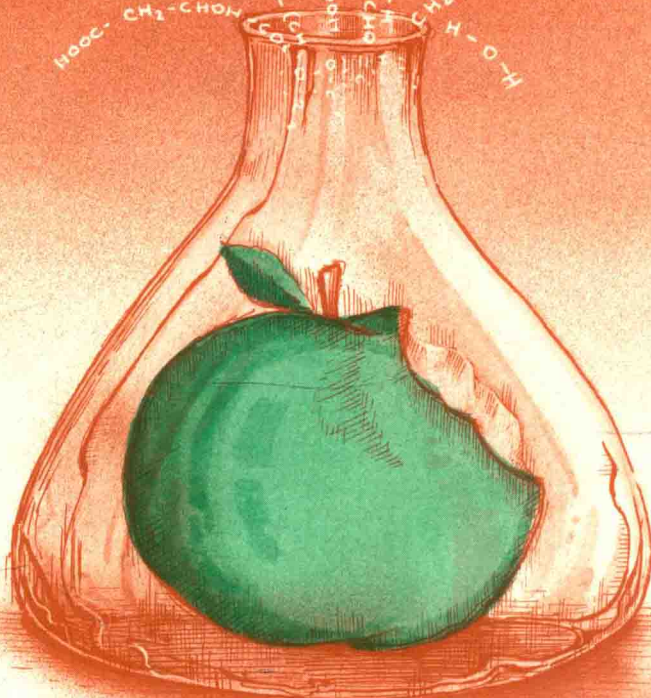


The SCIENCE of

Third Edition



**P. M. Gaman &
K. B. Sherrington**

The Science of Food

AN INTRODUCTION TO FOOD SCIENCE,
NUTRITION AND MICROBIOLOGY

THIRD EDITION

by

P. M. GAMAN

and

K. B. SHERRINGTON



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AN INTRODUCTION TO FOOD SCIENCE,
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THIRD EDITION

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Preface to Third Edition

In the course of teaching applied science to catering students, we came to realise the need for a textbook which dealt with the various scientific aspects of food preparation at an intermediate level.

In this book we have covered three different subject areas; food science, nutrition and microbiology. Microbiology has been given more emphasis than is usual in books on food science and nutrition, since we feel that this is an area which is often overlooked.

This book is intended to fill the gap between elementary books, containing little scientific explanation, and advanced books which examine the subjects in detail but are only suitable for those students who have a comprehensive scientific training. We have assumed little prior scientific knowledge on the part of the reader. An attempt has been made to convey basic scientific facts and principles, necessary for the understanding of food science, nutrition and microbiology, which are dealt with in some depth.

This book is intended primarily for students following BTEC diploma courses in Catering and Hospitality Management. It should also be of value to Home Economics students and students taking diploma courses in Food Science, Food Technology, Dietetics and Nutrition. It will serve as an introduction for undergraduates following degree courses in food related subjects. Science teachers in secondary schools may find it useful for developing courses in applied science. There may also be many other people, wishing to find out more about food and health, who would find this book both informative and interesting.

The third edition contains revised and updated information and figures. Since the second edition was published, there have been many changes in relation to nutrition and health, and in relation to the types and incidence of food poisoning. In this latest edition we have included sections on the NACNE and COMA reports together with practical measures for 'healthy eating'. The chapter on food poisoning and its prevention has been expanded into two chapters to include up-to-date information on food poisoning and an extended section on food legislation. We have also included an expanded section on irradiation of foods and a new chapter on food additives and food labelling.

Acknowledgements

We wish to acknowledge the help and encouragement given to us by many friends and colleagues during the writing of this book. Particular thanks go to Mrs. Valerie Ward for her very valuable assistance with proof reading.

Much of the statistical data in the book has been obtained from H.M.S.O. publications. The figures relating to the nutrient content of foods are taken from *McCance and Widdowson's The Composition of Foods* by A. A. Paul and D. A. T. Southgate and from the *Manual of Nutrition*.

The table in Appendix I which shows the percentage contribution of different foods to the nutrient content of the average household diet is an abridged version of that published in *Household Food Composition and Expenditure: 1984*. Appendix II, the table of recommended nutrient intakes, is a modified version of that published in *Recommended Daily Amounts of Food Energy and Nutrients for Groups of People in the U.K.* (1979). Both of these tables are reproduced with the permission of the Controller of Her Majesty's Stationery Office.

