



WALTHAM® pocket book of
essential nutrition
for cats and dogs

Edited by Prof. Dominique Grandjean
and Dr. Richard Butterwick



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Foreword

As a scientist working in companion animal nutrition, I believe that no other factor plays such a crucial role in the health and wellbeing of pets as a nutritionally balanced diet, whether the food format is wet, dry or semi-moist. For those of us that have owned pets, we fully understand their importance as integral members of the family, and our responsibility towards them.

The importance of complete and balanced nutrition is as true today as it was when our pet care business first started back in the 1930s. We can be proud of our heritage – but not complacent. Today, as the largest manufacturer of pet food, we hold a very privileged role. This position, however, demands that we act responsibly as a leader in developing the pet food category and, as part of this, that we define the nutritional agenda on behalf of our real customers, lest we forget, dogs and cats.

The WALTHAM® Centre for Pet Nutrition is a visible and tangible embodiment of the commitment Mars has made, and continues to make, in advancing pet nutrition. WALTHAM® published its first paper on canine nutrition in 1961, and since then has taken a leadership role in advancing knowledge in dog and cat nutrition. Over the past 50 years, significant steps have been made in defining the nutritional needs of dogs and cats. We now know the 'essential' nutrients needed to maintain health and well-being in dogs and cats. We also know that whilst there are some similarities in the nutritional needs of dogs and cats, there are profound differences, which in part reflect the unique nature of the cat

as an 'obligate' carnivore. For this reason cats should not be treated as small versions of dogs in terms of their nutrient requirements. This book will help to emphasise the specific and unique nutritional needs of these two important species.

Advancing knowledge in pet nutrition continues to be a key goal for WALTHAM® – however, sharing that knowledge is equally as important. The ambition of this book is to provide you with an insight into the basic building blocks that contribute to complete and balanced nutrition for dogs and cats. The intent of this booklet is to improve your understanding of the importance of cat and dog nutrition.

The book has been designed in bite-sized chunks that you can ingest, digest and assimilate in discrete meals, or as a grand banquet. Whichever way you choose to read it, I hope that it will become a key reference for you – and please recommend it to your colleagues.

Finally, I would like to acknowledge the contributors, who have written this because of their passion and commitment to pets.

Dr. Richard Butterwick PhD
Head of Nutrition
WALTHAM® Centre for Pet Nutrition



WALTHAM®

The world's leading authority on pet care and nutrition

For nearly 50 years WALTHAM® has been the leading authority within the field of cat and dog nutrition. WALTHAM® science and publications have been instrumental in helping define the nutrient requirements of cats and dogs, from determining the amino acid requirements of the dog, through to understanding the taurine levels required in manufactured cat foods.

Today this knowledge is often taken for granted by the pet food manufacturers of the 21st century. This booklet aims to summarise the essential nutrients required by every cat or dog, regardless of age, size or lifestyle.

The WALTHAM® approach to pet nutrition

WALTHAM® scientists work in partnership with the pets at the WALTHAM® Centre for Pet Nutrition, where fundamental pet-focused research supporting Mars Petcare delivers scientific breakthroughs in the areas of pet nutrition, health, wellbeing and behaviour.

In collaboration with global scientific institutes and experts, the WALTHAM® team of pet carers, scientists and research staff support leading Mars Petcare brands such as Whiskas®, Pedigree®, Trill®, Cesar®, Sheba®, Kitekat®, Aquarian®, Winergy®, Nutro® and Royal Canin.

For every associate working in Mars Petcare, whether for example in R&D, Sales, Franchise, Corporate Affairs, Manufacturing or Commercial, this book provides a valuable introduction to the essential nutrients required by cats and dogs. Today, delivering essential nutrient requirements within manufactured main meal pet foods, regardless of brand positioning, is entry level for the category. A good understanding of essential nutrition and what that means is vital for anyone working in the pet food industry.

www.waltham.com



Introduction

The importance of complete and balanced nutrition

Many years of scientific research have shown that nutrition is essential for the provision of energy to sustain a healthy life and to help reduce the risk of certain diseases, often referred to as functional nutrition. This book focuses on those nutrients essential for sustaining life.

Essential nutrients

Essential nutrients are those required by the animal that either cannot be synthesised by the body or cannot be synthesised in adequate amounts for good health. Essential nutrients are supplied by complete, balanced nutrition.

Complete and balanced nutrition

Cats and dogs require about 40 essential nutrients, each in the right form and in the right amount (balanced) to deliver complete nutrition. Complete and balanced nutrition delivers the right amount of every essential nutrient within the daily calorie needs of the cat or dog, whether the pet food format is wet, dry or semi-moist. Manufacturing a complete and balanced food for cats and dogs is a science in itself, requiring expertise at all stages of production, from sourcing raw materials to blending the vitamin and mineral mixes, understanding the role of processing for each pet food format and knowledge of the nutrient and energy requirements of cats and dogs.

Each essential nutrient has a recommended minimum daily requirement that has been defined through many years of research, although for some nutrients work continues to further refine these levels. Where appropriate, a maximum daily intake has also been defined. To deliver complete and balanced nutrition each essential nutrient should fall within the minimum and maximum levels required by cats and dogs (Figure 1).

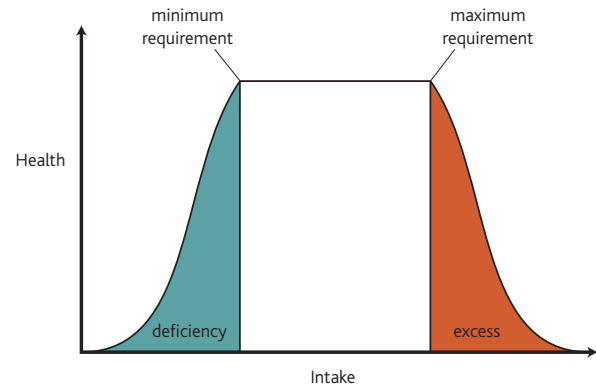


Figure 1. Recommended daily nutrient intake



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Who determines nutrient requirements of cats and dogs?

There are a number of different bodies that produce guidelines for the nutrient requirements of cats and dogs. These bodies base their recommendations on the vast quantity of information that exists in scientific literature. All these bodies are broadly similar in their guidelines, but they may vary slightly – often due to differences in interpretation of the scientific evidence.

National Research Council (NRC)

The NRC committee consists of key academic experts in the field of companion animal nutrition who define the nutrient requirements of cats and dogs. The most recent NRC guidelines on these requirements were produced in 2006. The NRC guidelines influence all other nutritional standards – although there are examples of differences between the NRC and other nutritional agencies.

American Association of Feed Control Officials (AAFCO)

AAFCO guidelines are written by invited experts from the industry and academia. Compliance with these guidelines is a legal requirement in most states in the USA. Although AAFCO produces an official publication every year, it doesn't necessarily update the information each time.

Fédération Européenne de L'Industrie des Aliments Pour Animaux Familiers (FEDIAF)

These guidelines represent the industry best practice in Europe. Whilst followed by the majority of manufacturers they are not legally binding. FEDIAF's nutritional guidelines are based on state of the art knowledge

on cat and dog nutrition, providing pet food manufacturers with nutritional recommendations. Apart from nutrient profiles, FEDIAF also provides guidelines for methods of assessing the nutritional values of pet food and advice on specific topics, such as human foods that are poisonous for cats and dogs.

WALTHAM®

WALTHAM® produces guidelines for Mars using external and internal knowledge. These are solely produced for internal use by Mars Petcare associates and are updated every two years with the latest scientific knowledge.



Energy requirements of the adult cat and dog

Energy is provided in the diet through protein, fat and carbohydrate and is expressed either in kilocalories (kcal) or kilojoules (kJ). Fat delivers approximately twice as much energy per gram as protein and carbohydrate. Dogs and cats need energy to maintain normal metabolic function.

An inadequate energy intake will be detrimental to the health and performance of the animal, whereas an energy intake in excess of the daily requirement will cause weight gain and compromised health.

The gross energy (GE) of a food is the amount of chemical energy released when that food undergoes complete combustion in a bomb calorimeter. The GE values of protein, fat and carbohydrate are 5.7 kcal g⁻¹, 9.4 kcal g⁻¹ and 4.1 kcal g⁻¹ respectively.

When the food is ingested, the majority of GE is utilised by the pet (termed digestible energy) but some is lost in faeces. When further losses of energy in urine and gas are taken into account, the result is metabolisable energy (ME); this is energy available for metabolism (Figure 2). When nutritional requirements are stated for an animal, they are expressed per 1000 kcal ME.

The daily energy requirement of a cat and dog is calculated according to their bodyweight. For the average adult cat, there is a simple formula that calculates the daily energy requirement directly from the bodyweight: Cat energy requirement = 55 W kcal per day (where W = bodyweight in kg)

Since there is a broad variation in bodyweights of dogs, ranging from around 1 kg to 90 kg, the energy requirement of dogs does not have a linear relationship with bodyweight. In this situation, a mathematical function derived from scientific evidence must be applied to the bodyweight to give the following equation for an average adult dog: Dog energy requirement = 110 W^{0.75} kcal per day (where W = bodyweight in kg)

In addition to bodyweight, there are a number of other factors that may affect the energy requirement of an animal including its physical activity, body condition, lifestage and environmental conditions. The above formulae must be applied whilst taking individual variability into account. Different formulae exist for puppies, kittens, gestating/lactating mothers, senior or overweight pets.

