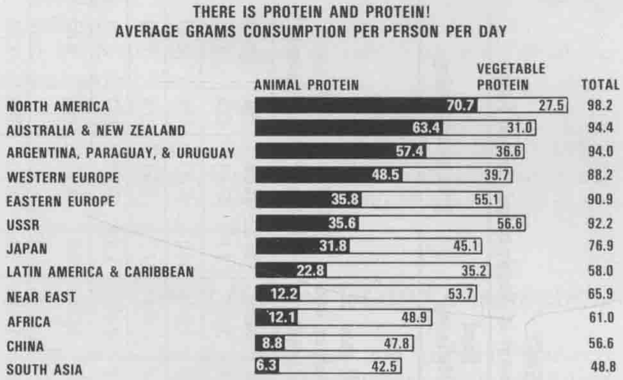



Fig. 1-8. Average grams protein consumption per person per day, with a breakdown into animal and vegetable protein, by geographic areas and countries. (From: *Ceres,* FAO/UN, Vol. 8, No. 3)

The most important role of animal protein is to correct the amino acid deficiencies of the cereal proteins, which supply about ⅔ of the total protein intake, and which are notably deficient in the amino acid, lysine. The latter deficiency can also be filled by soybean meal, fish, protein concentrates and isolates, synthetic lysine, or high-lysine corn. But such products have neither the natural balance in amino acids nor the appetite appeal of animal protein.

3. **Animals produce protein of higher value than plants.** Proteins from animal sources (meat, milk, and eggs) have a higher value than proteins from plant sources because they have every amino acid needed for growth, including lysine, tryptophan, and methionine, which are deficient in vegetable sources.

4. **Ruminants convert nonprotein nitrogen to protein.** Ruminant animals, by their ability to fix nitrogen through bacterial action, can use nonprotein nitrogen, like urea, to produce protein for humans in the form of meat and milk (see Fig. 1-9).

5. **Animals step up the protein content and quality of foods.** Grains, such as corn, are much lower in protein content in cereal form than after conversion into meat, milk, and eggs. On a dry basis, the protein contents of selected products are corn, 10.45%; beef (Choice grade, total edible, trimmed to retail level, raw), 30.7%; milk, 26.4%; and eggs, 47.0%.[4] Also, animals increase the quality (*i.e.,* biological value) of the protein.

6. **Animals provide products that meet consumer preferences.** Most people who can afford to do so eat a portion of their food in the form of livestock products simply because of preference—because they like them.

7. **Much of the world's land is not cultivatable.** Vast acreages throughout the world—including arid and semiarid grazing lands; and brush, forest, cutover, and swamplands—are unsuited to the production of bread grains or any other type of farming; their highest and best use is, and will remain, for grazing and forest.

[4]*Composition of Foods,* Ag. Hdbk. No. 8, Agricultural Research Service, USDA.

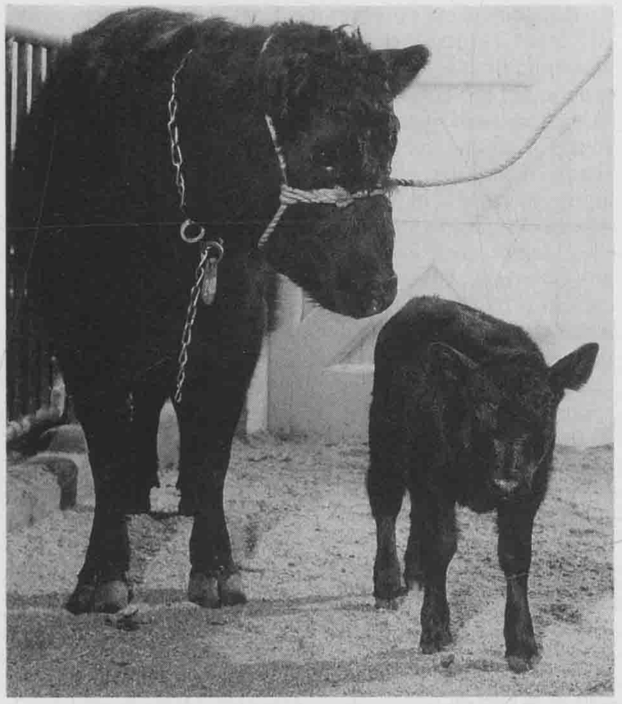


Fig. 1-9. This cow is believed to be the first in the world to have grown, conceived, and given birth to a healthy calf when fed since weaning (7 months) on a protein-free diet that contained urea as the only source of nitrogen. The cow weighed 930 lb and the calf 61 lb at the time of birth. (Courtesy, Robert R. Oltjen, U.S. Meat Animal Research Center, Clay Center, Nebr.)

