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ABSTRACT

This module consists of three activities and an evaluation section. Each activity can be conducted in class or assigned as homework. Activity 1 introduces the students to food chains and energy transfers through trophic levels. Activity 2 explores energy inputs and outputs in the United States food system and encourages the student to identify inefficiencies in the system. Activity 3 relates the financial cost of the energy intensive food system to the consumer. The evaluation section allows the student to suggest means of decreasing the energy consumption of our food system. (Author/RE)

DRAFT

OF 100 YOU ONLY GET 10 OR FOOD FOR THOUGHT

TEACHER'S GUIDE

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OF 100 YOU ONLY GET 10 OR FOOD FOR THOUGHT

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Unit Title: Net Energy

Module Title: Of 100 You Only Get 10 or Food for Thought

Description of Module: Consisting of three activities and an evaluation section, each part can be conducted in the classroom or completed individually as homework. Activity 1 introduces the students to food chains and energy transfers between trophic levels in natural food systems and acquaints the students with their position in food chains. Activity 2 explores the energy inputs and outputs of the U.S. food system and gives the students the opportunity to locate the energy inefficiencies in the system. Activity 3 relates the financial cost of the energy intensive food system to the consumer. The evaluation section allows the student to suggest possible ways of decreasing the energy consumption of our food system.

Unit Objectives Met: 1e, and 2a.

Materials Needed: Paper, pencil, pocket computer, gram (metric) food scale.

Module Type: Alternative

Context: Science, Math, Social Studies.

Time Required: One class period.

Mode: Group activities (comparing data, interpreting graphical information, etc.); class discussion; individual activities.

Sample Evaluation Items

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Summary of Activity Objectives

1. Energy flow through natural systems creates an awareness that:

   a. energy flows through food chains.

   b. energy is lost at each transformation (trophic level) in a food chain.

   c. man is part of these natural systems.

   d. by being at the end of a food chain, man receives only a small part of the energy potentially available to him.

2. Energy gain of intensive agricultural products in the U.S. food system creates an awareness that:

   a. in modern agricultural systems, more goes into producing a crop or farm product than just the energy from the sun.

   b. some crops and products require more energy input than others.

   c. most crops produced by intensive agriculture have a favorable energy gain.

   d. the largest part of energy inputs in the U.S. food system is expended in getting the agricultural products from the field to the consumer's table.

   e. this expenditure of energy on non-agricultural activities gives the entire U.S. food system a very inefficient energy gain.

3. An energy menu creates an awareness of the financial relationship between an energy inefficient food system and the consumer.

Activity I

The concept of energy flow through an ecosystem is an important one for students to understand. We, as Americans, have another inefficient food system, both in production and consumption. We tend to eat food items farther removed from the original source of energy--the sun.

These student exercises are quite self-explanatory and provide the students with some background information they will need to fully understand the activities to follow in the Agriculture and Food Module, (Of 100 You Only Get 10 or Food For Thought).

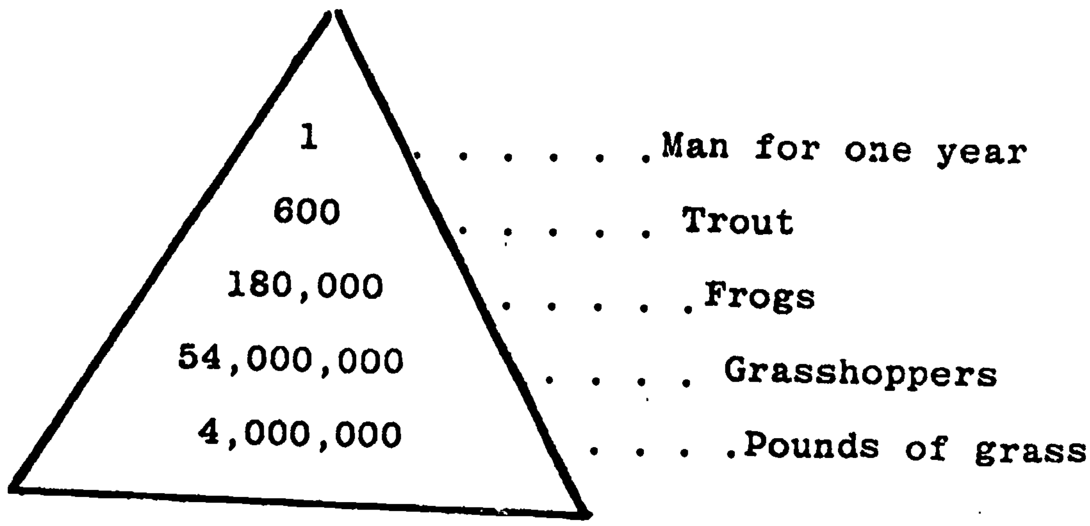
Some figures from Environmental Science are given here that you may want to share with your students for further clarification of the 10% Rule of energy flow.

1. Sun	1,000 calories
Plant	780 calories not absorbed
	228 calories absorbed but released as heat
	12 calories of gross production
	7 calories used as plant respiration
	5 calories left for net production of new plant tissue
Deer	4.5 calories used for respiration, movement, etc.
	0.5 calories left for new animal tissue.

As you can see from this example, the initial loss of energy from the sun at the producer level is around 99%. The 10% Rule applies only from the producer level through consumer levels. While in nature specific examples of energy transfers between trophic levels have been found to vary from 5% to 20%, most are around 10% and, therefore, the 10% Rule is a useful generalization.

1. 27,000 lbs of alfalfa will produce 3,300 lbs of beef in cattle, which in turn will produce 150 lbs of body weight in humans.

Another example adapted from Replenish the Earth by G. Tyler Miller and included in Energy, Food, and You is this pyramid of numbers.



STUDENT GUIDE

Activity I Energy Flow Through Natural Systems

Energy for all living organisms comes from the sun. Solar energy is captured by green plants and transformed into chemical energy or food energy by a process called photosynthesis. These green plants may be called autotrophs for this reason--they are self (auto) nourishing (troph) organisms; that is, they manufacture their own food. Members of the animal kingdom, on the other hand, are other nourishing or heterotrophic organisms because they must feed on the green plants or on other animals to acquire the energy or nutrients (food) they need for life processes. Thus, energy flows through a living system from the sun to autotrophs and then to heterotrophs. Such an energy chain (or food chain) would look like this:

sun ——> autotroph ——> heterotroph
(green plant) (mouse, cow, man, deer)

Because different organisms have varying positions in the energy chain, ecologists place organisms on trophic levels or levels of nourishment. The first (or bottom) level is made up of the autotrophs, also called the producers, because these green plants produce food for other organisms. Orgamisms that eat the producers are called primary consumers and occupy the second trophic level. The third trophic level is made up of secondary consumers who feed upon the primary consumers. Consumer levels continue through the fourth and even fifth levels in a few cases depending on the length of the energy or food chain. One example of a food chain would be: sun ⟶ grass ⟶ mouse ⟶ owl
Another example would be: sun ⟶ algae ⟶ mosquito larvae ⟶ sunfish ⟶ pike ⟶ man

Identify the following for the above food chains:

Producers

Primary Consumers

Secondary Consumers

Tertiary Consumers (third level consumer)

Quaternary Consumers (fourth level consumers)

*Producers - grass and algae
1st Consumer - mouse and mosquito larvae
2nd consumer - owl and sunfish
3rd Consumer - pike
4th Consumer - man

In the next food chain, what trophic level does man occupy?

sun ⟶ tomatoes ⟶ man

*Man is the primary consumer.

What about this food chain? sun ⟶ grass ⟶ cow ⟶ man

*Here, man is the secondary consumer.

Other terms often used to describe positions in food chains are--herbivore, carnivore, and omnivore, where the trophic levels match as follows:

herbivore -- primary consumer (plant eater)

carnivore -- secondary consumer

tertiary consumer (meat eater)

quaternary consumer

omnivore -- occupies varying trophic levels from primary through quaternary consumer depending upon food eaten (eats both plant and animal)

Another group of organisms, which are extremely important to our ecosystem, function as decomposers in the food chain. These organisms, such as fungi, bacteria, snails, etc., are called saprovores and feed on non-living organic matter and aid in the process of decay.

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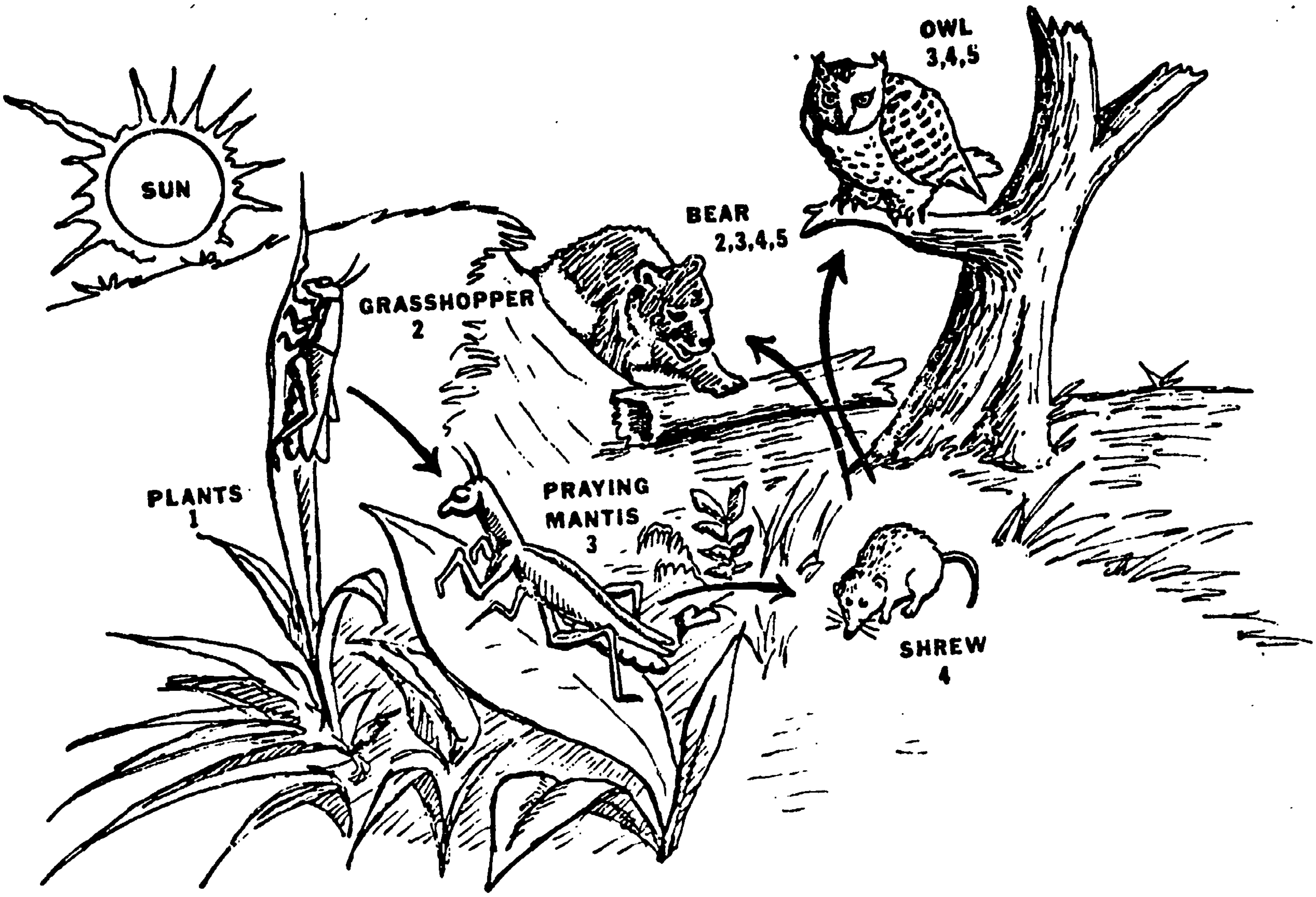


1 = Producer Level

2 = Primary Consumer

3 = Secondary Consumer

4 = Tertiary Consumer (3rd level)

5 = Quaternary Consumer (4th level)

To illustrate the use of these terms, when you eat a raw carrot, you are occupying the primary consumer's trophic level and are eating as an herbivore when you eat beef or pork or chicken, you are functioning as a secondary consumer and as a carnivore. In eating fish, you may be at either the second, third or fourth consumer level depending upon what that particular fish had eaten before it was caught. Because the fish is animal matter, you are again eating as a carnivore. As you can see from the above examples, you are also an omnivore because your diet consists of both plant and animal material.