Introduction

Many people do not associate science with food. Even though they are aware of the rapid development of technology and of the applications of science to many aspects of everyday life, they remain unaware of the importance of science in the preparation of the food on their tables.

Scientific study related to the food we eat can be roughly divided into three broad categories: food science, nutrition and microbiology.

Food science involves the study of all aspects of science related to food. A major part of this book deals with the chemistry of food, since this is an important aspect. An understanding of the chemical nature of food is essential if one is to achieve an understanding of the composition of food and the reactions which take place in food when conditions are changed. A study of food science will explain, for example, why baking powder makes cakes rise or why freshly cut apples go brown when exposed to the air.

Food, like oxygen, is a necessity of life. The human body requires food as a source of energy and for the growth and replacement of tissues. Food also supplies substances which help to regulate the reactions involved in these processes. Nutrition is the study of the composition of food and the utilisation of food by the body. Foods are mixtures of substances known as nutrients. Each nutrient has a particular type of chemical composition and performs at least one specific function in the body.

The six groups of nutrients are:

1. Carbohydrates provide energy and dietary fibre.
2. Fats and oils provide energy.
3. Proteins used for the growth and replacement of tissue, may also provide energy.
4. Vitamins regulate body processes.
5. Minerals regulate body processes; some are used for growth and replacement of tissue.
6. Water essential for body processes.

A well-balanced diet is necessary for the maintenance of good health. This means that the food a person consumes should provide adequate, but not excessive, amounts of essential nutrients and energy. A poor diet leads to malnutrition, which literally means 'bad nutrition'. There are many types of malnutrition. Malnutrition may be caused by a lack of one or more of the essential nutrients in the diet. For example, a prolonged lack of vitamin C will give rise to a deficiency disease known as scurvy.

Not only is malnutrition caused by the consumption of foods with an incorrect nutrient balance but also by the consumption of either too little or too much food.

Insufficient food will lead to starvation, a form of malnutrition which, if prolonged, will lead to death. In some poorer, less developed parts of the world in recent years natural disasters, such as drought and flooding, have caused famines in which many people have died.

In wealthy, industrialised countries malnutrition occurs either as a result of eating too much food, or by the consumption of a diet with an unbalanced nutrient intake. Excesses and deficiencies of some components of the diet are associated with certain 'diseases of affluence'. For example, an excessive intake of fat is linked with heart disease, too little dietary fibre with cancer of the bowel, too much sugar with tooth decay and too much food (energy) with obesity (overweight). Advice is now available on how the diet should be altered in order to make it more healthy. It is recommended that the amounts of fat, sugar and salt in the diet should be reduced, while the amounts of starch and dietary fibre should be increased.

Microbiology is the study of microorganisms; these are very small, simple forms of life, such as bacteria and yeasts. Some species of microorganisms are beneficial and are used extensively in food production. Other types are responsible for many undesirable effects in food. Certain bacteria, if present in food in large enough numbers, will cause food poisoning. Currently there is widespread concern over the rapid increase in cases of food poisoning in England and Wales in recent years. Microorganisms can also cause food spoilage, e.g. the souring of milk, the growth of moulds on foods such as bread and cheese. A knowledge of the nature of microorganisms, their growth requirements and how growth can be prevented, is necessary if one is to understand correct procedures of hygiene and the principles involved in the various methods of food preservation.

In order to obtain adequate food supplies in urbanised societies, we depend very greatly on food technology. It is no longer possible for people to depend on locally grown, fresh foods. Food is now transported, often over very great distances, from rural areas, where it is produced, to urban areas. Unless food is processed or preserved in some way, much of it would be unfit for human consumption by the time it reaches the consumer. Food can be canned, frozen, chilled or dried in order to extend its shelf life. Preservation of food may also reduce the preparation and cooking time and is advantageous from the point of view of convenience. Many foods are 'manufactured' with convenience and acceptability in mind. Food technologists have developed a large variety of products ranging from frozen complete meals, dried soups, pie fillings and cake mixes to breakfast cereals. Food technology is an important part of modern society.

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CHAPTER 1

Measurement

All scientific study involves accurate measurement. This applies to food science, nutrition and microbiology as much as to any other scientific discipline. For example, in order to assess the nutritional value of a food it is necessary to be able to state its nutrient content in precise terms.

The metric system has, for a long time, been the universal system of measurement in pure science. Being a decimal system it is logical and easy to use. Many people in Britain may still be more familiar with Imperial units (inches, pints, pounds, etc.) than with metric units (metres, litres, kilograms, etc.) but Imperial units are being phased out.