Pet food feeding guides, whether wet, dry or semi-moist in format, are based on the kilocalories provided by the food and utilise the above equations to calculate how much food should be fed to pets of various size, age and activity levels. Owners should always use the feeding guide as the foundation for estimating how much food to offer their pets, adjusting the amount according to individual pet requirements.



Energy requirements of the adult cat and dog

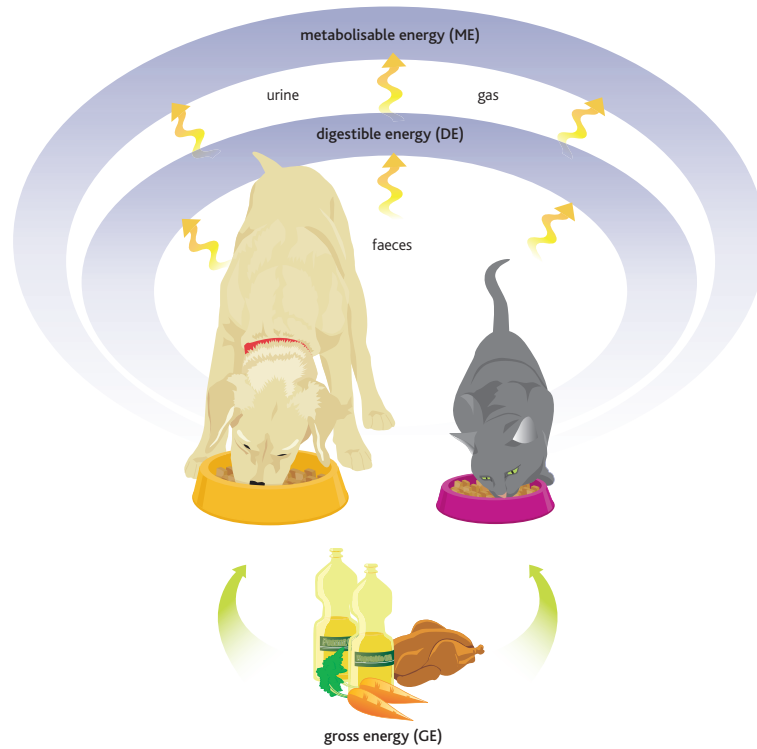


Figure 2: Energy utilisation in the cat and dog



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Understanding dogs

The dog is classified in the Order Carnivora (carnivores). It is well adapted for eating meat. The dog is able to consume a more omnivorous diet.

Dogs

1. Sense of smell is up to 10,000 times more sensitive than humans
2. 42 teeth designed for cutting, tearing and grinding. The enamel of dogs' teeth is approximately five times thinner than that of humans
3. Fewer taste buds than humans
4. Limited salivary amylase (little carbohydrate predigestion). Saliva pH is more alkaline than humans
5. A very expandable stomach designed to cope with large meals
6. Stomach pH is more acidic than in humans for digestion of bones and destruction of harmful bacteria
7. Transit time through the intestine is 12-30 hours compared with 30 hours to five days in humans
8. Bacterial fermentation takes place in the large intestine

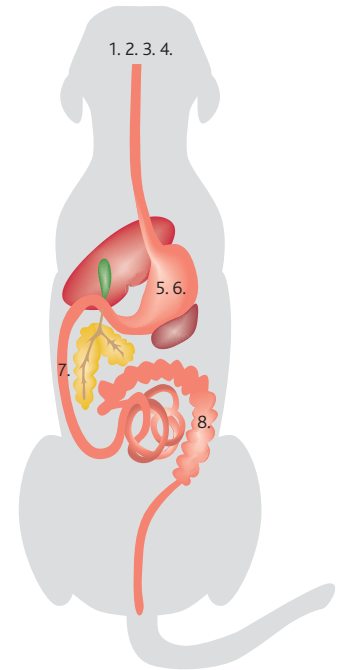


Figure 3. Anatomy of the canine digestive tract



Understanding cats

The cat is classified in the Order Carnivora (carnivores). It is well adapted for eating meat. The cat is an obligate carnivore and therefore must have meat in its diet.

Cats

1. 30 teeth, all of them sharp and designed for cutting and tearing. No sideways movement of the jaw. The enamel of cats' teeth is approximately ten times thinner than that of humans
2. Cats have even fewer taste buds than dogs. They have non-functional sugar taste receptors
3. No salivary amylase (no predigestion of carbohydrate)
4. The stomach is designed for many small meals spread throughout the day
5. Stomach pH is more acidic than humans for digestion of bones and destruction of harmful bacteria
6. Transit time through the intestine is 12-24 hours compared with 30 hours to five days in humans
7. Small intestine – well suited to digesting proteins and fats. Cats are not able to down-regulate protein digesting enzymes and therefore need a protein rich diet
8. Bacterial fermentation takes place in the large intestine

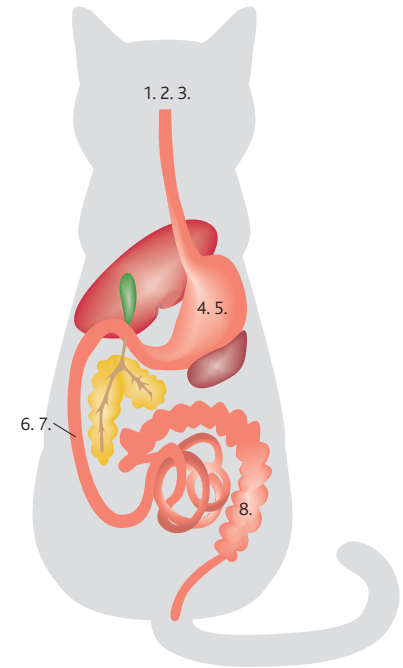


Figure 4. Anatomy of the feline digestive tract



Macronutrients

Macronutrients (Figure 5) are ingested daily in relatively large quantities (gram amounts).

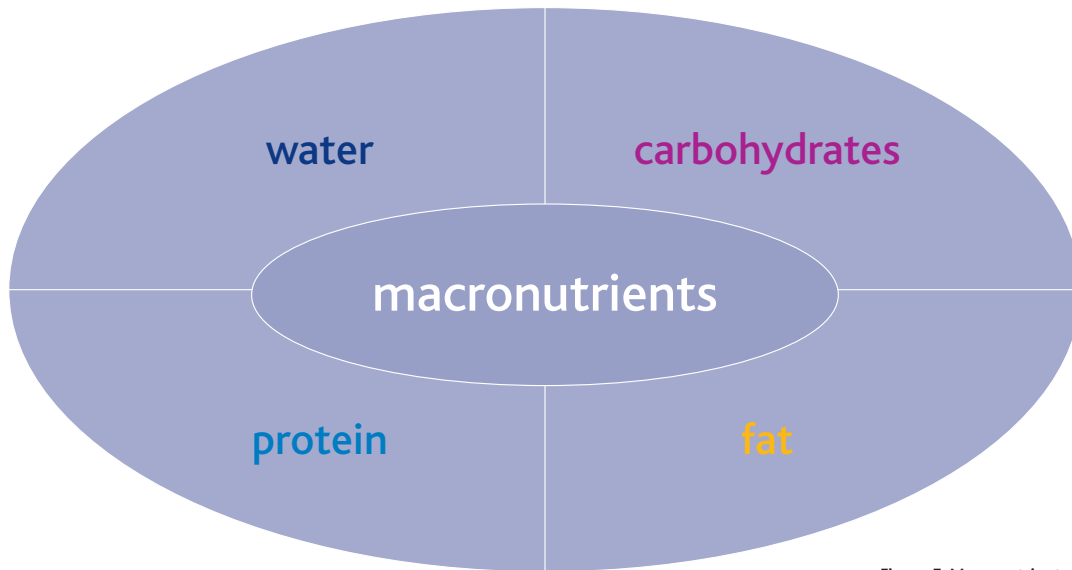


Figure 5. Macronutrients ingested by cats and dogs





Water

Life's most essential nutrient



Background

Water is a major constituent of an animal's body (75% at birth and 60% in adult life). It is the most important nutrient for life and plays a part in all major physiological functions. Cats have a reputation for drinking little because they are descended from desert animals and are able to concentrate their urine. However, if that concentration is too high, it increases the risk of crystal and stone formation within the urinary tract.

Cats and dogs must have free access to drinking water at all times.

Role in the body

Water has many essential functions for life:

- Ideal medium for transporting nutrients and waste through the body
- Required for most metabolic processes
- Regulation of body temperature
- Lubrication of the joints, the eyes and the inner ear (for the transmission of sound)

Common sources

There are three sources of water:

- Drinking

- Food (dry food contains up to 10% water and wet food around 80% water). Dogs and cats fed wet food will drink far less water than pets fed dry food due to the higher water content
- By-product of metabolic processes

Deficiency and excess

Free access to clean drinking water helps prevent dehydration, the signs of which are dry skin that lacks elasticity, a higher heart rate and high fever. Body water loss of more than 10% can have serious health implications. Increased intake can be a sign of diabetes mellitus or kidney disease.