8. **Forages provide most of the feed for livestock.** Pastures and other roughages—feeds not suitable for human consumption—provide most of the feed for livestock, especially for ruminants, throughout the world. In the 48 states of the U.S., grassland, pasture and range constitute a major land use (see Fig. 1–10).

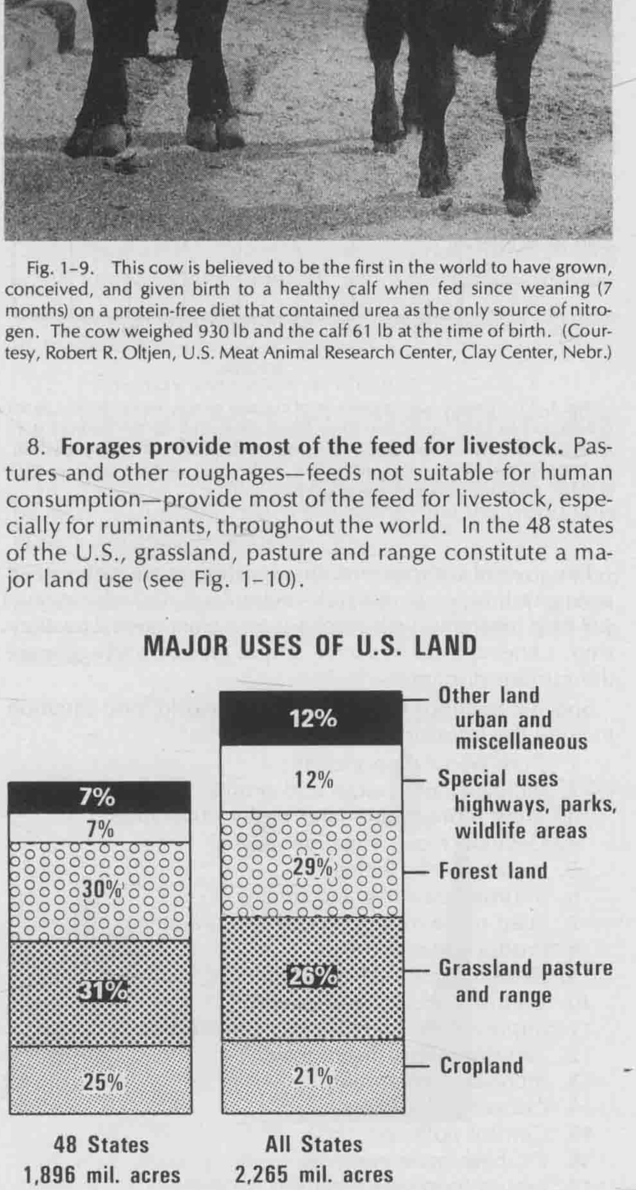



Fig. 1-10. Major uses of land. (From: Ag. Hdbk. No. 652, USDA, p. 16, Chart 41)

Despite grains being relatively plentiful in the United States, forages provide the bulk of animal feeds; pastures and other roughages account for 93.8% of the total feed of sheep and goats, 84.5% of the feed of beef cattle, 58.7% of the feed of dairy cattle, and 61.7% of the feed of all livestock.[5]

9. **Food and feed grains are not synonymous.** Animals do not compete to any appreciable extent with the hungry people of the world for food grains, such as rice or wheat. Instead, they eat feed grains and by-product feeds—such as field corn, grain sorghum, barley, oats, milling by-products, distillery wastes, and fruit and vegetable wastes—for which there is little or no demand for human use in most countries, plus forages and grasses—fibrous stuff that people cannot eat.

10. **Ruminants utilize low-quality roughages.** Cattle, sheep, and goats efficiently utilize large quantities of coarse, high-cellulose roughages, including crop residues, straw, and coarse low-grade hays. Such products are indigestible by humans, but from 30 to 80% of the cellulose material is digested by ruminants.