SI units

SI is an abbreviation for *Système International d'Unités* (International System of Units). It is an extension and refinement of the traditional metric system and it has been adopted in the United Kingdom for all scientific measurement. There are six basic SI units; each is used for measuring a different physical quantity and each is represented by a different symbol. These basic units are shown in Table 1.1.

TABLE 1.1. *Basic SI units*

Physical quantity	Name of unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	degree Kelvin	K
Luminous intensity	candela	cd

In addition there are other units, derived from these basic quantities, and also some non-SI units, still in common use, which are allowed in conjunction with SI. Units which are relevant to this book are shown in Table 1.2.

It is sometimes more convenient for practical purposes to use a unit considerably larger or smaller than the standard unit. In order to make the units larger or smaller, words can be used in front of the unit. These prefixes increase or decrease the basic units

TABLE 1.2. *Other units*

Physical quantity	Name of unit	Symbol	
Energy	joule	J	} derived units
Customary temperature	degree Celsius	°C	
Area	square metre	m ²	
Volume	cubic metre	m ³	
Density	kilogram per cubic metre	kg m ⁻³	
Force	newton	N	} allowed in conjunction with SI
Pressure	pascal	Pa	
Volume	litre	l	

by multiples or fractions of ten. Each multiple or fraction has a symbol which is placed in front of the symbol of the unit (Table 1.3).

The following examples illustrate the use of prefixes:

5 kJ = five kilojoules = five thousand joules

12 mm = twelve millimetres = twelve thousandths of a metre

8 µg = eight micrograms = eight millionths of a gram

N.B. Symbols never take a plural form; 12 mms would be incorrect.

TABLE 1.3. *Metric prefixes*

Multiple	Prefix	Symbol
10 (ten)	deca-	da
10 ² (hundred)	hecto-	h
10 ³ (thousand)	kilo-	k
10 ⁶ (million)	mega-	M
Fraction	Prefix	Symbol
10 ⁻¹ (tenth)	deci-	d
10 ⁻² (hundredth)	centi-	c
10 ⁻³ (thousandth)	milli-	m
10 ⁻⁶ (millionth)	micro-	µ
10 ⁻⁹ (thousand millionth)	nano-	n

Length

The basic unit for the measurement of length is the metre. Large distances are now measured in kilometres rather than miles, and small distances in centimetres or millimetres. Very short lengths, such as the wavelength of light and the size of micro-organisms, are measured in micrometres or nanometres.

$$\begin{aligned}
 1 \text{ kilometre (km)} &= 1000 \text{ metres (} 10^3 \text{ m)} \\
 1 \text{ centimetre (cm)} &= \frac{1}{100} \text{ metre (} 10^{-2} \text{ m)} \\
 1 \text{ millimetre (mm)} &= \frac{1}{1000} \text{ metre (} 10^{-3} \text{ m)}
 \end{aligned}$$

$$1 \text{ micrometre } (\mu\text{m}) = \frac{1}{1,000,000} \text{ metre } (10^{-6} \text{ m})$$

$$1 \text{ nanometre } (\text{nm}) = \frac{1}{1,000,000,000} \text{ metre } (10^{-9} \text{ m})$$

Some of the factors used for converting Imperial units to SI units are as follows:

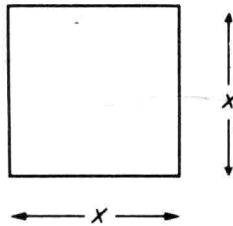
$$1 \text{ inch} = 2.54 \text{ cm (approximately } 2\frac{1}{2})$$

$$1 \text{ mile} = 1.61 \text{ km (approximately } \frac{8}{5})$$

Area

Area is a physical quantity derived from the measurement of length.

$$\text{Area} = \text{length} \times \text{breadth}$$



The area of a square of side x is x^2

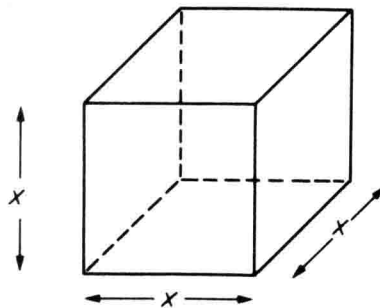
The SI unit of area is the square metre.