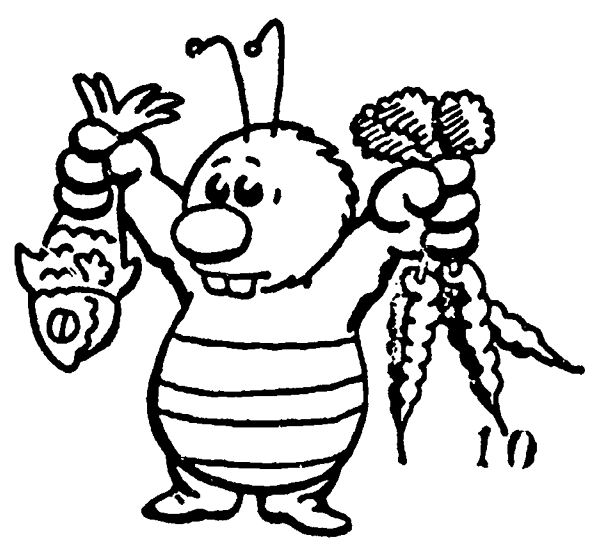
Would a person on a vegetarian diet be a herbivore, a carnivore or an omnivore? What if that person also ate eggs and cheese?

**A strict vegetarian would be an herbivore. If he ate eggs and cheese, he'd be a carnivore since they are animal products.*

List the foods you had for breakfast or lunch today. Trace the various food chains involved in each of the different foods you ate and record whether you were functioning as a primary consumer (herbivore), secondary or higher level consumer. Which level do you seem to occupy most often?

**Answers will vary with individual diets, but most students will most often occupy the primary or secondary consumer level.*

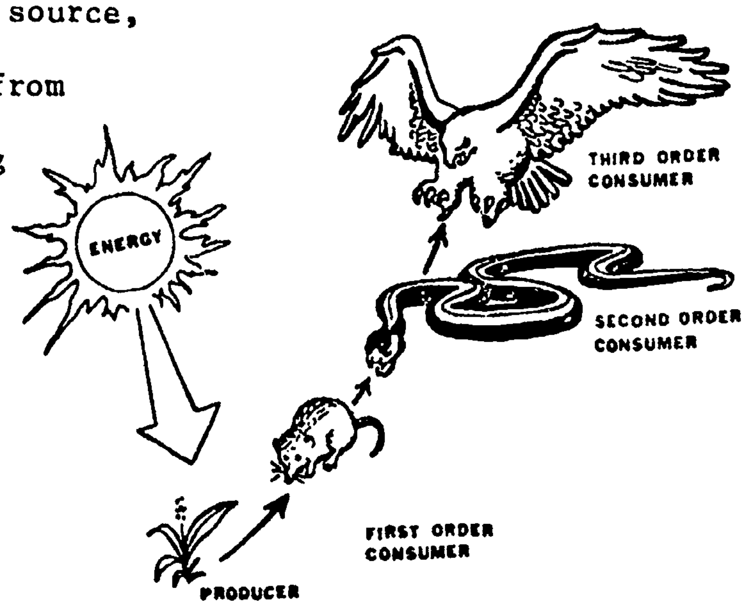
For some added information, try weighing your food on a gram (metric) food scale before you eat. How much does your entire meal weigh? Are you eating more meat (by weight) or more vegetables, fruits or breads? What percentage by weight is the meat? What percentage of your meal (by weight) is plant material? As measured by percent of diet by weight, which trophic level do you most often occupy?



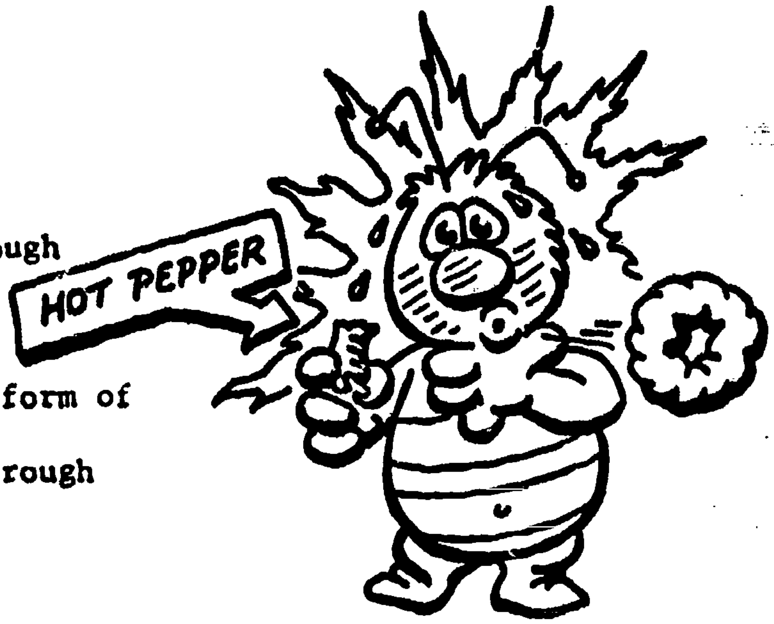
You have been introduced to various terms that help to catalogue the food you eat. You are now aware of trophic levels, herbivores, carnivores, omnivores, and saprovores. You have diagrammed some of your own food chains and found that you occupy different trophic levels depending upon the food you eat. But what does all this mean? What's the point?

The major point is one concerning energy. Why do we need to eat? We need to eat to supply our bodies with the energy needed to live. All our body processes and movements require energy and our energy source is food.

As you learned in previous modules, some energy is lost as it is transferred or transformed from one situation to the next. (Remember energy source and energy receiver?) Food is your energy source, and ultimately, all food energy comes from the sun. How efficient are we in using the sun's energy?



Study the diagram of the Energy Pyramid. Notice that the energy originally comes from the sun. The sun's energy is captured through photosynthesis at the producer level. Then the energy moves through the consumer levels from first order consumer through the second, third, fourth and sometimes fifth level. Notice that the diagram is in the shape of a pyramid. Why do you think this is so? According to the previous discussion on energy transfer, what is happening from one level to the next?



That's right! Some energy is "lost" through the food chain as heat energy. (The energy is not really "lost", it's just transformed into a form of energy we cannot use.) The food energy moves through the energy pyramid (through the trophic levels) with what is called the 10% Rule. Each higher level is able to obtain only 10% of the energy available from the lower level. For example, in the food chain grass mouse snake, the mouse receives 10% of the energy the grass has stored and the snake receives only 10% of the energy the mouse received from the grass. Thus, as the energy moves through the food chain, less and less of the original energy of the sun and the plants is available.

An analogy would be to think of 1,000 energy units representing the food energy available at the producer level. 10% of 1,000 is 100, which is the energy available at the first consumer level; 10% of 100 is 10 left at the second consumer level; 10% of 10 is 1 unit left at the third consumer level. So, in transferring energy through three trophic levels, 1,000 energy units were reduced to 1 energy unit available at that third level. Are we more efficient food energy consumers as herbivores or as carnivores?

Choose three of your favorite foods and trace the food energy through a food chain. Using the 10% Rule, compute the energy available to you from the sun's original energy. Which foods retain the highest energy level?

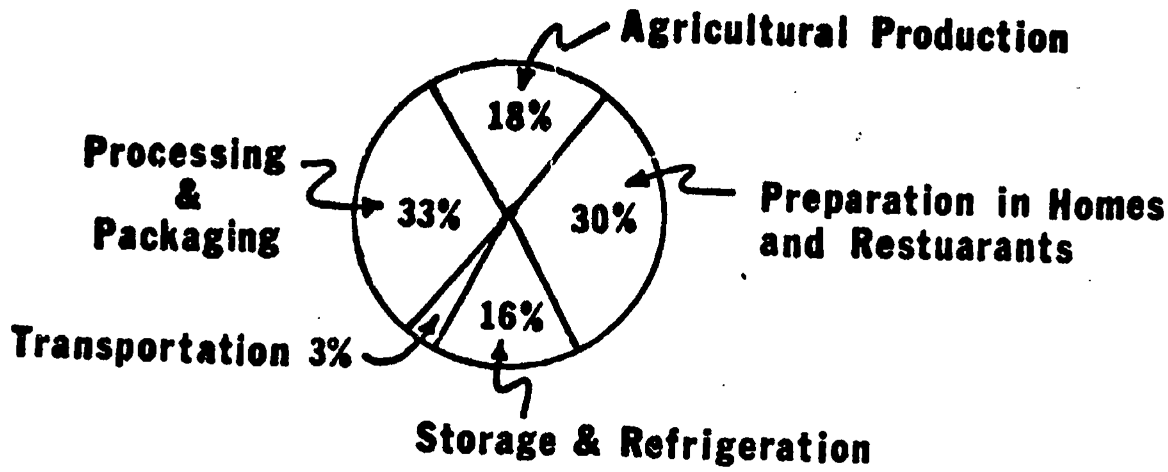
Activity II

Most students are aware of many of the things a farmer goes through to raise a crop or product and a few probably know something about the energy efficiency of this occupation, but certainly none are fully aware of what happens to the agricultural product after it is produced or of the tremendous amount of energy used in getting it from the farm to the table of the consumer. This activity is designed in the hope of impressing the students with the large quantities of energy involved in the U.S. food system. Perhaps your pointing out to the students that the average American needs 1500 kcal /day/100 lbs of body weight would make them more aware of this fact. This is one reason why all the energy measurements are made in kcal/100 lbs of crop or product.

While this activity is written so that a student could compare everything by himself, it is possible he might become engrossed in the computations and fail to look at where most of the energy is being used. For this reason it is suggested that the class be broken into groups of 2 or 3 and each assigned a crop or even two for comparison of crop efficiency. It is advisable that there be overlap in these assignments; that is, one group compares greenbeans and soybeans, another compares soybeans and grain corn, etc.

The data in Table I has been generated to reflect proportionate use of energy for each activity and is not actual data collected in a study. The energy gains for the crops and products, however, are factual results of intensive agriculture in the U.S.

The data in Table 2 is based on information in Cook's Man, Energy, Society and presented in the following diagram:



The final energy gain of a specific crop or product may be slightly larger or smaller than actually measured in studies. The inaccuracies will hopefully be offset by achieving the objective of making the students aware of the relative energy inputs in the food system.