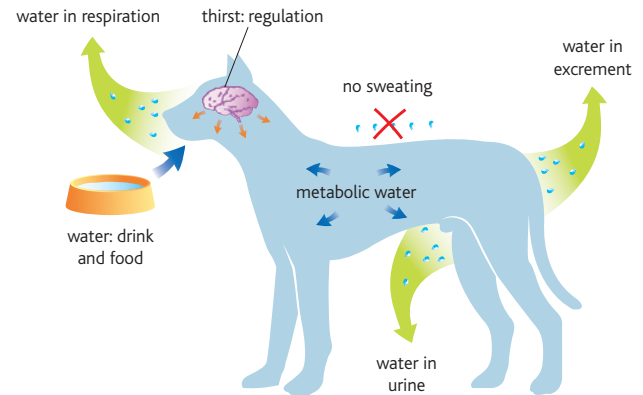


Figure 6. Water utilisation in the dog





Protein



Proteins are made up of amino acids, in predefined chains that determine their roles within the body. Amino acids, which are produced by the breakdown of dietary proteins in the digestive tract, play a role in synthesis of proteins needed to build and repair organs and tissues, transport molecules, send messages from one organ to another (hormones) and help combat disease (antibodies).

Good sources of proteins are from animal products (meat, offal and fish) and some vegetable products (cereal gluten, rice and soy).

Some physiological conditions require more protein than others; for example growth, gestation, lactation or physical activity are demanding in terms of protein utilisation.

Dogs and cats use 30-35% of dietary protein to maintain skin and coat health.


protein: a chain of amino acids

intestinal lumen

brush border

intestinal mucosa

gradual absorption of amino acids

 enzymes (proteases)

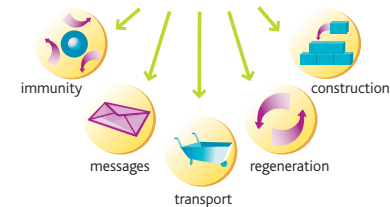


Figure 7. Protein metabolism



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Amino acids

Building blocks of proteins



Background

Amino acids are the building blocks of proteins and their derivatives. Proteins include a total of 20 different amino acids, only 11 (cats) or 10 (dogs) of which are essential; that means they cannot be produced by the body so must be provided in the diet.

Role in the body

Amino acids are required by the body to ensure healthy physiological function. Without essential amino acids, the growth of kittens and puppies will be slow and health may be compromised. Processes such as nitrogenous waste elimination and haemoglobin synthesis will be disrupted in deficient adult animals.

Common sources

All dietary proteins of animal or plant origin are composed of a series of chemically bound interlinked amino acids. Dietary proteins of 'high biological value' are those that combine good digestibility and a high content of essential amino acids, such as egg, meat (including organ meats such as heart, kidney, liver and lung), fish proteins and cereal gluteins.

Deficiency and excess

The absence of any of the essential amino acids from the diet stops the synthesis of essential proteins. Under these conditions, the animal then breaks down body tissue to provide the required amino acids, seriously compromising health.

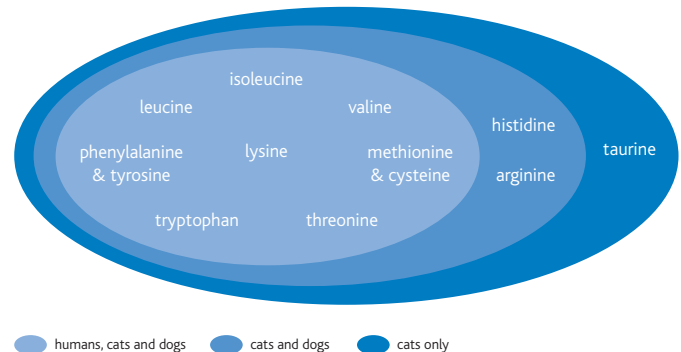


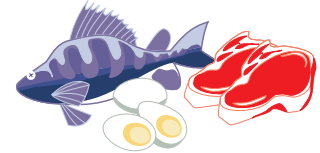
Figure 8. Essential amino acids in dogs, cats and humans





Methionine and cysteine

Key ingredients in the hair protein, keratin



Background

Methionine and cysteine are sulphur amino acids that are important for the synthesis of the hair protein, keratin. The keratin synthesis needed to maintain skin and hair can account for up to 30% of an adult dog's daily protein requirement.

Role in the body

Methionine is essential within the diet. Cysteine can be synthesised from methionine. However, if cysteine is provided in sufficient quantities, it helps free up methionine for other functions. The metabolism of sulphur amino acids produces sulphuric acid, which is eliminated through the urine.

A carnivore's natural diet, rich in sulphur amino acids, therefore tends to produce acidic urine.

Common sources

Methionine and cysteine are particularly abundant in fish and egg proteins, as well as casein. Wheat and maize glutes are also very rich sources.

Deficiency and excess

A deficiency of methionine and cysteine can result in hair loss, slow hair growth and a generally dry and brittle appearance of hair.

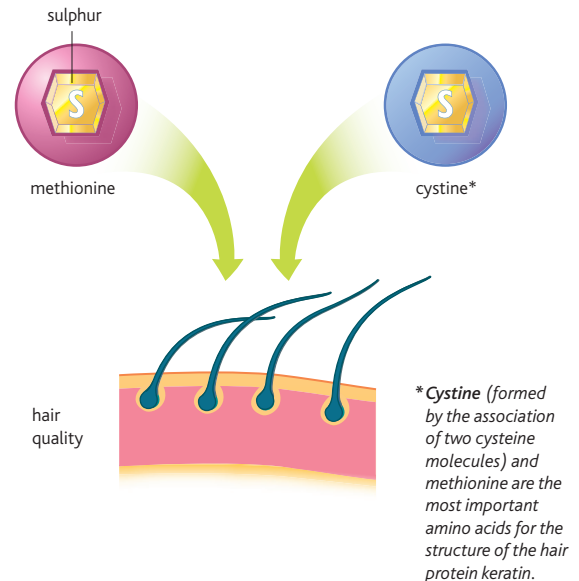


Figure 9. Role of methionine and cysteine in hair growth



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Taurine

Healthy eyesight, healthy heart, natural antioxidant



Background

Taurine is only essential for cats as, unlike dogs, they cannot synthesise it themselves. Taurine was discovered in 1826 in the bile of cattle (*Bos taurus*), hence its name. It is a sulphur amino acid found in most animal tissue. Unlike other essential amino acids, it does not have any role in protein synthesis. For reasons yet to be fully understood, wet cat food requires twice the level of taurine supplementation of dry food, to allow the cat to absorb adequate levels of the nutrient.

Role in the body

Taurine enables the liver to synthesise bile salts. It also works by regulating calcium flow into and out of the cells and has a role in healthy cardiac function.

Taurine is required for healthy reproduction, healthy eyesight and hearing. It is an important antioxidant, as well as playing a role as a precursor for the synthesis of complex fats (glycosphingolipids), that support the barrier function of the skin.

Common sources

Animal protein sources, in particular the organs (e.g. heart, kidney, liver), are the main natural sources of taurine.

Deficiency and excess

Taurine deficiency can result in feline central retinal degeneration (FCRD) and subsequent blindness, inadequate immune response, poor growth, and poor reproductive function including decreased live birth rate and congenital birth defects.

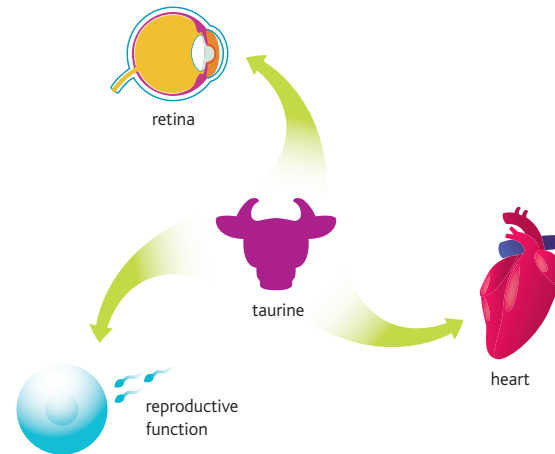


Figure 10. Role of taurine in the cat





Arginine

Essential amino acid for growth and urea production



Background

Arginine is important for the synthesis of urea from ammonia. In the absence of arginine, cats rapidly develop clinical signs of ammonia intoxication (hyperammonaemia), which include vomiting, hypersalivation and nerve problems. This deficiency may prove fatal within hours if left untreated.

Role in the body

In addition to its involvement in the excretion of ammonia, arginine plays a role in blood vessel relaxation and the release of several hormones.

Common sources

Arginine is abundant in meat including organs. Gelatine is a rich source.

Deficiency and excess

Arginine free diets are associated with excessive salivation, muscle tremors, vomiting and death. In the long term, marginal arginine deficiency can lead to cataract development. Signs of deficiency tend to be more severe in cats than dogs.