$$\begin{aligned} 1 \text{ square metre } (\text{m}^2) &= 100 \text{ cm} \times 100 \text{ cm} \\ &= 10,000 \text{ square centimetres } (10^4 \text{ cm}^2) \end{aligned}$$

Volume and capacity

Volume is also derived from the measurement of length.

$$\text{Volume} = \text{length} \times \text{breadth} \times \text{height}$$



The volume of a cube of side x is x^3

The SI unit of volume is the cubic metre.

$$\begin{aligned} 1 \text{ cubic metre (m}^3\text{)} &= 100 \text{ cm} \times 100 \text{ cm} \times 100 \text{ cm} \\ &= 1,000,000 \text{ cubic centimetres (10}^6\text{ cm}^3\text{)} \end{aligned}$$

For liquid measure or capacity the litre is the unit most often used. Quantities of wine are often measured in centilitres. The litre is derived from the measurement of volume, since it was originally defined as the volume occupied by 1 kg of water at its temperature of maximum density and under a pressure of one standard atmosphere.

$$\begin{aligned} 1 \text{ litre (l)} &= 1000 \text{ cm}^3 \\ 1 \text{ millilitre (ml)} &= \frac{1}{1000} \text{ litre (10}^{-3}\text{ l)} \end{aligned}$$

It will therefore follow that

$$1 \text{ millilitre (ml)} = 1 \text{ cubic centimetre (cm}^3\text{)}$$

Some of the factors used for converting Imperial units to SI units are as follows:

$$\begin{aligned} 1 \text{ fluid ounce} &= 28.4 \text{ ml} \\ 1 \text{ pint} &= 568 \text{ ml (0.568 l)} \\ 1 \text{ gallon} &= 4.55 \text{ l} \end{aligned}$$

For some purposes it is convenient to know that

$$1 \text{ litre} = 1.76 \text{ pints (approximately } 1\frac{3}{4}\text{)}$$

Mass and weight

For practical purposes mass and weight are the same and the terms are interchangeable, although the scientific definitions of mass and weight are different.

The basic SI unit of mass is the kilogram, which is now used instead of the pound. It has been suggested that a new name be found for the kilogram, since it is the only basic unit which is a multiple and has a prefix in its name. Quantities formerly measured in ounces are now measured in grams. Very small quantities of substances found in foods, such as vitamins and mineral elements, are measured in milligrams or micrograms. For large weights the tonne is used.

$$\begin{aligned} 1 \text{ tonne (t)} &= 1,000,000 \text{ grams (10}^6\text{ g)} \\ 1 \text{ kilogram (kg)} &= 1000 \text{ grams (10}^3\text{ g)} \\ 1 \text{ milligram (mg)} &= \frac{1}{1000} \text{ gram (10}^{-3}\text{ g)} \\ 1 \text{ microgram (}\mu\text{g)} &= \frac{1}{1,000,000} \text{ gram (10}^{-6}\text{ g)} \end{aligned}$$

Some of the factors used for converting Imperial units to SI units are as follows:

$$\begin{aligned} 1 \text{ ounce} &= 28.4 \text{ g (approximately 30)} \\ 1 \text{ pound} &= 454 \text{ g (0.454 kg—approximately } \frac{1}{2}\text{)} \\ 1 \text{ stone} &= 6.35 \text{ kg} \\ 1 \text{ ton} &= 1.016 \text{ t (metric tonnes)} \end{aligned}$$

For some purposes it is useful to remember that

$$1 \text{ kg} = 2.2 \text{ pounds}$$

Density

Density is derived from volume and weight. The density of a substance is a measure of its 'heaviness'. The popular expressions 'as heavy as lead' and 'as light as a feather' imply correctly that lead has a high density and feathers a very low density. A given weight of feathers will occupy a much greater volume than the same weight of lead.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

Since the SI unit of weight is the kilogram and the unit of volume is the cubic metre, the SI unit of density is the kilogram per cubic metre (kg/m^3 or more correctly kg m^{-3}). Density is also measured in grams per cubic centimetre (g cm^{-3}). The density of water is 1.0 g cm^{-3} . The **Relative Density** (RD) of a substance is the number of times a substance is heavier than an equal volume of water, i.e. its density relative to water.

$$\text{Relative Density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

N.B. Relative density is a ratio and therefore has no units.

If a substance is dissolved in water to form a solution, the density is altered. The density varies directly with the concentration of the solution. Most substances, e.g. sugar and salt, cause the density to increase but sometimes the density may be lowered, e.g. by the presence of fat or alcohol.