If students are to do this exercise individually, they can generate their own composite chart of energy gains, or the teacher may dictate a format to be followed. If performed as groups in class, the teacher may wish to present only the first half of the composite chart on the board. After the students have computed and entered their findings on the chart, a class discussion on the energy gains and information in Figure 1 may be desirable. While the students are computing the energy gains for the total food system from Table 2, the teacher may then add on the remainder of the composite chart, to be filled in by the students and followed by a summary discussion.

Additional information you may want to make available to the students during the discussions is presented on the following page.

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1. **Acreage Required to Produce One Million Calories (kcal)**

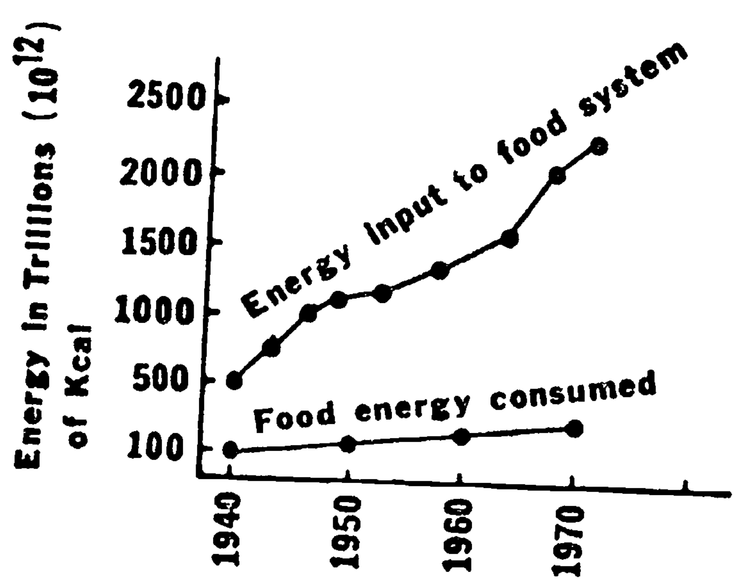
Food Source	Acres of Land	Food Source	Acres of Land
Sugar	0.15	Hogs (pork and Lard)	2.0
Potatoes	0.44	Whole milk	2.8
Corn - as meal	0.9	Eggs	7.8
Wheat - as whole wheat flour	0.9	Chicken	9.3
Wheat - as refined wheat flour	1.2	Steers	17.0

2. Energy Inputs of Fresh and Processed Foods (Units in BTU*/lb)
(from Energy and Food, A.J. Friesch, et.al.)

	Home Grown	Fresh Produce	Canned	Frozen	Dehydrated
Carrots	1,300	4,750	9,200	12,750	37,100
Peas	7,450	10,900	14,250	12,750	37,100
Apples	917	5,950	4,000	9,200	23,200
Potatoes	2,850	6,250	9,000	14,950	26,700

* 1 BTU = 0.252 kcal

3. Energy use in the U.S. food system, 1940 through 1970, compared to the caloric content of food consumed. (From Steinhart and Steinhart, 1974)



Activity II Energy Gain of Intensive Agricultural Products in the U.S. Food System

Now that you are familiar with man's position in food chains and the transfer of energy through those natural food systems, let's look at the energy involved in man's food systems. When man was a hunter-gatherer, very little energy beyond manpower was invested to obtain his energy requirements. With the advent of agriculture, man began investing energy into tools and agricultural practices to increase the amount of sunlight energy captured by his crops in the field. However, the efficiency of raising a crop would be greatly reduced if the amount of energy invested equalled or exceeded the amount of energy captured by that crop and made available to man.

One way of measuring the efficiency of agricultural crops and products is in terms of energy gain. As defined earlier, energy gain = $\frac{\text{energy available to society (output)}}{\text{energy put in by society (input)}}$ but as applicable to this agricultural situation, it would be:

$$\text{energy gain} = \frac{\text{calories (kcal) value of food}}{\text{energy (kcal) put in to make this food available to man.}}$$

For example, if a farmer invests only 40 kcal of energy for every 100 kcal that is released by some crop, then that crop has an energy gain of 2.5 (which means, for every kcal put into producing that crop, 2.5 kcal is released and available to the consumer). Agricultural crops and products which have gains of more than 1.0 are very efficient because we're getting more energy out of them than we're putting in. Gains less than 1.0 are inefficient but tolerated and often encouraged because of consumer demand for the agricultural product.

**Most often the efficiency of agricultural products are measured in terms of an energy subsidy; that is, how much energy must be invested to get a specific amount of energy out of that product.*

$$\textit{Energy subsidy} = \frac{\textit{energy input}}{\textit{energy output}}$$

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Table 1. Energy output and inputs for various agricultural crops and products. Energy units are in Kcal/100 pounds of crop or product.

Crop / Product	Food Value (Output)	Energy from gasoline, fuel oil, LP gas, and electricity to plow, disk, plant and harvest crops, heat buildings, run machinery.	Fertilizers	Pesticides	Irrigation	Additional Factors
Potatoes	38,640	13,310	7,290	1,460	3,700	
Onions	22,270	9,090	3,330	1,080	3,000	
Greenbeans	38,200	44,340	11,310	6,650	14,100	
Cabbage	16,180	6,520	2,180	1,030	2,720	
Sweet Corn	160,000	21,310	10,490	6,900	5.150	
Grain Corn	160,000	17,940	8,970	4,300	5,150	
Soy Beans	159,000	31,190	10,830	4,500	12,370	
Apples	29,100	10,960	1,500	5,700	4,230	
Grapes	35,460	17,960	3,770	5,160	5,350	
Milk	31,370	4,830				Hay Feed 26,030
Beef	115,600	153,750				Grain Feed 1,021,250
Eggs	67,270	82,800				Grain Feed 168,000

This is just the inverse of energy gain. For reasons of simplicity and to avoid confusing the student, it was decided to present everything in terms of energy gain. Should you run across energy subsidies in your search for additional information, the conversion to energy gains is easily accomplished by inverting and dividing. For instance a subsidy of 0.4 would be:

$$\frac{0.4}{1};$$

inverted to $\frac{1}{0.4} = 2.5$ *energy gain.*

Table 1 shows the amount of energy used by the various activities needed to produce 100 lbs of a number of agricultural crops and products and also the amount of energy available to the consumer in that 100 lbs. Which of these crops or products do you think have gains greater than 1.0? Compute the total energy input and the energy gain for each crop and product to verify your suspicions. Can you suggest any explanations for those crops or products with a gain less than 1.0?

**As shown in the composite chart of Energy Gains, only greenbeans, beef, and eggs have gains less than 1.0. The beef and eggs should have been suspected because they are from the second trophic level (herbivore) in the food pyramid while all the others are producers.*

Greenbeans and other seed vegetables comprise only a small part of the entire plant, by weight. As a result, much of the energy input is "wasted" growing the rest of the plant. In practice, the rest of the plant is often used as fodder for domestic animals, but this does not directly increase the energy output of the greenbeans. Compared to the low energy output of greenbeans, soybeans release about four times as much energy and therefore have a high energy gain.

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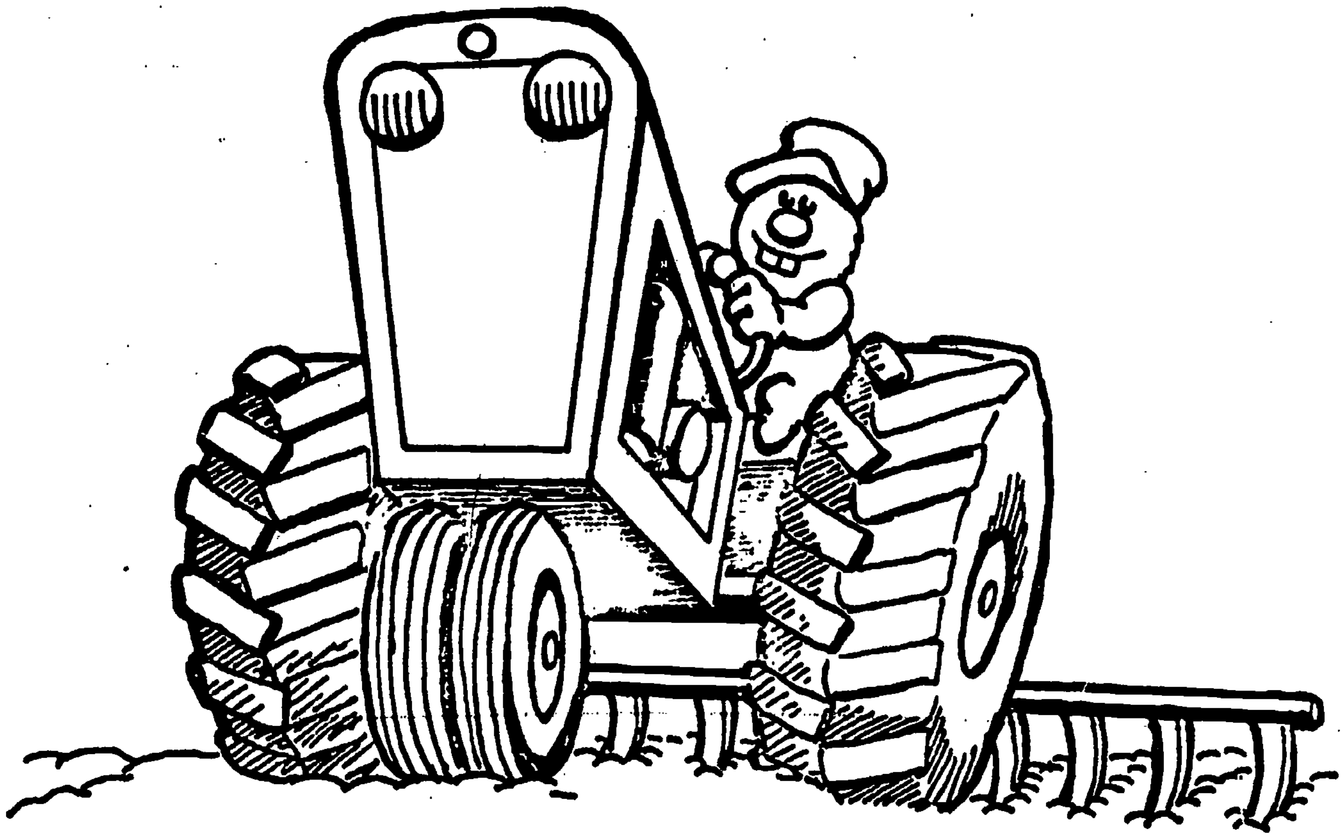

A hundred years ago, much manpower and animal labor was used to raise a crop, and domestic animals were allowed to forage in the pasture or on an open range. All these practices produced low yields, but also required low energy input resulting in very high gains. Modern farm practices use farm machinery, fertilizers, pesticides and irrigation to increase the crop yield per acre, but this also requires the expenditure of large amounts of energy. Such energy intensive agricultural practices reduce the efficiency of raising crops, but usually keep the energy gains above 1.0. Figure 1 compares the energy gains for low intensity and intensive crops and products. It is obvious that much of the inefficiency in our agricultural system comes from our raising of animal products. Using your knowledge of food chains and energy gains in raising crops, explain why beef cattle can be efficiently raised on the range, but are inefficient when raised on grass and hay in the pasture or on grain corn in the feedlots.

Range plants are not cultivated and, therefore, their energy output is "free" sunlight energy. The grass and hay for cattle is fertilized, mowed, baled, transported, stored, and redistributed to the field or barn where the cattle spend the winter. The favorable energy gain of hay (about 5.0) is lost because of all the energy expended in this mechanized harvesting, etc. The favorable energy gain of grain corn is lost to an even greater extent due to the energy involved in transporting, etc.