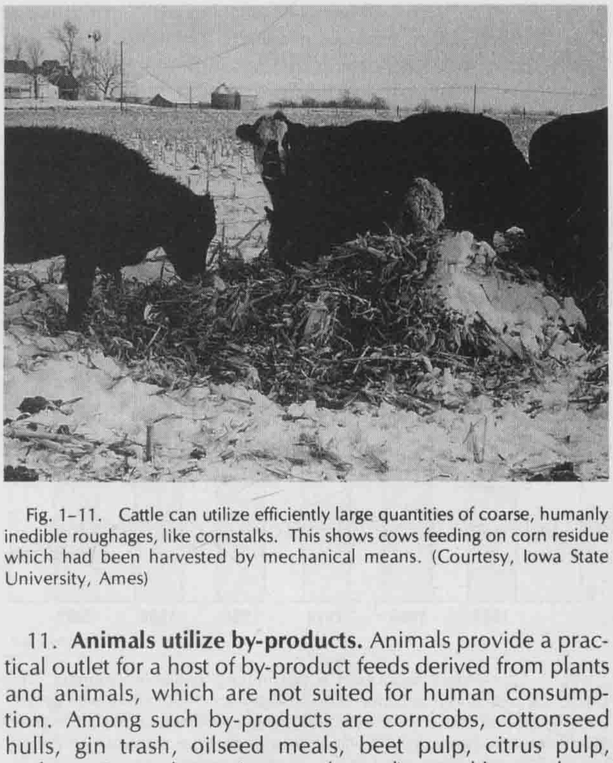


Fig. 1-11. Cattle can utilize efficiently large quantities of coarse, humanly inedible roughages, like cornstalks. This shows cows feeding on corn residue which had been harvested by mechanical means. (Courtesy, Iowa State University, Ames)

11. **Animals utilize by-products.** Animals provide a practical outlet for a host of by-product feeds derived from plants and animals, which are not suited for human consumption. Among such by-products are corncobs, cottonseed hulls, gin trash, oilseed meals, beet pulp, citrus pulp, molasses (cane, beet, citrus, and wood), wood by-products, rice bran and hulls, wheat milling by-products, and fruit, nut, and vegetable refuse.

12. **Animals provide elasticity and stability to grain production.** Livestock feeding provides a large and flexible outlet for the year-to-year changes in grain supplies. When there is a large production of grain, more can be fed to livestock, with the animals carried to heavier weights and higher finish. On the other hand, when grain supplies are low, herds and flocks can be maintained by reducing the grain that is fed and by increasing the grasses and roughages in the ration.

[5]Unpublished data provided to the authors by Commodity Economics Division, Economic Research Service, USDA.

13. **Animals provide medicinal and other products.** Animals are not processed for meat alone. They are the source of hundreds of important by-products, including some 100 medicines such as insulin, epinephrine, thyroxin, estrogen, cortisone, and ACTH, along with a multitude of products used in making everything from candles to cosmetics; without which the health and life-style of many people would be altered.

14. **Animals are an effective method of food storage.** In many countries, there are no facilities for storing or transporting crops. Animals may be fed crops in productive years, store food nutrients until needed, and transport themselves to market.

15. **Animals maintain soil fertility.** Animals provide manure for the fields, a fact which was often forgotten during the era when chemical fertilizers were relatively abundant and cheap.

## *WORLD WITHOUT END—WITH ANIMALS*

World population, which is increasing by 76 million per year, is outrunning acres of cropland (see Fig. 1-12). So, food supplies have become more dependent upon increased productivity. But just as Middle East oil is being depleted, so too are soils. Reversing this alarming trend calls for an increased animal agriculture worldwide.