As ammonia is produced from the breakdown of protein, the higher the protein content of the diet the higher the arginine requirement.

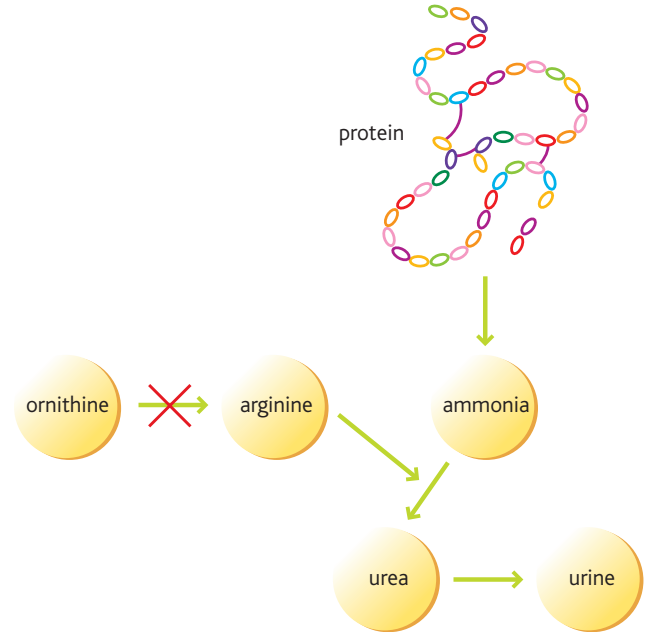


Figure 11. Unique requirement for arginine in the cat





Lysine

Essential amino acid for the synthesis of all proteins



Background

Lysine is often the first limiting amino acid in the diet, which means it has the greatest risk of being deficient if a pet food is not carefully formulated. Lysine is sensitive to heat, and during pet food processing it undergoes a chemical reaction with sugar (Maillard reaction), thought to be important for generating flavours and aromas.

Role in the body

Lysine is an essential amino acid that is used for the synthesis of proteins.

Common sources

Lysine is abundant in animal sources especially muscle tissue. Soy proteins are also a good source.

Deficiency and excess

Lysine is an essential amino acid that must be provided in the diet. Deficiency can lead to reduced food intake and weight loss. Too much lysine in puppies can cause signs of arginine deficiency.

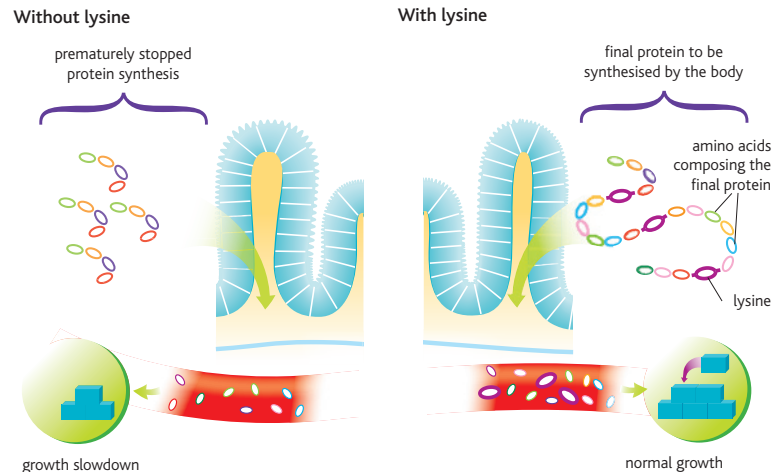


Figure 12. The influence of lysine on protein synthesis



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Phenylalanine and tyrosine

Thyroid and adrenal gland function, hair pigmentation



Background

Phenylalanine and tyrosine are aromatic amino acids (so named because of their ring structure) that are vital for the production of pheomelanins (yellow to red pigments) and eumelanin (brown to black pigments) that define the colour of an animal's coat.

Of the aromatic amino acids, only phenylalanine is considered to be essential. Tyrosine can be synthesised from phenylalanine. However, if tyrosine is provided in sufficient quantities, it helps free up phenylalanine for other functions.

Role in the body

Phenylalanine is essential for the production of thyroid hormones and other key metabolites as well as being vital for tyrosine synthesis. Besides its role in hair and iris pigmentation, tyrosine is also a dopamine, noradrenalin and adrenalin precursor. These molecules are required for the proper functioning of the brain and in reproduction.

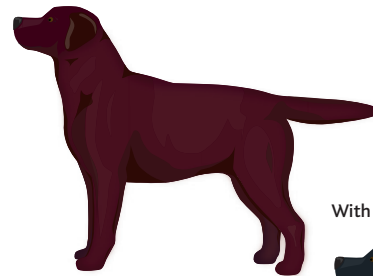
Common sources

Phenylalanine is found in most animal protein sources such as beef, pork, poultry and fish. Tyrosine is either provided directly in the diet or synthesised from phenylalanine, an essential amino acid. Rice is the only vegetable source to contain useful quantities of tyrosine.

Deficiency and excess

Signs of deficiency include neurological dysfunction, uncoordinated gait and hyperactivity in cats. In dogs, signs include weight loss and reduced food intake, and reddening of black coats.

Without phenylalanine and tyrosine



With phenylalanine and tyrosine



Figure 13. The influence of phenylalanine and tyrosine on coat colour





Branched chain amino acids (BCAA)

Essential amino acids for synthesis of muscle proteins



Background

Leucine, isoleucine and valine constitute the class of branched chain amino acids (BCAA) within the essential amino acid family. The body is unable to make them sufficiently quickly, and therefore a dietary source is required.

Role in the body

Leucine, isoleucine and valine stimulate the synthesis of proteins and slow their breakdown in the muscles. The effectiveness of BCAA in both these actions appears to diminish with age. BCAA help increase lean mass and help prevent muscle wasting.

Common sources

Leucine, isoleucine and valine are commonly found in muscle meats including beef, lamb and poultry.

Deficiency and excess

Deficiency of any of the BCAA can result in weight loss and lethargy.

Deficiency of isoleucine in particular can result in rough coat, lesions on the paws and an uncoordinated gait.

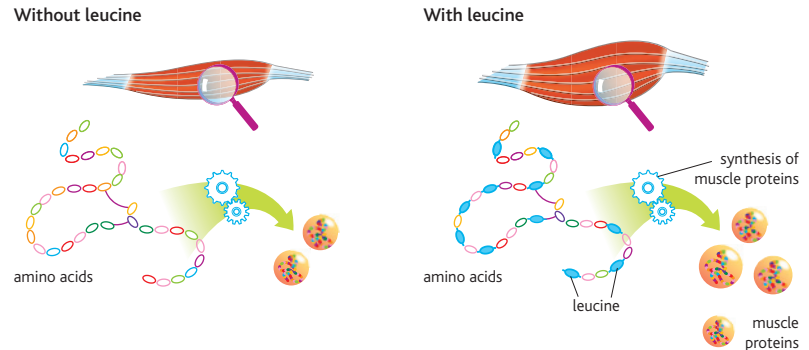


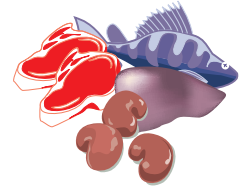
Figure 14. Role of branched chain amino acids in protein synthesis





Histidine

A structural protein



Background

Histidine was first isolated in 1896.

Histidine acts as a precursor for a number of important compounds.

Role in the body

Besides its structural function in proteins, histidine is a precursor for a number of neurological compounds such as histamine.

Common sources

Meat is a good source of histidine. It is present in particularly high concentrations in blood.

Deficiency and excess

Histidine deficiency can result in weight loss and refusal to eat. In cats, even a marginal deficiency when fed over a long period of time can result in cataracts.

Threonine

Essential for energy production

Background

Threonine is an alpha amino acid and is the only essential amino acid to contain an alcohol group within its structure.

Role in the body

Threonine acts as a precursor for a number of metabolically active molecules including pyruvate, involved in the production of energy.

Common sources

Poultry, fish, lamb, pork and beef are all good dietary sources of threonine.

Deficiency and excess

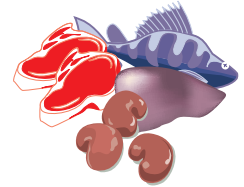
Threonine deficiency can result in weight loss and refusal to eat in both cats and dogs. In cats, even a marginal deficiency can result in nervous system problems.





Tryptophan

Required for hormone production



Background

Tryptophan was first isolated in 1901 and is a precursor of many important metabolic molecules.

Role in the body

Tryptophan acts as the precursor of niacin synthesis in dogs. Although cats do have the ability to synthesise niacin from tryptophan, the activity of the enzyme picolinic carboxylase diverts tryptophan away from this function. Tryptophan also acts as the precursor of serotonin and melatonin.

Common sources

Poultry, fish and soy are excellent sources of tryptophan.

Deficiency and excess

Tryptophan deficiency can result in refusal to eat and weight loss.