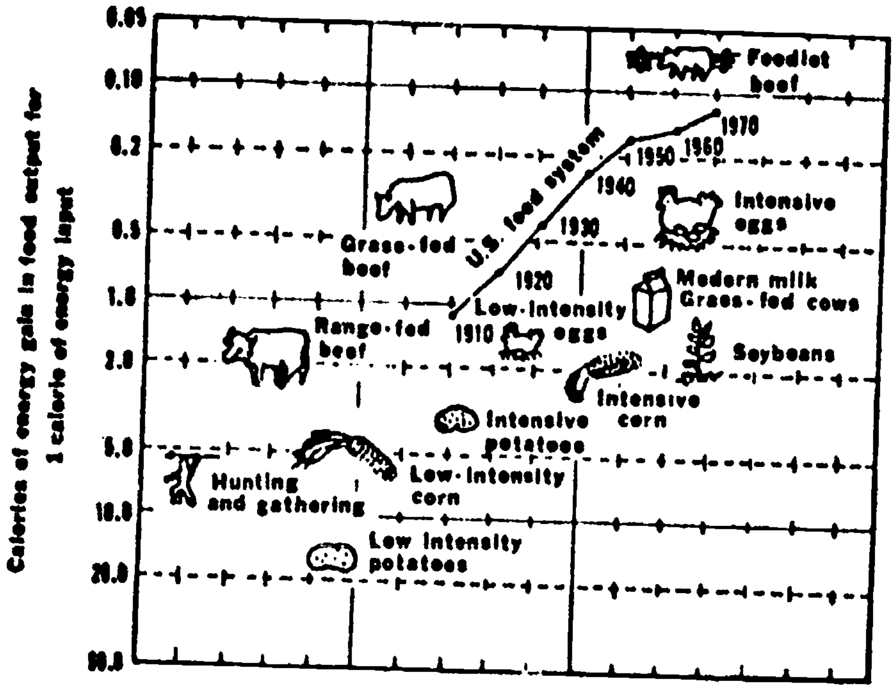

Figure 1. Energy gains for low intensity and intensive agricultural products. For comparison, the energy history of the U.S. food system is also shown. (Adapted from Steinhart and Steinhart, 1974).

The overall pattern for the energy history of the U.S. food system is also shown in Figure 1 for purposes of comparison. If most of the crops produced by intensive agriculture are still efficiently grown, what could account for the tremendous decrease in the energy gain for the U.S. food system?

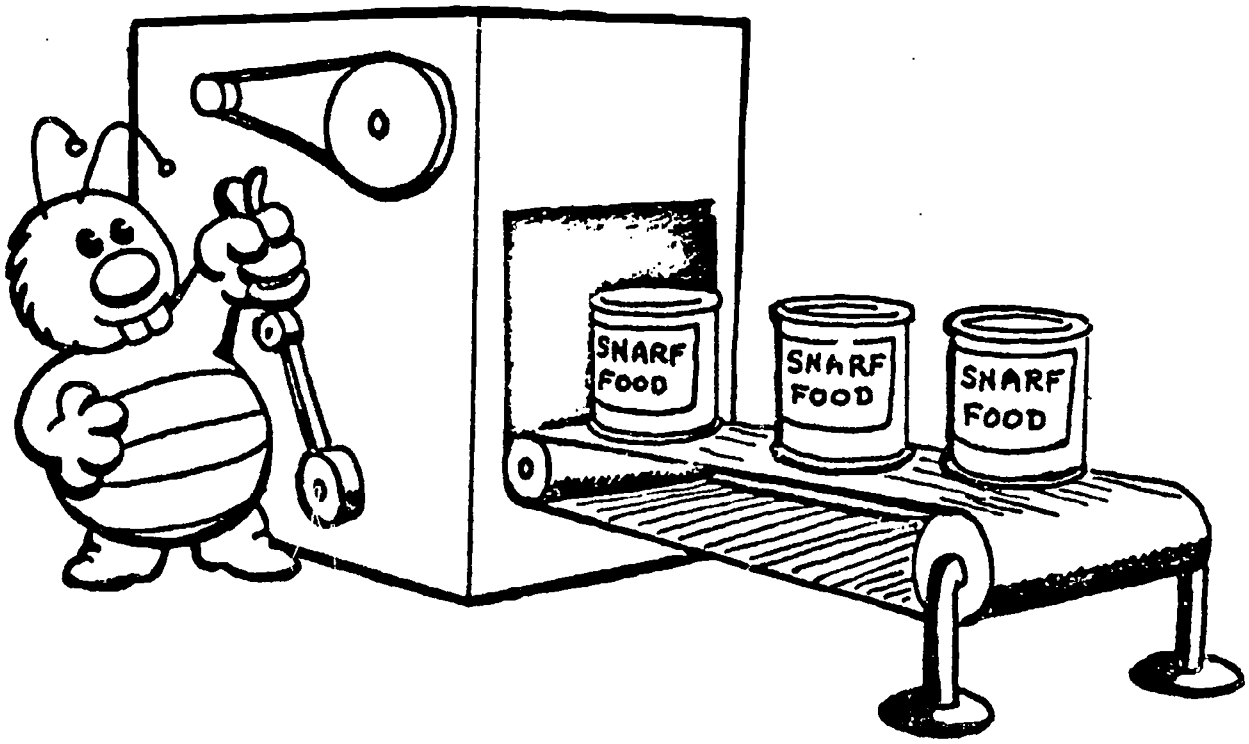

Table 2. Food related energy consumption after the crop or product is produced. Energy units are in Kcal/100 pounds of crop or product.

Crop / Product	Processing and Packaging	Transportation	Refrigeration and Storage	Preparation in the Home or Restaurant
Potatoes	47,230	4,290	22,900	42,930
Onions	30,250	2,750	14,670	27,500
Greenbeans	140,070	12,730	67,910	127,340
Cabbage	22,830	2,070	11,070	20,750
Sweet Corn	80,390	7,310	38,980	73,080
(used in bird feeders) Grain Corn	66,660	6,060	32,320	None
(used in vegetable oils) Soy Beans	107,970	9,810	52,350	None
Apples	41,050	3,730	19,900	37,320
Grapes	59,110	5,370	28,660	53,730
Milk	56,580	5,140	27,430	51,440
Beef	2,154,170	195,830	1,044,450	1,958,330
Eggs	459,800	41,800	222,930	418,000

Obviously, producing a crop or product is not the end of energy input into our food system, for a crop is seldom eaten in the field. It goes through a series of energy demanding steps before the agricultural product is on the table and ready to be eaten by the consumer. Table 2 shows the amounts of energy required for each of the various steps in the food system. Calculate the total energy required to produce and deliver each crop and product to the consumer's table and then the total energy gain.

What factors account for the largest energy consumption in our food system? Such large inputs of energy into our food system, relative to such low outputs in our food, is not compatible with the present world energy situation. What can be done to reduce these energy inputs?

Energy Units in Kcal/100 lbs.
Crop Product

Composite Chart of Energy Gains for Various Agricultural Crops and Products

Crop / Product	Energy Output	Energy Input to Produce Crop or Product	Energy Gain	Energy Input to Bring the Farm Product to the Consumer	Total Energy Input in the Food System for Crop or Product	Food System Energy Gain
Potatoes	38,640	25,760	1.5	117,350	143,110	0.27
Onions	22,270	16,500	1.35	75,170	91,670	0.24
Greenbeans	38,200	76,400	0.5	348,050	424,450	0.09
Cabbage	16,180	12,450	1.3	56,720	69,170	0.23
Sweet Corn	160,000	43,850	3.65	199,760	243,610	0.66
Grain Corn	160,000	36,360	4.4	165,640	202,000	0.79
Soy Beans	159,000	58,890	2.7	268,280	327,170	0.49
Apples	29,100	22,390	1.3	102,000	124,390	0.23
Grapes	35,460	32,240	1.1	146,870	179,110	0.20
Milk	31,370	30,860	1.0	140,590	171,450	0.18
Beef	115,600	1,175,000	0.1	5,352,780	6,527,780	0.02
Eggs	67,270	250,800	0.3	1,142,530	1,393,330	0.05

Activity III An Energy Menu (from Energy Conservation in the Home)

Review the items offered in the Menu on the following page and select your "first preferences" based strictly on likes and dislikes. Place checks beside those items on Column 1. Next, make selections from the menu on the basis of *least* energy consumption. Remember, the energy cost of a food includes: fertilizers and insecticides; equipment; transportation; processing, packaging, and preparation. Place a check by each "low energy" item selected in Column 2. Then refer to the Energy Price List for each item's Energy Cost. Indicate the "price" of each item you chose and determine your total bill. To discover how you might have saved energy, find the differences between the individual items in the two columns and enter those figures in Column 3. The differences will be losses or gains in costs. Add the toal "pluses and minuses" in this column to find total energy savings. If you were to select items or Column 1 (preferences) again, would your choices be any different?

**This activity is meant to be performed individually, but a class discussion could easily be generated afterwards about other products and their costs in relation to their energy consumptiveness.*

The class could even be divided into groups, each one analysing the cafeteria menu for a different day of the week.

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ENERGY MENU

	1 FIRST PREFERENCE $	2 LEAST ENERGY $	3 DIFFERENCES (+ or -) $
APPETIZERS (CHOOSE ONE FROM EACH PAIR)			
Frozen Juice			
Fresh Juice			
Crackers A (unwrapped, available to the cafeteria in bulk)			
Crackers B (wrapped individually, packed in small cartons)			
Butter			
Margarine			
MAIN DISH (PLEASE MAKE A FIRST AND SECOND CHOICE AS WE DO NOT ALWAYS CARRY EACH ENTREE)			
Luncheon Meat			
Chicken			
Turkey			
Rice with Vegetables			
Beef (grass-fed)			
Beef (grain-fed)			
VEGETABLE (SORRY, TODAY WE HAVE ONLY CARROTS, BUT YOU MAY CHOOSE YOUR PREFERRED TYPE)			
Fresh Carrots			
Dehydrated Carrots			
Frozen Carrots			
Canned Carrots			
DRINKS (PLEASE CHOOSE A FIRST AND SECOND CHOICE AS WE SOMETIMES RUN SHORT OF ONE KIND OF DRINK AT LUNCH)			
Soft Drink (in aluminum can)			
Soft Drink (in returnable glass bottle)			
Milk			
Beer (in aluminum can)			
Beer (in returnable glass bottle)			
DESSERT: CHOOSE ONE			
Apples (homegrown in our cafeteria's own garden)			
Apples (store-bought)			
Walnuts (shelled)			
Walnuts (unshelled)			
Ice Cream			
TOTAL BILL			

ENERGY PRICES

(Prices are proportional to actual energy expenditure)

APPETIZERS:

Fresh Juice: 12¢
Frozen Juice: 46¢
(Freezing and processing use a great deal of energy, both initially and for storage)
Cracker A: 10¢
Cracker B: 15¢
(Food excessively packaged or only available in small packages is more energy-intensive than unwrapped foods or foods available in bulk)
Butter: 15¢
Margarine: 5¢

MAIN DISH:

Luncheon Meat: $1.60
Chicken: .96
Turkey: 1.06
Rice with Vegetables: .45
Beef (grass-fed) 1.48
Beef (grain-fed) 2.08

(Animals are inefficient converters of protein. A pound of meat requires about four times the energy to produce and market as a pound of vegetable protein. Some animals are more efficient converters of protein than others.)