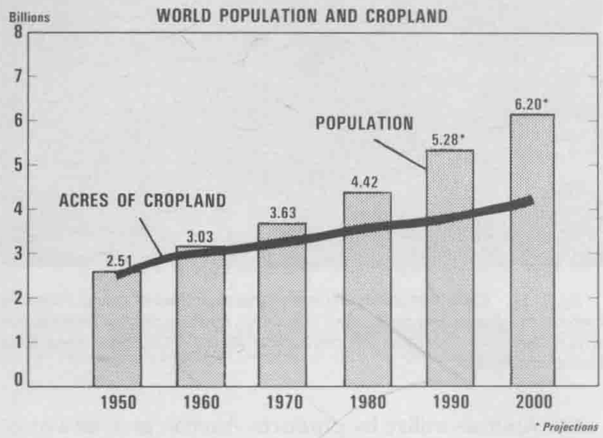



Fig. 1-12. World population is outrunning available cropland. This shows the cropland/population relationship since 1950, along with projections for the year 2000. (World population figures from Worldwatch Institute. World cropland figures from *World Agriculture Outlook and Situation Report*, USDA, Economic Research Service, WAS-36, cover page, June 1984)

World population reached 5 billion in 1987. Population growth during the 1990s is expected to be below the rate of the previous decades—around 1.6% per year, compared to 1.7% in the 1980s, and 1.9% in the 1950s and 1960s. In the year 2000, world population is expected to reach 6.2 billion. (See Fig. 1-12.)

World food consumption is determined by population and the amount eaten per person. It is expected to double over the next three decades, led by greater per capita consumption linked to rising incomes, changing tastes—preference for animal products, and improved food supplies in the developing countries.

Practicality dictates that in the years ahead a hungry world will meet its increased food needs through having plants and animals play complementary roles—and with animal products complementing the deficiencies of plant products. The virtue, even necessity, of using the plant-animal relationship is illustrated in Fig. 1-13. As shown, crops vary in their return of captured solar energy per unit of cultural energy input. Grazing land is highly efficient in the capture of solar energy—requiring little energy for a high return. Hay and silage rank second in energy return, followed by feed grains and oil crops. For the most part, however, these efficient capturers of solar energy do not store the energy in a form available to humans. It follows that ruminants which can utilize grazing land, hay, and silage (not suitable for human consumption) and convert them into meat and milk, are essential.

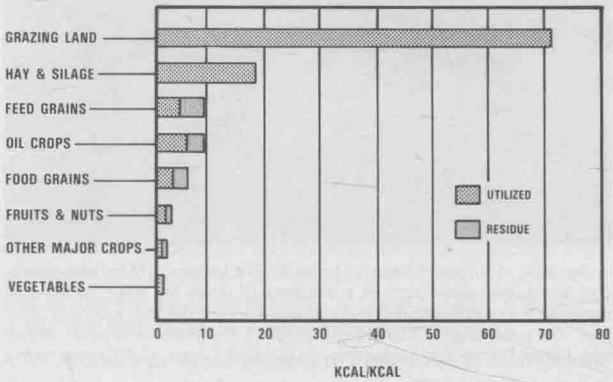



Fig. 1-13. Energy output per unit of cultural energy input (kcal/kcal) for production of food, feed, and fiber crops. (Adapted by the authors from *American Society of Agricultural Engineers*, St. Joseph, Mich., paper No. 75-7505, p. 10, Fig. 5, prepared by L. F. Nelson, W. C. Burrows, and F. C. Stickler, Deere & Company, Moline, Ill.)

For a world without end, the developing countries need a massive infusion of research, technology, and education—self-help programs, with emphasis on a plant-animal relationship. Other approaches serve only to prolong and aggravate the current disparities.

Specific methods for improving the world food situation include the following:

1. Curb population growth.
2. Increase farm prices and profits.
3. Bring more arable land under cultivation.
4. Develop more irrigation.
5. Increase crop yields.
6. Improve pastures and ranges.
7. Feed more roughage and less grain.
8. Produce leaner meats.
9. Develop more efficient animals.
10. Control diseases and parasites.
11. Improve and increase protein sources.
12. Tap the sea for more food.
13. Increase fish farming.
14. Conserve energy.
15. Control pollution.
16. Establish grain reserves.
17. Lessen food waste caused by pests.
18. Increase scientific exchange between countries.
19. Increase research, education, and extension.

## *QUESTIONS FOR STUDY AND DISCUSSION*

1. List the essential nutrients, and give the percentage of each, contributed to the American diet by animal products.

2. Why is it said that "all flesh is grass?"

3. How do animal and plant food products compare in B-12 and iron content?

4. Define photosynthesis, and explain the process.

5. Why is photosynthesis classed as the most vital of all chemical reactions on earth?

6. Discuss the efficiency of photosynthesis from the standpoint of capturing the potentially available energy of the sun.