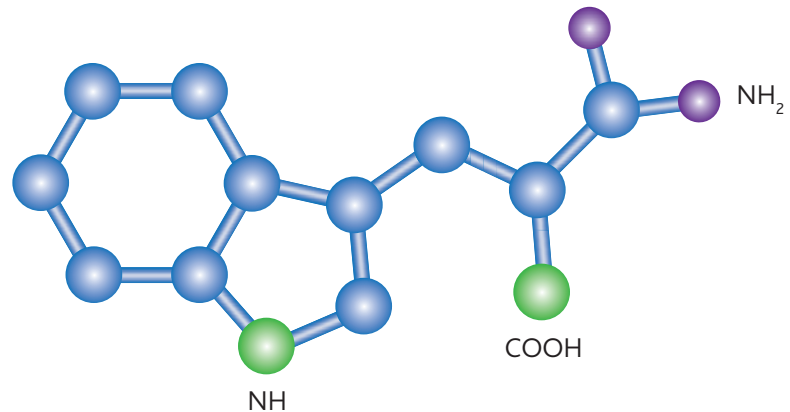


Figure 15. Structure of tryptophan



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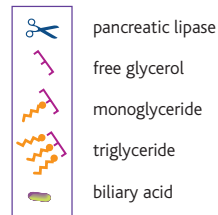
Fats



Fats are a rich source of energy, providing more than twice as much energy per gram than protein and carbohydrate. In terms of nutrition, fats deliver essential fatty acids and provide the necessary environment for absorption of fat-soluble vitamins in the gut.

Fats (and oils) from both animal and vegetable origins provide varied sources of essential fatty acids. Ingredients such as beef tallow and seed oils are regularly used in pet food to deliver these nutrients.

Fatty acids are required for a number of processes in the body including maintenance of a healthy skin and coat, a strong immune system and reproductive function.



In the intestine, the dietary fats are emulsified by biliary acid and digested by the pancreatic enzymes (lipases). The fatty acids are then absorbed into the blood stream or lymphatic system.

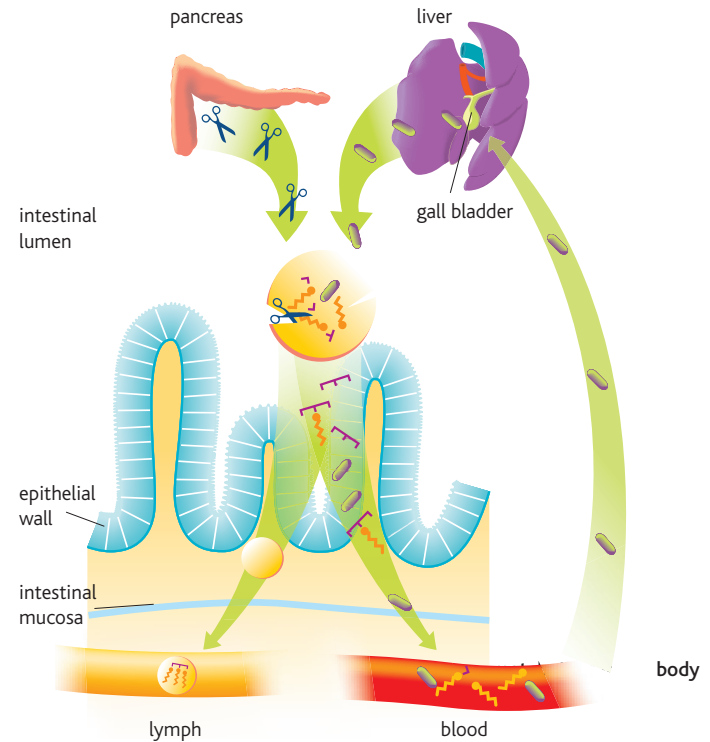


Figure 16. Fat metabolism in the body



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Fatty acids

Energy source, transport of fat-soluble vitamins



Background

Fatty acids are the main constituent of fats and consist of a carbon chain varying in length and chemical structure. Saturated and unsaturated fatty acids are named according to the absence or presence respectively of at least one double bond within the carbon chain.

Role in the body

Saturated long-chain fatty acids are used exclusively for energy within the body whilst the role of polyunsaturated fatty acids (PUFAs) is more diverse. Fatty acids are termed essential when they cannot be generated within the body.

The omega-3 and omega-6 groups of PUFAs represent the key essential fatty acids in mammalian nutrition.

Common sources

Vegetable oils, e.g. sunflower and linseed, and animal fats, e.g. fish oil and beef tallow.

Deficiency and excess

Deficiency of fatty acids can result in fat-soluble vitamin deficiency (vitamins A, D, E and K) and poor skin and coat condition.

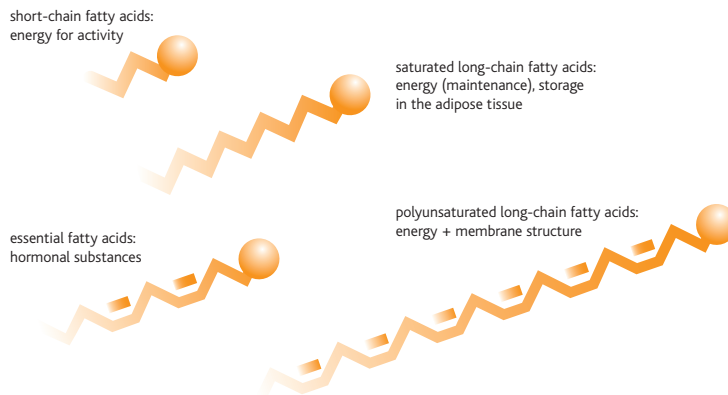


Figure 17. Types of fats





Omega-3 fatty acids

Anti-inflammatory action, cell oxygenation, physical effort



Background

Eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and alpha-linolenic acid (ALA) together form the omega-3 family of PUFAs.

Role in the body

There is evidence to suggest that omega-3 PUFAs are required in the diet of gestating animals for normal embryonic growth and development. However, in the adult cat and dog, there is insufficient evidence to support an absolute minimum requirement of omega-3 PUFAs in the diet. Whilst not essential for adult cats and dogs, omega-3 fatty acids may provide a number of functional benefits including improving skin and coat condition and acting as anti-inflammatory agents. In the ageing animal, omega-3 PUFAs may help prevent deterioration of cognitive function by improving brain oxygenation.

Common sources

Rich sources of ALA include flaxseed oil, whilst the most abundant source of DHA and EPA is marine fish oil. Alternatively, EPA and DHA can also be found in phytoplankton and single cell algae.

Deficiency and excess

Excess omega-3 PUFAs can lead to impairment of immune function in dogs.

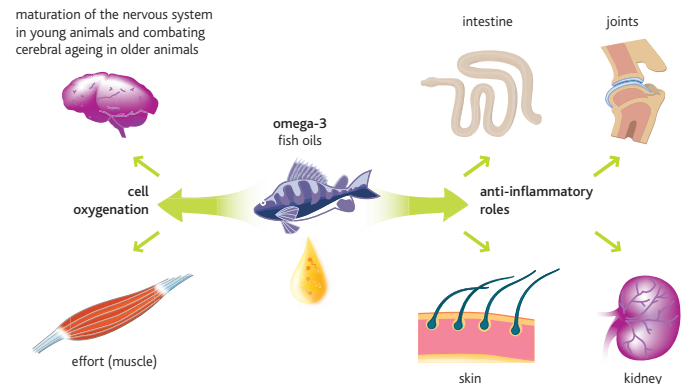


Figure 18. Role of omega-3 fatty acids in the body



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Omega-6 fatty acids

Skin health, coat condition, reproduction



Background

Arachidonic acid and linoleic acid are essential fatty acids belonging to the omega-6 family of PUFAs. Dogs can synthesise arachidonic acid from dietary linoleic acid but cats are unable to carry out this conversion step, making arachidonic acid an essential nutrient in the diet of cats.

Role in the body

Omega-6 fatty acids are essential for healthy reproduction since they are involved in the synthesis of prostaglandins. Prostaglandins are hormone-like compounds that regulate a number of reproductive processes including ovulation and parturition.

Common sources

Arachidonic acid can be found in animal fats such as beef tallow and poultry skin. Linoleic acid can be found in vegetable oils such as sunflower oil.

Deficiency and excess

A deficiency in omega-6 fatty acids can cause poor reproductive performance, poor skin and coat condition resulting in dry, irritated, flaky skin and a dull appearance of the coat.

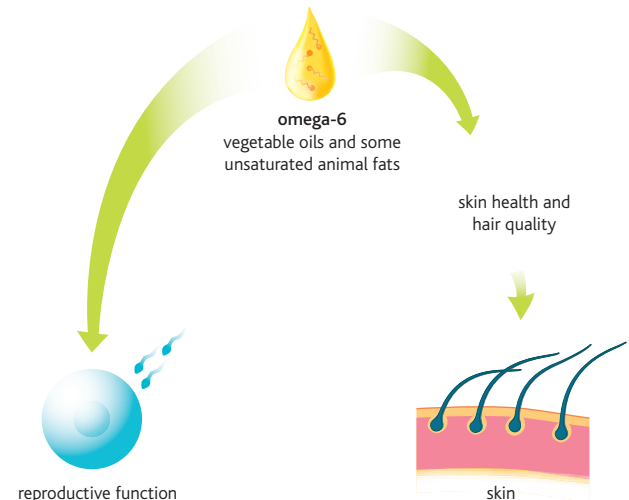


Figure 19. Role of omega-6 fatty acids in the body



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Carbohydrates



Cats and dogs can synthesise their own blood glucose from amino acids. Carbohydrate, therefore is not an essential macronutrient. However, if provided in their diet, cats and dogs can utilise carbohydrates and they are used in pet foods as sources of energy and dietary fibre. Carbohydrate levels tend to be higher in dry pet food than in wet pet food.