VEGETABLE:

Fresh Carrots: 12¢
Dehydrated Carrots: 92¢
Frozen Carrots: 31¢
Canned Carrots: 23¢
(Processed vegetables require more energy than fresh vegetables; freezing and dehydration especially require large amounts of energy.)

DRINKS:

Soft Drink (aluminum can): 45¢
Soft Drink (returnable bottle): 31¢
Milk: 34¢
Beer (aluminum can): 50¢
Beer (returnable bottle): 25¢

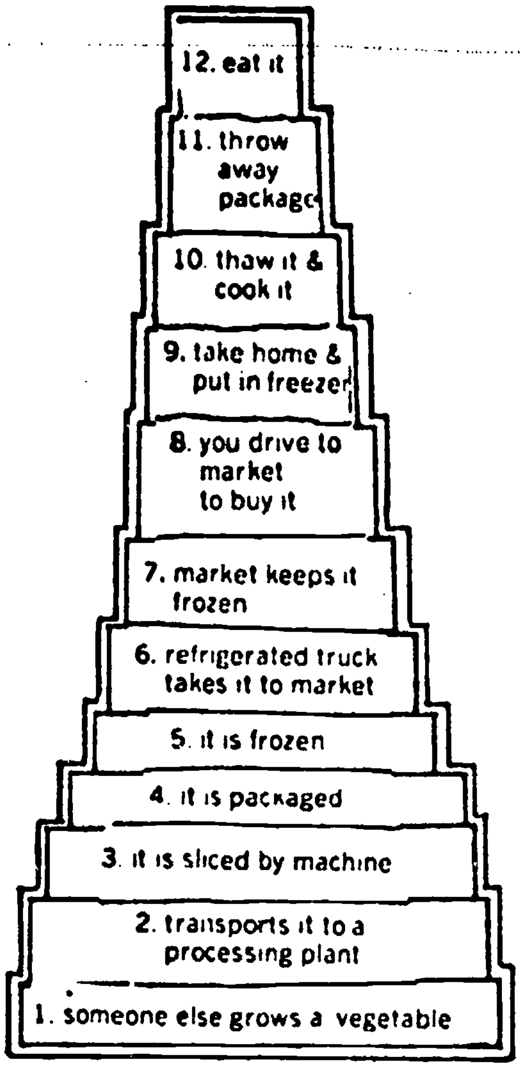
DESSERT:

Homegrown apple: 3¢
Store-bought apple: 19¢
(Homegrown apple by commercial methods saves commerce and transport; organic methods would save more.)
Walnuts, shelled: $1.04
Walnuts, unshelled: 39¢
Ice Cream: 60¢
(Large quantities of milk are used; freezing is necessary.)

Source: (adapted from) Energy Menu. *Food: Where Nutrition, Politics and Culture Meet* by Deborah Katz and Mary T. Goodwin

EVALUATION (From Energy Conservation in the Home.)

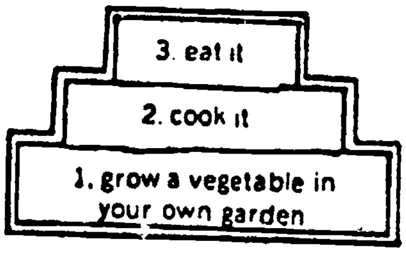
1. Twelve areas in a food system are listed below for a frozen vegetable. Which steps could be eliminated to save energy?



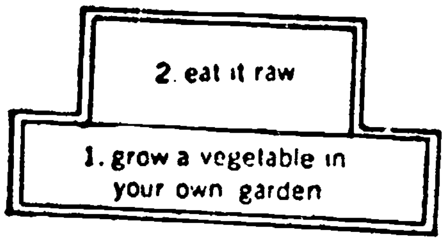
Possible answers may be:

a.

b.



c.



Construct the food chain steps for a canned soft drink and then make suggestions for steps which might be eliminated to save energy.

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2. Cook, Earl, Man, Energy, Society, W. H. Freeman and Company, San Francisco. 1976.

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5. Fritsch, A. J., et.al., Energy and Food, CPI Energy Series VI, Center for Science in the Public Interest, Washington, D.C. 1975.

6. Steinhart, J.S. and C.E. Steinhart. 1974. Energy use in the U.S. Food System. Science, 185:307-316.

7. Turk, A., J. Turk, J. Wittes and R. Wittes, Environmental Science (2nd Edition), Rand McNally and Company, Chicago. 1978.

STUDENT GUIDE

Activity I Energy Flow Through Natural Systems

Energy for all living organisms comes from the sun. Solar energy is captured by green plants and transformed into chemical energy or food energy by a process called photosynthesis. These green plants may be called autotrophs for this reason--they are self (auto) nourishing (troph) organisms; that is, they manufacture their own food. Members of the animal kingdom, on the other hand, are other nourishing or heterotrophic organisms because they must feed on the green plants or on other animals to acquire the energy or nutrients (food) they need for life processes. Thus, energy flows through a living system from the sun to autotrophs and then to heterotrophs. Such an energy chain (or food chain) would look like this:

sun ——→ autotroph ——→ heterotroph
(green plant) (mouse, cow, man, deer)

Because different organisms have varying positions in the energy chain, ecologists place organisms on trophic levels or levels of nourishment. The first (or bottom) level is made up of the autotrophs, also called the producers, because these green plants produce food for other organisms. Orgamisms that eat the producers are called primary consumers and occupy the second trophic level. The third trophic level is made up of secondary consumers who feed upon the primary consumers. Consumer levels continue through the fourth and even fifth levels in a few cases depending on the length of the energy or food chain. One example of a food chain would be: sun → grass → mouse → owl
Another example would be: sun → algae → mosquito larvae → sunfish → pike → man

Identify the following for the above food chains:

Producers

Primary Consumers

Secondary Consumers

Tertiary Consumers (third level consumer)

Quaternary Consumers (fourth level consumers)

In the next food chain, what trophic level does man occupy?

sun ⟶ tomatoes ⟶ man

What about this food chain? sun ⟶ grass ⟶ cow ⟶ man

Other terms often used to describe positions in food chains are--herbivore, carnivore, and omnivore, where the trophic levels match as follows:

herbivore -- primary consumer (plant eater)

carnivore -- secondary consumer

tertiary consumer (meat eater)

quaternary consumer

omnivore -- occupies varying trophic levels from primary through quaternary consumer depending upon food eaten (eats both plant and animal)

Another group of organisms, which are extremely important to our ecosystem, function as decomposers in the food chain. These organisms, such as fungi, bacteria, snails, etc., are called saprovores and feed on non-living organic matter and aid in the process of decay.

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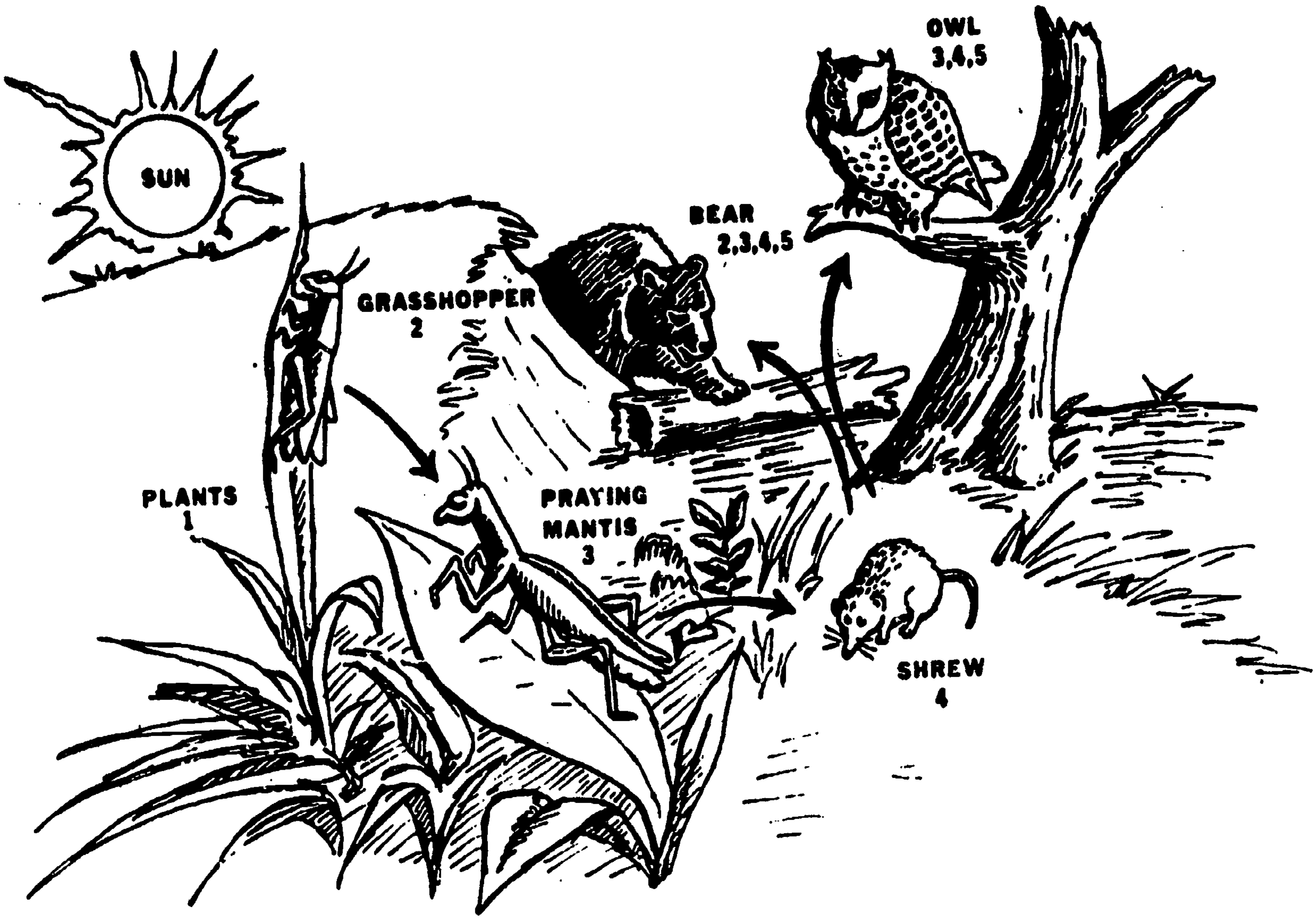


1 = Producer Level

2 = Primary Consumer

3 = Secondary Consumer

4 = Tertiary Consumer (3rd level)

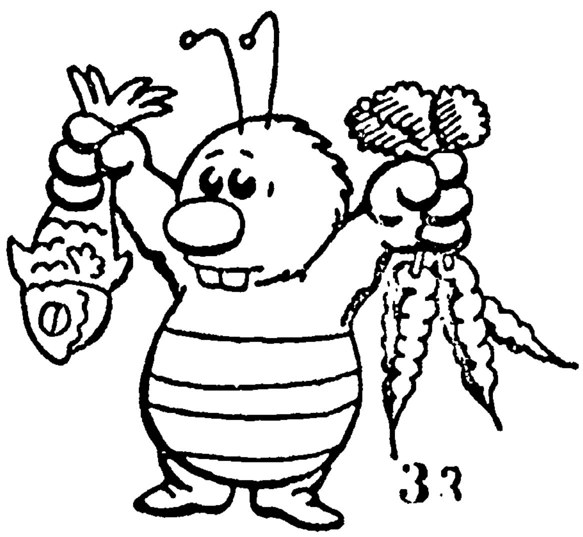
5 = Quaternary Consumer (4th level)

To illustrate the use of these terms, when you eat a raw carrot, you are occupying the primary consumer's trophic level and are eating as an herbivore when you eat beef or pork or chicken, you are functioning as a secondary consumer and as a carnivore. In eating fish, you may be at either the second, third or fourth consumer level depending upon what that particular fish had eaten before it was caught. Because the fish is animal matter, you are again eating as a carnivore. As you can see from the above examples, you are also an omnivore because your diet consists of both plant and animal material.