A quick method of determining the concentration of pure solutions in water is to measure the density of the solution, using an instrument known as a **hydrometer**.

A hydrometer consists of a glass bulb weighted with lead shot; attached to this is a thin glass stem bearing a scale (see Figure 1.1).

The hydrometer is placed in the solution so that it floats freely. The further it sinks into the solution the lower the density. The scale may give the density of the solution or it may be calibrated to give a direct reading of the concentration of a substance. Some examples of hydrometers used to give direct readings of concentration are saccharo-

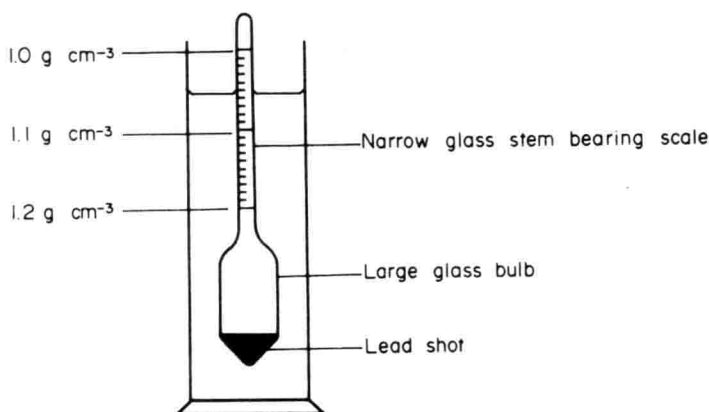


FIG. 1.1. Diagram of a hydrometer used to measure densities in the range 1.0 g cm^{-3} to 1.2 g cm^{-3} .

meters, used to measure sugar in solution, and salinometers, which measure the concentration of brine (salt solutions). Lactometers are used in dairies to give a rapid measurement of the density of milk, giving an indication of its quality. Normal milk should have a relative density of 1.030. In the wine industry hydrometers are used to show how much alcohol has been produced during fermentation.

Energy

The measurement of the energy released when a nutrient or food is oxidised is of importance in nutrition. The energy value of a food can be assessed by burning the food in oxygen and measuring the amount of heat energy produced.

The SI unit of energy is the joule and this has replaced the calorie. In nutrition the kilojoule has replaced the kilocalorie.

$$1 \text{ kilojoule (kJ)} = 1000 \text{ joules}$$

The factor used for conversion is

$$1 \text{ kilocalorie (kcal)} = 4.18 \text{ kilojoules (kJ)}$$

Kilocalories are often written as Calories (using a capital letter).

$$1 \text{ kilocalorie} = 1 \text{ Calorie (Cal)} = 1000 \text{ calories (cal)}$$

The use of the same word for two units of widely differing magnitudes causes a lot of confusion and term kilocalorie is preferred.

Temperature

The customary unit of temperature is the degree Celsius ($^{\circ}\text{C}$). The Celsius (or Centigrade) scale is a temperature scale in which the melting point of ice is 0° and the boiling point of water is 100° . On the Fahrenheit scale the melting point of ice is 32° and the boiling point of water is 212° .

Fixed point	Celsius scale	Fahrenheit scale
Melting point of ice	0°	32°
Boiling point of water	100°	212°

On the Celsius scale it can be seen that there are 100 degrees between the two fixed points, whereas on the Fahrenheit scale there are 180 degrees. The ratio 100:180 is equal to 5:9 and therefore 5 Celsius degrees are equal to 9 Fahrenheit degrees.

To convert $^{\circ}\text{C}$ to $^{\circ}\text{F}$

- Multiply by 9 then
- Divide by 5 then
- Add 32

Example: to convert 10°C to $^{\circ}\text{F}$

- $10 \times 9 = 90$
 - $90 \div 5 = 18$
 - $18 + 32 = 50$
- $10^{\circ}\text{Celsius} = 50^{\circ}\text{Fahrenheit}$

To convert $^{\circ}F$ to $^{\circ}C$

- (a) Subtract 32 then
- (b) Multiply by 5 then
- (c) Divide by 9

Example: to convert $104^{\circ}F$ to $^{\circ}C$

- (a) $104 - 32 = 72$
- (b) $72 \times 5 = 360$
- (c) $360 \div 9 = 40$
 $104^{\circ}\text{Fahrenheit} = 40^{\circ}\text{Celsius}$