Carbohydrates are molecules composed of carbon, oxygen and hydrogen that have certain chemical characteristics in common. Carbohydrates are predominantly of vegetable origin, with the exception of blood glucose, glycogen in the muscles and liver, and milk lactose.

Carbohydrates can be divided into four types:

1. Absorbable carbohydrate – a form that is immediately useable by the body. Glucose is the most common dietary unit of carbohydrate but is usually present as a component of more complex carbohydrates which must be degraded by enzymes.
2. Digestible carbohydrate – mainly starch, the predominant form being of plant origin. Broken down by enzymes into absorbable carbohydrates.
3. Fermentable carbohydrate – utilised by bacteria in the gut and may be broken down into a form useable by the body. May be classed as prebiotics if they are specifically used by gut bacteria beneficial to the host. An example is pectin.

4. Non-fermentable carbohydrate – commonly known as fibre, this category of carbohydrate passes through the body undigested (e.g. lignin) and serves to add bulk to the bowel contents.

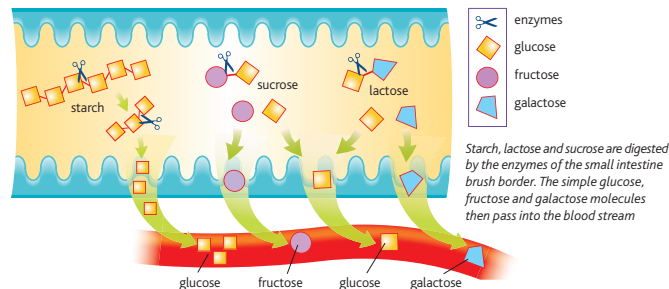
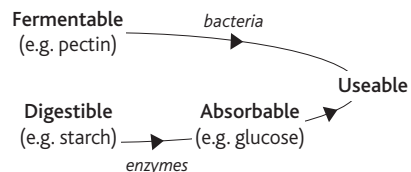


Figure 20. Carbohydrate digestion



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Sugars

Energy source



Background

The term sugar refers to some absorbable (e.g. glucose and fructose) and some digestible carbohydrates (e.g. lactose and sucrose). When provided in the diet, sugars provide energy. In prepared pet foods dietary sugar can react with lysine during processing, enhancing flavours and aromas.

Role in the body

Although not essential, sugars can be used as an energy source when provided in the diet.

While lactose in the mother's milk acts as an energy source for young puppies or kittens, a digestive enzyme, lactase, is necessary to make it biologically available; lactase disappears once the animal stops feeding on milk.

Common sources

Sugars are naturally found in most fruits, cereals, roots and tubers.

Deficiencies and excess

When fed in excess, sugars may cause diarrhoea and small intestinal bacterial overgrowth.

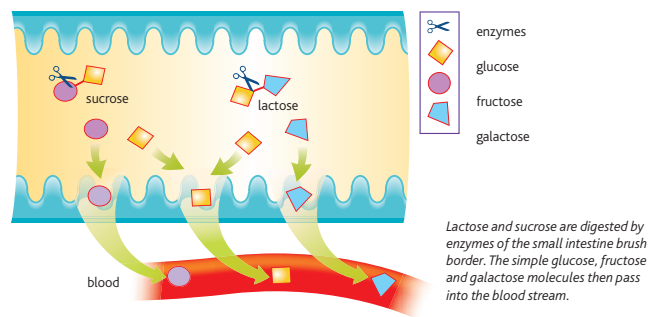


Figure 21. Lactose and sugar digestion



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Starch

Non-essential digestible carbohydrate, energy source



Background

Starch is a digestible carbohydrate, composed of thousands of glucose molecules linked together by simple chemical bonds.

Role in the body

Although not essential, dietary starch is utilised as an energy source. Starch molecules are broken down by digestive enzymes into glucose molecules that are absorbed in the small intestine. Cooking starch increases the gelatinisation, making it easier to digest.

Common sources

Starch is common in plants and is used to store energy (in a similar way to fats in animals). Common sources include rice, maize, wheat, barley and potato.

Deficiency and excess

As starch is not an essential nutrient for cats and dogs, they cannot develop deficiencies. However, poorly cooked starch, or high dietary levels may cause diarrhoea.

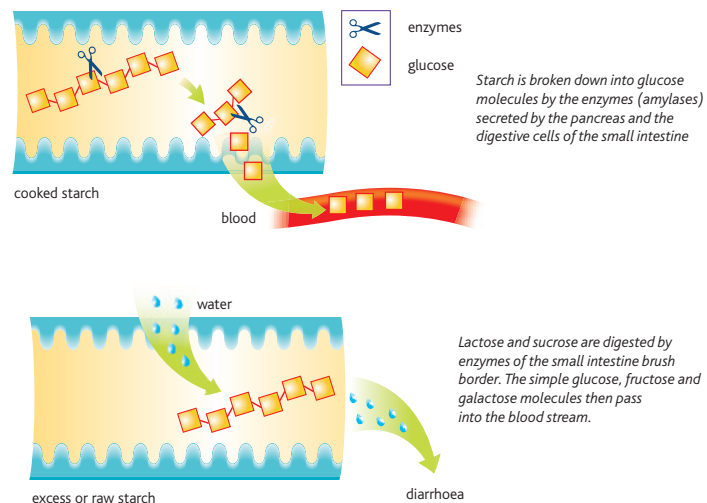


Figure 22. Starch digestion



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Fibre

Beneficial for gut health



Background

Most soluble fibres are fermentable (e.g. fructooligosaccharides (FOS) and pectin) and most insoluble fibres are non-fermentable (e.g. lignin and cellulose). However, an exception is psyllium, which is a soluble but non-fermentable fibre. Fibre is beneficial for gut transit. Some fibres, known as prebiotics, may also promote colonisation by beneficial gut bacteria.

Role in the body

The role of fibre varies according to type. Non-fermentable fibres, such as lignin, act as bulk within the digestive tract, regulating digestive transit. Intestinal transit must be slow enough to allow efficient absorption of nutrients but not so slow that constipation occurs. The right level of dietary fibre can help to optimise intestinal transit time.

Fermentable fibres such as FOS and mannanoligosaccharides (MOS) can improve the health of the digestive tract by providing food for beneficial bacteria. These specific fibres are known as prebiotics (not to be confused with probiotics – which are live bacteria that are beneficial to gut health). However, not all fermentable fibres have a prebiotic effect.

Common sources

Most fibre is plant-based. Common examples include beet pulp, cellulose, alfalfa, gums and pectin.

Deficiency and excess

As fibres are not essential nutrients for cats and dogs, they cannot develop a deficiency. However, too little or too much fibre can compromise faeces quality.

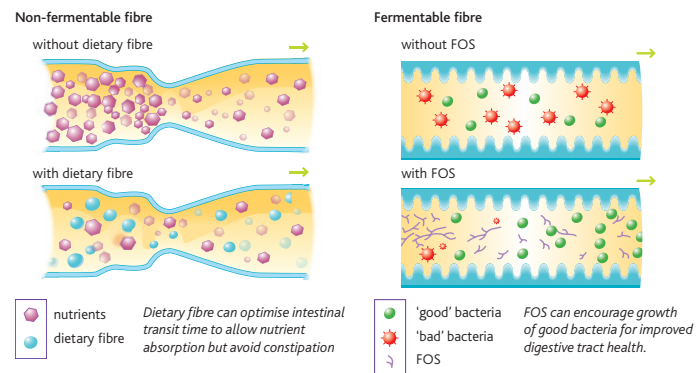


Figure 23. The role of non-fermentable and fermentable fibre in the digestive tract



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Vitamins



The word vitamin is derived from the word amine, vital for life (vital amine). Thiamin was the first vitamin to be named. By extension, other substances that play a similar role are also referred to as vitamins.

The vitamins are split into two families: vitamins that are soluble in fats (vitamins A, D, E, K: Table 1) and vitamins that are soluble in water (B vitamins: Table 2). If consumed excessively, fat soluble vitamins accumulate in the body and can become toxic whereas excess water soluble vitamins are passed out in the urine.

Vitamins are provided through various ingredients and they can also be added to pet food in pre-prepared vitamin mixes. As they are sensitive to light, heat and oxidation, care should be taken during cooking processes and in determining the shelf life of a product.

Each vitamin is involved in several different functions.