Would a person on a vegetarian diet be a herbivore, a carnivore or an omnivore? What if that person also ate eggs and cheese?

List the foods you had for breakfast or lunch today. Trace the various food chains involved in each of the different foods you ate and record whether you were functioning as a primary consumer (herbivore), secondary or higher level consumer. Which level do you seem to occupy most often?

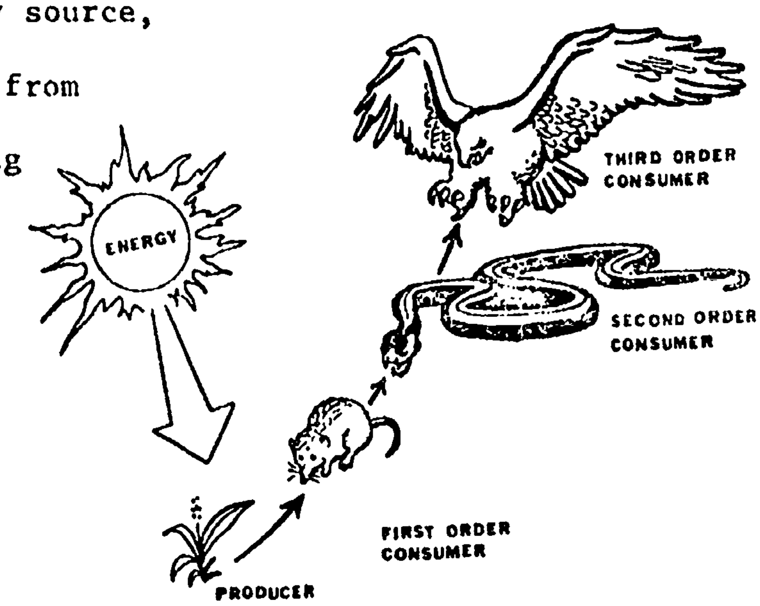
For some added information, try weighing your food on a gram (metric) food scale before you eat. How much does your entire meal weigh? Are you eating more meat (by weight) or more vegetables, fruits or breads? What percentage by weight is the meat? What percentage of your meal (by weight) is plant material? As measured by percent of diet by weight, which trophic level do you most often occupy?



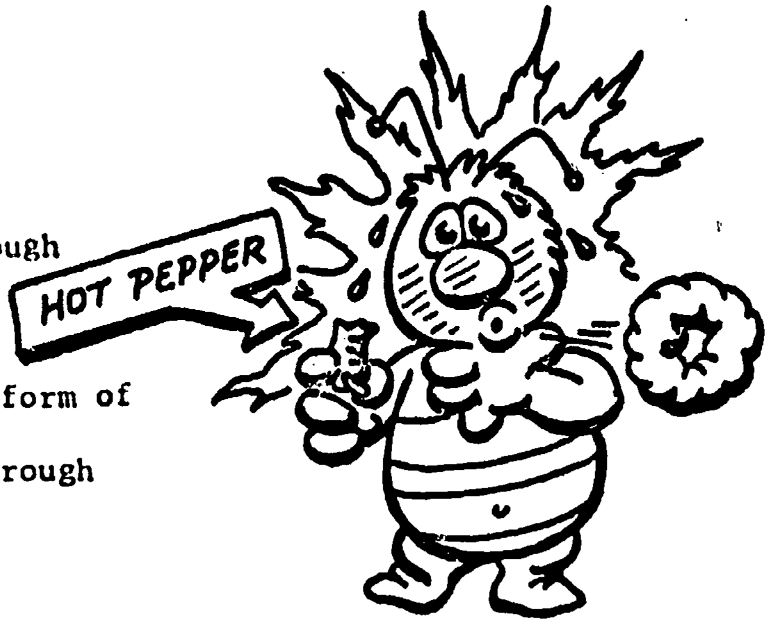
You have been introduced to various terms that help to catalogue the food you eat. You are now aware of trophic levels, herbivores, carnivores, omnivores, and saprovores. You have diagrammed some of your own food chains and found that you occupy different trophic levels depending upon the food you eat. But what does all this mean? What's the point?

The major point is one concerning energy. Why do we need to eat? We need to eat to supply our bodies with the energy needed to live. All our body processes and movements require energy and our energy source is food.

As you learned in previous modules, some energy is lost as it is transferred or transformed from one situation to the next. (Remember energy source and energy receiver?) Food is your energy source, and ultimately, all food energy comes from the sun. How efficient are we in using the sun's energy?



Study the diagram of the Energy Pyramid. Notice that the energy originally comes from the sun. The sun's energy is captured through photosynthesis at the producer level. Then the energy moves through the consumer levels from first order consumer through the second, third, fourth and sometimes fifth level. Notice that the diagram is in the shape of a pyramid. Why do you think this is so? According to the previous discussion on energy transfer, what is happening from one level to the next?



That's right! Some energy is "lost" through the food chain as heat energy. (The energy is not really "lost", it's just transformed into a form of energy we cannot use.) The food energy moves through the energy pyramid (through the trophic levels) with what is called the 10% Rule. Each higher level is able to obtain only 10% of the energy available from the lower level. For example, in the food chain grass mouse snake, the mouse receives 10% of the energy the grass has stored and the snake receives only 10% of the energy the mouse received from the grass. Thus, as the energy moves through the food chain, less and less of the original energy of the sun and the plants is available.

An analogy would be to think of 1,000 energy units representing the food energy available at the producer level. 10% of 1,000 is 100, which is the energy available at the first consumer level; 10% of 100 is 10 left at the second consumer level; 10% of 10 is 1 unit left at the third consumer level. So, in transferring energy through three trophic levels, 1,000 energy units were reduced to 1 energy unit available at that third level. Are we more efficient food energy consumers as herbivores or as carnivores?

Choose three of your favorite foods and trace the food energy through a food chain. Using the 10% Rule, compute the energy available to you from the sun's original energy. Which foods retain the highest energy level?

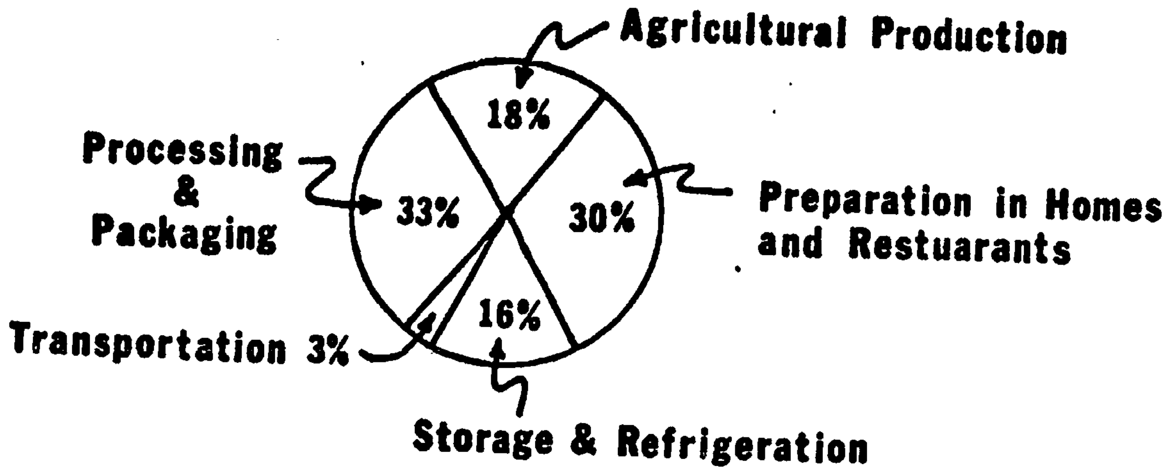
Activity II

Most students are aware of many of the things a farmer goes through to raise a crop or product and a few probably know something about the energy efficiency of this occupation, but certainly none are fully aware of what happens to the agricultural product after it is produced or of the tremendous amount of energy used in getting it from the farm to the table of the consumer. This activity is designed in the hope of impressing the students with the large quantities of energy involved in the U.S. food system. Perhaps your pointing out to the students that the average American needs 1500 kcal /day/100 lbs of body weight would make them more aware of this fact. This is one reason why all the energy measurements are made in kcal/100 lbs of crop or product.

While this activity is written so that a student could compare everything by himself, it is possible he might become engrossed in the computations and fail to look at where most of the energy is being used. For this reason it is suggested that the class be broken into groups of 2 or 3 and each assigned a crop or even two for comparison of crop efficiency. It is advisable that there be overlap in these assignments; that is, one group compares greenbeans and soybeans, another compares soybeans and grain corn, etc.

The data in Table I has been generated to reflect proportionate use of energy for each activity and is not actual data collected in a study. The energy gains for the crops and products, however, are factual results of intensive agriculture in the U.S.

The data in Table 2 is based on information in Cook's Man, Energy, Society and presented in the following diagram:



The final energy gain of a specific crop or product may be slightly larger or smaller than actually measured in studies. The inaccuracies will hopefully be offset by achieving the objective of making the students aware of the relative energy inputs in the food system.

If students are to do this exercise individually, they can generate their own composite chart of energy gains, or the teacher may dictate a format to be followed. If performed as groups in class, the teacher may wish to present only the first half of the composite chart on the board. After the students have computed and entered their findings on the chart, a class discussion on the energy gains and information in Figure 1 may be desirable. While the students are computing the energy gains for the total food system from Table 2, the teacher may then add on the remainder of the composite chart, to be filled in by the students and followed by a summary discussion.

Additional information you may want to make available to the students during the discussions is presented on the following page.