7. What is the most practical approach for converting a greater proportion of the total energy of plants (the other 95%) into a form available to humans?

8. Discuss the potential for solving the world food problems of the future through manipulating plants for increased solar energy conversion.

9. What is a ruminant?

10. Why and how are ruminants so important in lessening world food shortages, hunger, and malnutrition?

11. Why and how has modern food production become so inefficient in energy utilization?

12. How may we conserve energy?

13. Who was Thomas Robert Malthus? What, and when, did he prophesy relative to world population and food?

14. Why is it important that livestock producers answer by more than simple denial the charge that the world goes hungry because of animals?

15. In the developed countries, little more than one-third of the calories come from direct consumption of cereals, compared with 62% in the developing countries. Why this difference?

16. List and discuss the factors favoring direct human grain consumption.

17. Table 1-2 shows that on a calorie or protein conversion basis it is not efficient to feed grain to animals and then consume the livestock products. Evaluate this table.

18. Beef and lamb are the least efficient of all animals in feed conversion in pounds of feed required to produce one pound of product. Why not eliminate them entirely?

19. List and discuss the factors favoring an animal agriculture sharing grain with animals.

20. Why retain so much animal power in the developing countries, rather than go entirely to mechanical power?

21. What nutrients can best be obtained from animal proteins, rather than from plant proteins?

22. Fig. 1-9 pictures a cow and a calf that were produced on a protein-free diet. What's unique and significant about this?

23. World population is outrunning world cropland. What can be done to check or lessen this situation?

24. How and why should plants and animals play complementary roles in lessening world food shortages, hunger and malnutrition in the years ahead?

25. Rank crops in their return of captured solar energy per unit of cultural energy input.

26. How can world food shortages be lessened through increased research, technology, and education?

27. Will world food production be adequate to meet world demand in the 21st century?

28. What solution do you propose for the world food problem?

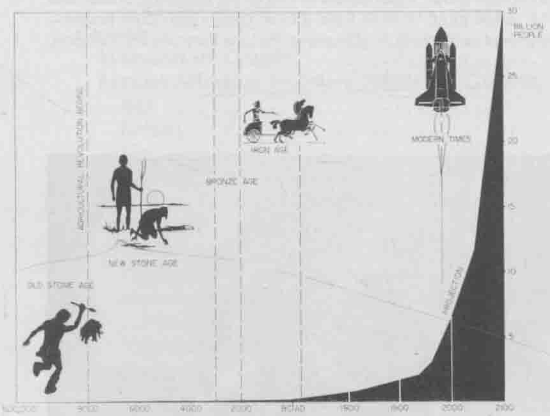



Fig. 1-14. Human population growth, the main determinant of demand for food. This shows the population growth of the world over the past 1½ million years. **NOTE:** If the Old Stone Age were in scale, its base line would extend 8 feet to the left.

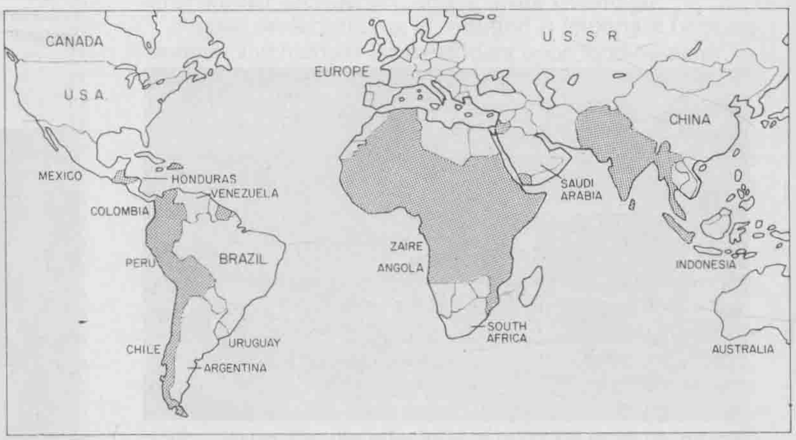



Fig. 1-15. World geography of food problems. The shaded areas are countries where undernourished population exceeds 15%.