Table 1. Essential fat soluble vitamins – key functions

Vitamin A	vision, skin
Vitamin D	calcium and phosphorus metabolism
Vitamin E	antioxidant
Vitamin K	blood clotting

Table 2. Essential water soluble vitamins – key functions

B1 (thiamin)	nervous system
B2 (riboflavin)	skin
B3 (niacin)	skin, cell energy
B5 (pantothenic acid)	growth, skin
B6 (pyridoxine)	cell energy
B7 (biotin)	skin, hair
B9 (folic acid)	formation of blood cells
B12 (cobalamin)	formation of blood cells
Choline	synthesis of phospholipids





Vitamin A (retinol)

Essential for vision



Background

Vitamin A was isolated in 1913 and its chemical structure was mapped in 1931. It is a long chain alcohol that is soluble in fat. It is absorbed in the small intestine and stored in the liver. Dogs can synthesise vitamin A from beta carotene, but cats lack the required enzyme to do this. Both cats and dogs are adapted to process large amounts of vitamin A.

Role in the body

Vitamin A is required for healthy vision, in particular adaptation to darkness. It is also involved in the synthesis of reproduction hormones and protein synthesis, as well as regulating the growth of skin cells and the production of sebum.

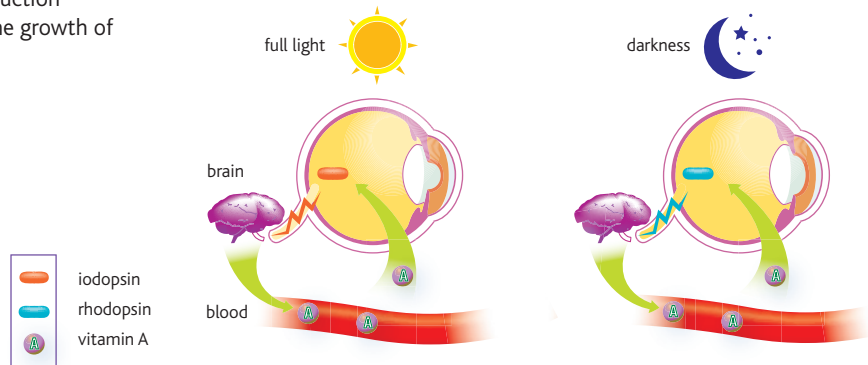
Common sources

Good sources of dietary vitamin A are liver, fish and eggs.

Deficiency and excess

Vitamin A deficiency can result in eye problems, dry skin, reproductive anomalies and greater sensitivity to infections and pulmonary complications.

High levels of vitamin A can result in joint abnormalities and poor reproductive performance.



Vitamin A (retinol) plays a role in the synthesis of the retinal pigments needed for the perception of colour (iodopsin of the cones) and night vision (rhodopsin of the rods).



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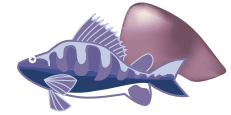


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Vitamin D (cholecalciferol)

Bone growth and mineralisation



Background

The benefit of fish liver oil for prevention of rickets was discovered in 1782 and vitamin D was isolated in 1932. Humans and herbivores synthesise this vitamin from skin sterols in the presence of sunlight. However, this process is absent in cats and dogs, meaning that vitamin D must be provided in the diet. To be active in the body, ingested vitamin D must be modified in the liver and kidney.

Role in the body

Vitamin D plays an essential role in the regulation of calcium and phosphorus metabolism by increasing intestinal absorption of both minerals, optimising calcium incorporation into bone and reducing the loss of calcium and phosphorus in the urine.

Common sources

Meat and vegetables are almost completely lacking in vitamin D. Good sources include oily fish (sardines, tuna) and liver.

Deficiency and excess

Vitamin D deficiency can cause rickets (rare in dogs and cats), weight loss and osteomalacia (joint and muscle pains, bone fractures).

Excessive intake of vitamin D can cause lower bone turnover and ossification in dogs resulting in excessive bone mineralisation. In the cat, excess vitamin D can cause mineral deposits in the soft tissues, hypercalcaemia, depression, vomiting and lethargy. Effects are most pronounced in puppies and kittens resulting in bone abnormalities and calcification of soft tissues.

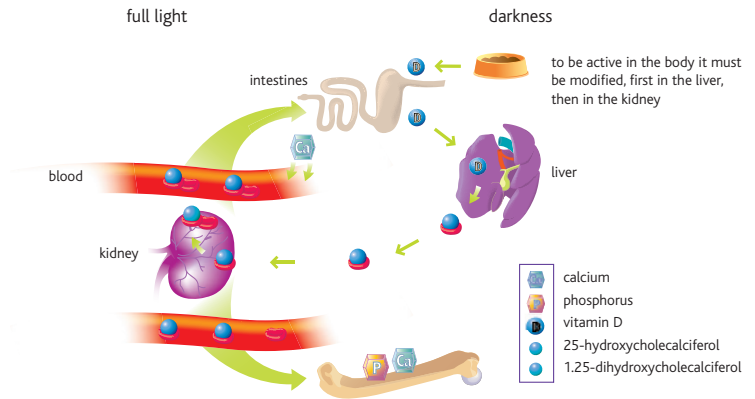


Figure 25. Role of vitamin D in the body



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Vitamin E (alpha tocopherol)

Antioxidant – protection against free radicals



Background

Vitamin E was discovered in 1920 and it was isolated in 1936. It was not until the 1980s that its antioxidant potential was discovered. Vitamin E is a generic term that covers several substances. Alpha tocopherol is the most common form that has the greatest biological activity. Vitamin E is stored in fat tissue, within the liver and muscles. Diets high in polyunsaturated fatty acids require more vitamin E to prevent fatty liver disease.

Role in the body

Vitamin E helps to protect the cell from the action of free radicals. Free radicals are produced by cells through normal metabolism, and consequently contribute to the ageing process. Free radicals are also produced as a result of external factors that affect the body such as exercise, pollution and sunlight. Free radicals can contribute to cell death.

Vitamin E helps to protect the cell membranes from free radical damage and strengthens the immune system.

Common sources

The most important sources of vitamin E are of vegetable origin and include oils, grains and cereals. Vitamin E is also found in some animal products such as liver.

Deficiency and excess

Signs of deficiency in dogs and cats include muscle weakness, reproductive failure, retinal degeneration and discolouration of adipose tissue.

Excess vitamin E in cats has been shown to prolong blood-clotting time. Vitamin E is the least toxic fat-soluble vitamin.

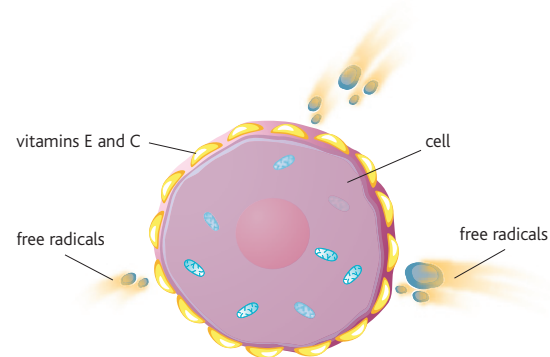


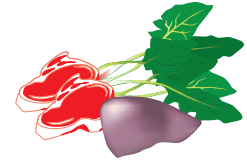
Figure 26. Antioxidant role of vitamin E





Vitamin K (menaquinone-7 – MK-7)

Essential for blood clotting processes



Background

The existence of a dietary factor that prevented haemorrhaging was proven in 1929 and Vitamin K was isolated in 1936. Vitamin K is now known to be a group of several similar fat soluble substances that enable blood clotting through complex biochemical pathways.

Role in the body

The vitamin K group are co-factors for many enzymes, meaning that vitamin K has to be present to enable enzyme activity. As a consequence, it is essential for some blood coagulation processes. It also has a role in protein metabolism and helping calcium incorporation into bone. Vitamin K is usually stored in the liver.

Common sources

The intestinal bacteria of cats and dogs produce vitamin K. However, this process may not provide the full daily requirement in all circumstances, so a dietary source is required. The main sources of vitamin K are liver, meat and vegetables such as spinach.

Deficiency and excess

A vitamin K deficiency can result in digestive, nasal, skin and cerebral haemorrhaging due to inadequate blood clotting processes. In time, these often minor haemorrhages can lead to anaemia (lack of the red cells that transport oxygen in the blood).

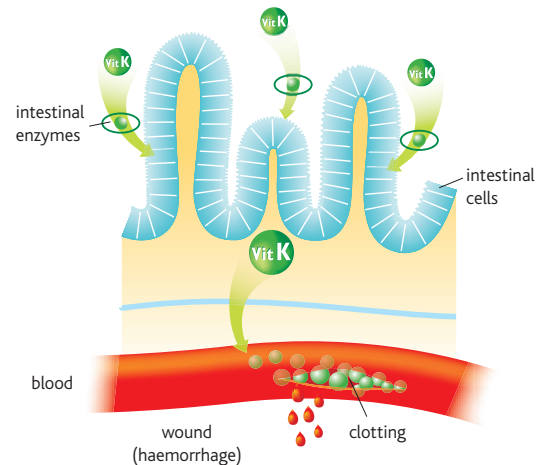


Figure 27. Role of vitamin K in the blood clotting process





Vitamin B1 (thiamin)

Important for nerve function



Background

Thiamin was the first vitamin to be discovered. Beriberi was observed in humans as early as 2600 BC but it was only in 1885 that its nutritional origin was proven and not until 1910 was thiamin deficiency identified as the cause of the disease. This vitamin is soluble in water and concentrated in the heart, the liver, the kidneys and the brain.