1. **Acreage Required to Produce One Million Calories (kcal)**

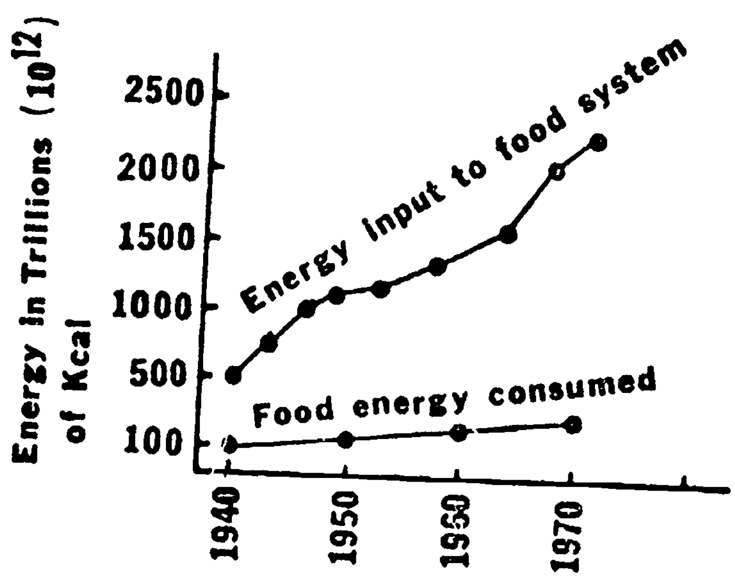
Food Source	Acres of Land	Food Source	Acres of Land
Sugar	0.15	Hogs (pork and Lard)	2.0
Potatoes	0.44	Whole milk	2.8
Corn - as meal	0.9	Eggs	7.8
Wheat - as whole wheat flour	0.9	Chicken	9.3
Wheat - as refined wheat flour	1.2	Steers	17.0

2. Energy Inputs of Fresh and Processed Foods (Units in BTU*/lb)
(from Energy and Food, A.J. Friesch, et.al.)

	Home Grown	Fresh Produce	Canned	Frozen	Dehydrated
Carrots	1,300	4,750	9,200	12,750	37,100
Peas	7,450	10,900	14,250	12,750	37,100
Apples	917	5,950	4,000	9,200	23,200
Potatoes	2,850	6,250	9,000	14,950	26,700

* 1 BTU = 0.252 kcal

3. Energy use in the U.S. food system, 1940 through 1970, compared to the caloric content of food consumed. (From Steinhart and Steinhart, 1974)



Activity II Energy Gain of Intensive Agricultural Products in the U.S. Food System

Now that you are familiar with man's position in food chains and the transfer of energy through those natural food systems, let's look at the energy involved in man's food systems. When man was a hunter-gatherer, very little energy beyond manpower was invested to obtain his energy requirements. With the advent of agriculture, man began investing energy into tools and agricultural practices to increase the amount of sunlight energy captured by his crops in the field. However, the efficiency of raising a crop would be greatly reduced if the amount of energy invested equalled or exceeded the amount of energy captured by that crop and made available to man.

One way of measuring the efficiency of agricultural crops and products is in terms of energy gain. As defined earlier,

$$\text{energy gain} = \frac{\text{energy available to society (output)}}{\text{energy put in by society (input)}}$$

but as applicable to this agricultural situation, it would be:

$$\text{energy gain} = \frac{\text{calories (kcal) value of food}}{\text{energy (kcal) put in to make this food available to man.}}$$

For example, if a farmer invests only 40 kcal of energy for every 100 kcal that is released by some crop, then that crop has an energy gain of 2.5 (which means, for every kcal put into producing that crop, 2.5 kcal is released and available to the consumer). Agricultural crops and products which have gains of more than 1.0 are very efficient because we're getting more energy out of them than we're putting in. Gains less than 1.0 are inefficient but tolerated and often encouraged because of consumer demand for the agricultural product.

Table 1. Energy output and inputs for various agricultural crops and products. Energy units are in Kcal/100 pounds of crop or product.

Crop / Product	Food Value (Output)	Energy from gasoline, fuel oil, LP gas, and electricity to plow, disk, plant and harvest crops, heat buildings, run machinery.	Fertilizers	Pesticides	Irrigation	Additional Factors
Potatoes	38,640	13,310	7,290	1,460	3,700	
Onions	22,270	9,090	3,330	1,080	3,000	
Greenbeans	38,200	44,340	11,310	6,650	14,100	
Cabbage	16,180	6,520	2,180	1,030	2,720	
Sweet Corn	160,000	21,310	10,490	6,900	5.150	
Grain Corn	160,000	17,940	8,970	4,300	5,150	
Soy Beans	159,000	31,190	10,830	4,500	12,370	
Apples	29,100	10,960	1,500	5,700	4,230	
Grapes	35,460	17,960	3,770	5,160	5,350	
Milk	31,370	4,830				Hay Feed 26,030
Beef	115,600	153,750				Grain Feed 1,021,250
Eggs	67,270	82,800				Grain Feed 168,000

Table 1 shows the amount of energy used by the various activities needed to produce 100 lbs of a number of agricultural crops and products and also the amount of energy available to the consumer in that 100 lbs. Which of these crops or products do you think have gains greater than 1.0? Compute the total energy input and the energy gain for each crop and product to verify your suspicions. Can you suggest any explanations for those crops or products with a gain less than 1.0?

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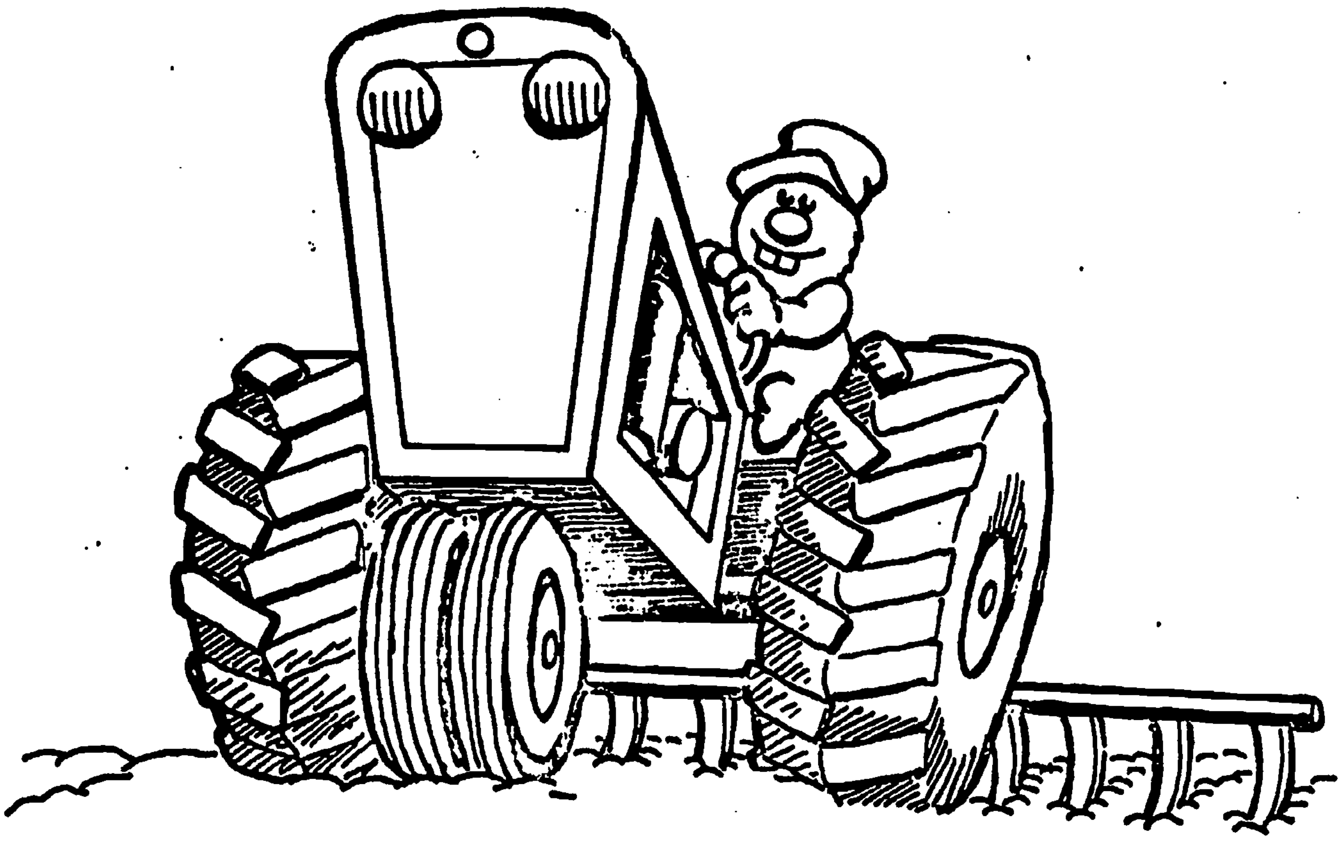

A hundred years ago, much manpower and animal labor was used to raise a crop, and domestic animals were allowed to forage in the pasture or on an open range. All these practices produced low yields, but also required low energy input resulting in very high gains. Modern farm practices use farm machinery, fertilizers, pesticides and irrigation to increase the crop yield per acre, but this also requires the expenditure of large amounts of energy. Such energy intensive agricultural practices reduce the efficiency of raising crops, but usually keep the energy gains above 1.0. Figure 1 compares the energy gains for low intensity and intensive crops and products. It is obvious that much of the inefficiency in our agricultural system comes from our raising of animal products. Using your knowledge of food chains and energy gains in raising crops, explain why beef cattle can be efficiently raised on the range, but are inefficient when raised on grass and hay in the pasture or on grain corn in the feedlots.

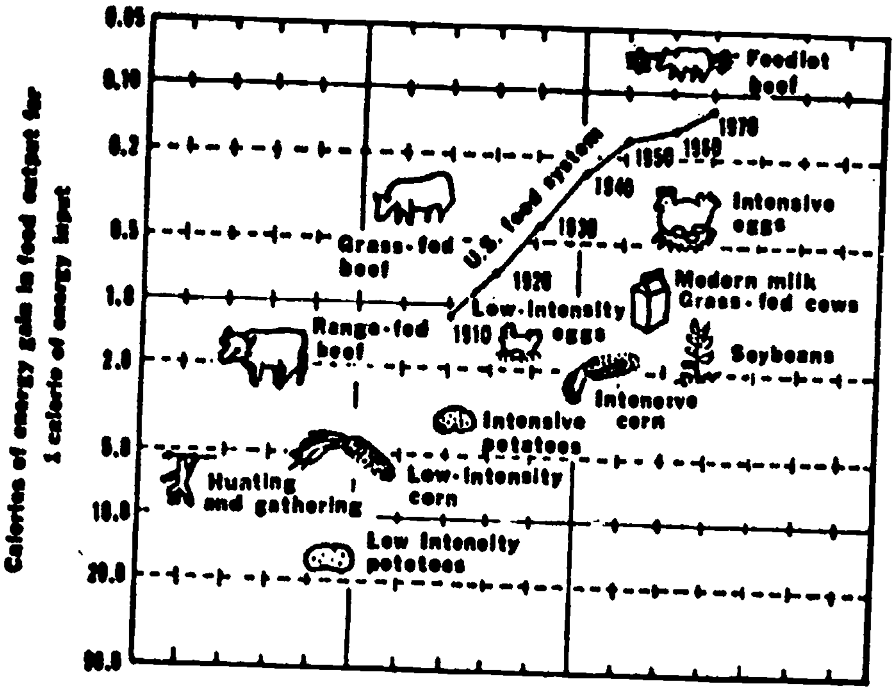

Figure 1. Energy gains for low intensity and intensive agricultural products. For comparison, the energy history of the U.S. food system is also shown. (Adapted from Steinhart and Steinhart, 1974).

The overall pattern for the energy history of the U.S. food system is also shown in Figure 1 for purposes of comparison. If most of the crops produced by intensive agriculture are still efficiently grown, what could account for the tremendous decrease in the energy gain for the U.S. food system?

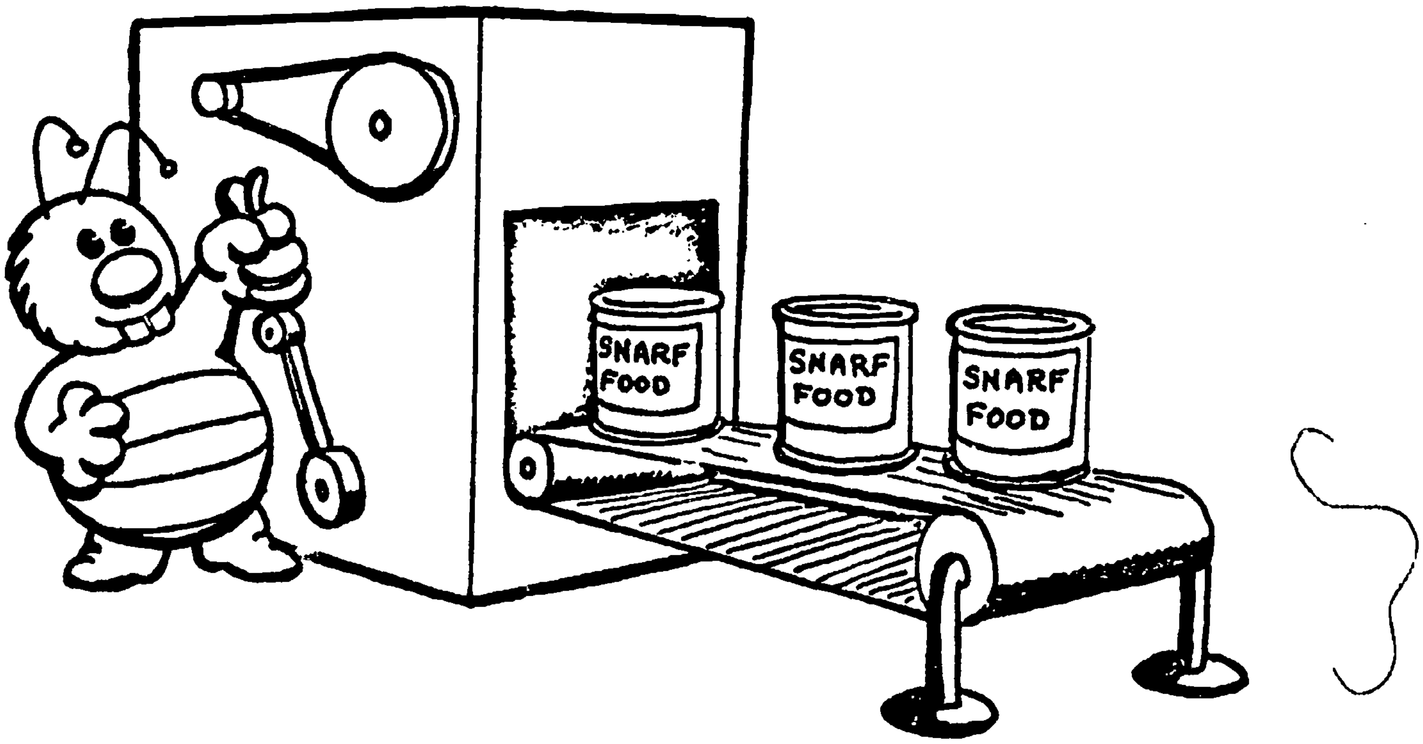

Table 2. Food related energy consumption after the crop or product is produced. Energy units are in Kcal/100 pounds of crop or product.

Crop / Product	Processing and Packaging	Transportation	Refrigeration and Storage	Preparation in the Home or Restaurant
Potatoes	47,230	4,290	22,900	42,930
Onions	30,250	2,750	14,670	27,500
Greenbeans	140,070	12,730	67,910	127,340
Cabbage	22,830	2,070	11,070	20,750
Sweet Corn	80,390	7,310	38,980	73,080
(used in bird feeders) Grain Corn	66,660	6,060	32,320	None
(used in vegetable oils) Soy Beans	107,970	9,810	52,350	None
Apples	41,050	3,730	19,900	37,320
Grapes	59,110	5,370	28,660	53,730
Milk	56,580	5,140	27,430	51,440
Beef	2,154,170	195,830	1,044,450	1,958,330
Eggs	459,800	41,800	222,930	418,000

Obviously, producing a crop or product is not the end of energy input into our food system, for a crop is seldom eaten in the field. It goes through a series of energy demanding steps before the agricultural product is on the table and ready to be eaten by the consumer. Table 2 shows the amounts of energy required for each of the various steps in the food system. Calculate the total energy required to produce and deliver each crop and product to the consumer's table and then the total energy gain.

What factors account for the largest energy consumption in our food system? Such large inputs of energy into our food system, relative to such low outputs in our food, is not compatible with the present world energy situation. What can be done to reduce these energy inputs?

Energy Units in Kcal/100 lbs.
Crop Product

Composite Chart of Energy Gains for
Various Agricultural Crops and Products

Crop / Product	Energy Output	Energy Input to Produce Crop or Product	Energy Gain	Energy Input to Bring the Farm Product to the Consumer	Total Energy Input in the Food System for Crop or Product	Food System Energy Gain
Potatoes	38,640	25,760	1.5	117,350	143,110	0.27
Onions	22,270	16,500	1.35	75,170	91,670	0.24
Greenbeans	38,200	76,400	0.5	348,050	424,450	0.09
Cabbage	16,180	12,450	1.3	56,720	69,170	0.23
Sweet Corn	160,000	43,850	3.65	199,760	243,610	0.66
Grain Corn	160,000	36,360	4.4	165,640	202,000	0.79
Soy Beans	159,000	58,890	2.7	268,280	327,170	0.49
Apples	29,100	22,390	1.3	102,000	124,390	0.23
Grapes	35,460	32,240	1.1	146,870	179,110	0.20
Milk	31,370	30,860	1.0	140,590	171,450	0.18
Beef	115,600	1,175,000	0.1	5,352,780	6,527,780	0.02
Eggs	67,270	250,800	0.3	1,142,530	1,393,330	0.05

Activity III An Energy Menu (from Energy Conservation in the Home)

Review the items offered in the Menu on the following page and select your "first preferences" based strictly on likes and dislikes. Place checks beside those items on Column 1. Next, make selections from the menu on the basis of *least* energy consumption. Remember, the energy cost of a food includes: fertilizers and insecticides; equipment; transportation; processing, packaging, and preparation. Place a check by each "low energy" item selected in Column 2. Then refer to the Energy Price List for each item's Energy Cost. Indicate the "price" of each item you chose and determine your total bill. To discover how you might have saved energy, find the differences between the individual items in the two columns and enter those figures in Column 3. The differences will be losses or gains in costs. Add the toal "pluses and minuses" in this column to find total energy savings. If you were to select items or Column 1 (preferences) again, would your choices be any different?

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ENERGY MENU

	1 FIRST PREFERENCE $	2 LEAST ENERGY $	3 DIFFERENCES (+ or -) $
APPETIZERS (CHOOSE ONE FROM EACH PAIR)			
Frozen Juice			
Fresh Juice			
Crackers A (unwrapped, available to the cafeteria in bulk)			
Crackers B (wrapped individually, packed in small cartons)			
Butter			
Margarine			
MAIN DISH (PLEASE MAKE A FIRST AND SECOND CHOICE AS WE DO NOT ALWAYS CARRY EACH ENTREE)			
Luncheon Meat			
Chicken			
Turkey			
Rice with Vegetables			
Beef (grass-fed)			
Beef (grain-fed)			
VEGETABLE (SORRY, TODAY WE HAVE ONLY CARROTS, BUT YOU MAY CHOOSE YOUR PREFERRED TYPE)			
Fresh Carrots			
Dehydrated Carrots			
Frozen Carrots			
Canned Carrots			
DRINKS (PLEASE CHOOSE A FIRST AND SECOND CHOICE AS WE SOMETIMES RUN SHORT OF ONE KIND OF DRINK AT LUNCH)			
Soft Drink (in aluminum can)			
Soft Drink (in returnable glass bottle)			
Milk			
Beer (in aluminum can)			
Beer (in returnable glass bottle)			
DESSERT: CHOOSE ONE			
Apples (homegrown in our cafeteria's own garden)			
Apples (store-bought)			
Walnuts (shelled)			
Walnuts (unshelled)			
Ice Cream			
TOTAL BILL			

ENERGY PRICES

(Prices are proportional to actual energy expenditure)

APPETIZERS:
- Fresh Juice: 12¢
- Frozen Juice: 46¢
- (Freezing and processing use a great deal of energy, both initially and for storage)
- Cracker A: 10¢
- Cracker B: 15¢
- (Food excessively packaged or only available in small packages is more energy-intensive than unwrapped foods or foods available in bulk)
- Butter: 15¢
- Margarine: 5¢

MAIN DISH:
- Luncheon Meat: $1.60
- Chicken: .96
- Turkey: 1.06
- Rice with Vegetables: .45
- Beef (grass-fed) 1.48
- Beef (grain-fed) 2.08

(Animals are inefficient converters of protein. A pound of meat requires about four times the energy to produce and market as a pound of vegetable protein. Some animals are more efficient converters of protein than others.)

VEGETABLE:
- Fresh Carrots: 12¢
- Dehydrated Carrots: 92¢
- Frozen Carrots: 31¢
- Canned Carrots: 23¢
- (Processed vegetables require more energy than fresh vegetables; freezing and dehydration especially require large amounts of energy.)

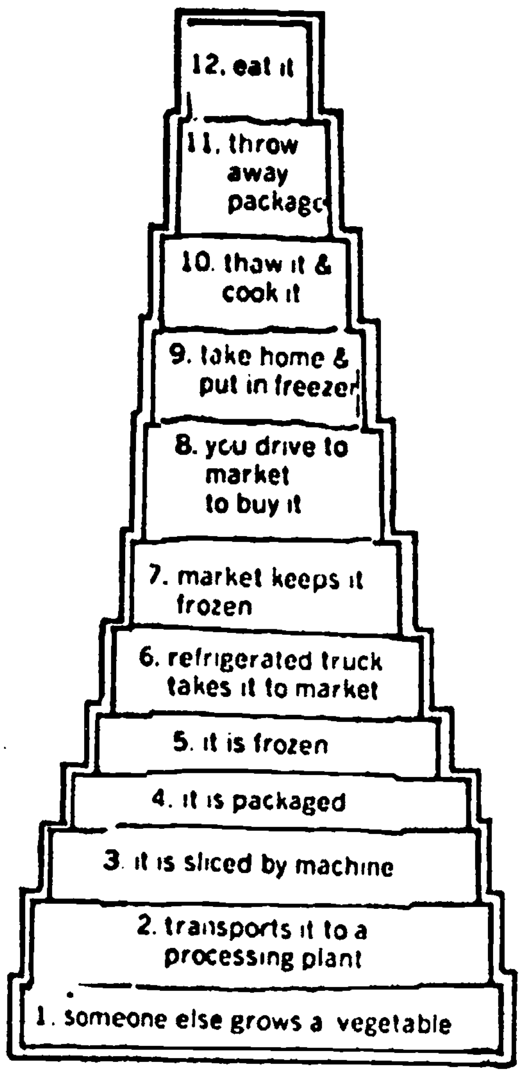
DRINKS:
- Soft Drink (aluminum can): 45¢
- Soft Drink (returnable bottle): 31¢
- Milk: 34¢
- Beer (aluminum can): 50¢
- Beer (returnable bottle): 25¢

DESSERT:
- Homegrown apple: 3¢
- Store-bought apple: 19¢
- (Homegrown apple by commercial methods saves commerce and transport; organic methods would save more.)
- Walnuts, shelled: $1.04
- Walnuts, unshelled: 39¢
- Ice Cream: 60¢
- (Large quantities of milk are used; freezing is necessary.)

Source: (adapted from) Energy Menu. *Food: Where Nutrition, Politics and Culture Meet* by Deborah Katz and Mary T. Goodwin

EVALUATION (From Energy Conservation in the Home.)

1. Twelve areas in a food system are listed below for a frozen vegetable. Which steps could be eliminated to save energy?



Construct the food chain steps for a canned soft drink and then make suggestions for steps which might be eliminated to save energy.