Role in the body

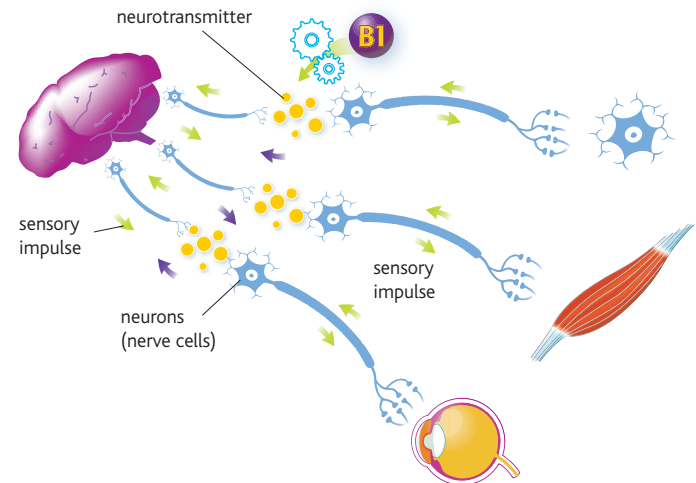
Thiamin is involved in many complex biochemical reactions that help generate energy for the cell. It is essential for healthy functioning of the nervous system, where it assists in transmission of sensory impulses.

Common sources

Yeast and wheat germ have the highest thiamin content, but it is also found in meat, bran and cereals.

Deficiency and excess

Thiamin deficiency can cause beriberi in humans and animals as shown by fatigue, muscle weakness, problems with gait and vision, seizures and ultimately death.



vitamin B1 has a role in the synthesis of acetylcholine, a neurotransmitter

Figure 28. Role of vitamin B1 in nerve function





Other B vitamins

Essential for health



Vitamin B2 (riboflavin)

Riboflavin was discovered in 1937, but its importance for the prevention of a number of diseases was only fully understood in the 1980s. Riboflavin contributes to skin and coat health. A deficiency can produce skin changes around the eyes and the abdomen.

It is very common in nature, being found in yeast, liver and eggs.

Riboflavin is water-soluble and is very sensitive to light.

Vitamin B2, along with vitamin B3, is involved in energy production (Figure 29).

Vitamin B3 (niacin)

Niacin is also known as vitamin PP and nicotinic acid. In humans, it helps prevent pellagra – a serious disease that combines skin, digestive, psychiatric and haematological disorders. In dogs, a deficiency can cause dermatitis around the abdomen and hind legs. Along with other B vitamins, niacin helps protect the skin by promoting the synthesis of skin fats, particularly ceramides, to help limit skin dehydration.

In dogs, some niacin is synthesised from tryptophan, an essential amino acid, but not enough to meet full daily requirements. Cats have a very limited capacity to do this and therefore niacin must be supplied within the diet. Present in most foods, niacin exists in large amounts in meat, fish and cereal.

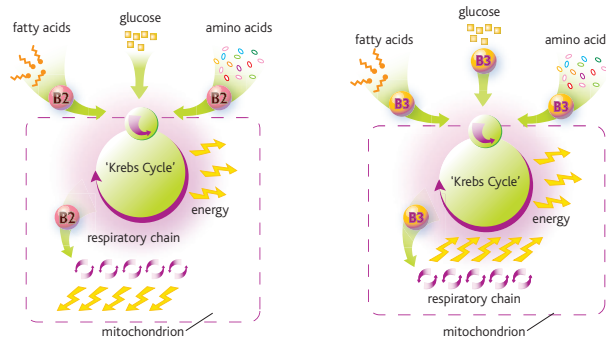


Figure 29. The roles of vitamins B2 and B3 in energy production



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Other B vitamins

Essential for health



Vitamin B5 (pantothenic acid)

Pantothenic acid is very common in food, which means that deficiencies are very rare and symptoms general. The discovery of its key role in the energy production of cells won Fritz Lipmann the 1953 Nobel Prize for chemistry.

As an element in coenzyme A, pantothenic acid is involved in almost every metabolic process. In synergy with other B vitamins (niacin and choline) it helps protect the skin by promoting the synthesis of skin fats.

This vitamin's name comes from the Greek pantos, which means 'found everywhere'. The main sources are meat, tripe and eggs.

Vitamin B6 (pyridoxine)

Pyridoxine was discovered in the mid 20th century and its many roles in the body are still being studied. As a coenzyme it plays multiple roles in different metabolic pathways, especially those of amino acids.

Its sources include yeast, wheat germ and meat.

A pyridoxine deficiency can cause skin, nerve and blood disorders.

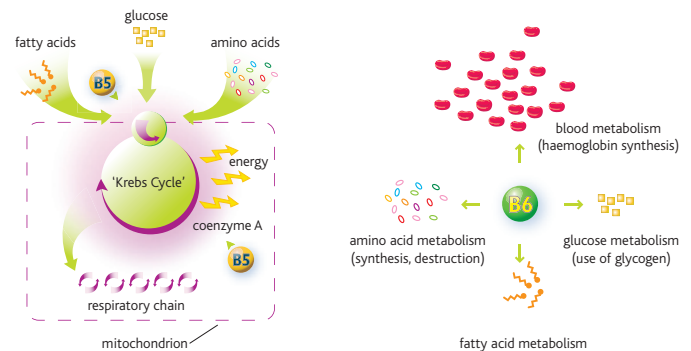


Figure 30. The roles of vitamins B5 and B6 within the body



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Other B vitamins

Essential for health



Vitamin B7 (biotin)

Also known as vitamin H, biotin is one of the most important vitamins for a glossy coat and healthy skin in animals, as well as being directly involved in the healthy functioning of the nervous system.

Discovered at the turn of the last century during research into 'egg white disease' – where eating large quantities of raw egg whites caused skin lesions, hair loss and neuromuscular disorders – biotin was found to be present in yeasts which are inhibited by an antibiotin in the raw egg whites.

In the dog, biotin is produced by intestinal bacteria, meaning dietary sources are only required in the presence of anti-bacterial agents. In cats, a dietary source is required.

Biotin is involved in breaking down glucose, fatty acids and some amino acids, as well as being essential for the synthesis of some other fatty acids. Biotin is also essential for skin and coat health. It is found in large amounts in liver and kidneys.

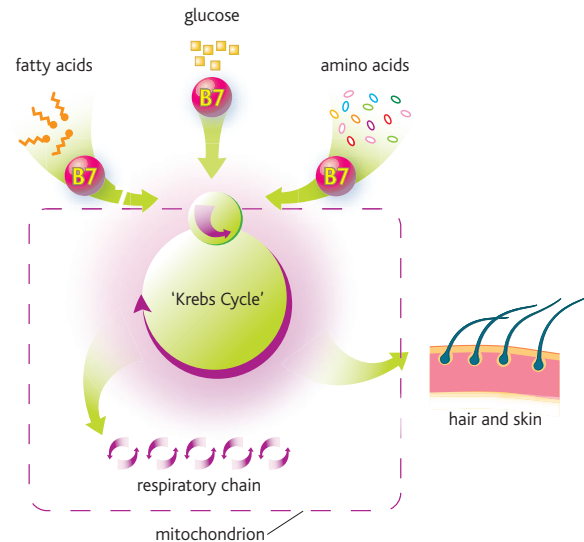


Figure 31. The roles of vitamin B7 in energy production



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Other B vitamins

Essential for health



Vitamin B9 (folic acid)

Folic acid is involved in the development of the tissues of the nervous system. A deficiency can cause malformation (such as spina bifida) in the foetus. Folic acid supplementation in gestating bitches helps reduce the incidence of cleft palate in newborn puppies. Folic acid also helps prevent anaemia.

Stored in the liver, folic acid is essential for fast cell multiplication (e.g. in the foetus) and is involved in the synthesis of essential DNA components. In the dog, some folic acid is produced by intestinal bacteria. However, it is not known whether this is sufficient for daily requirements and therefore a dietary source is required. Cats require a dietary source of folic acid.

Yeast is a good source of folic acid, along with liver, and green vegetables such as spinach.

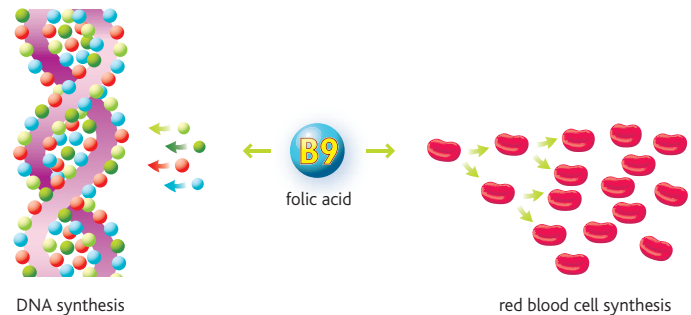


Figure 32. The roles of vitamin B9 in the body



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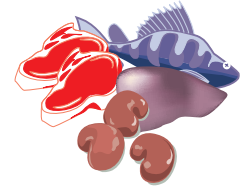


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Other B vitamins

Essential for health



Vitamin B12 (cobalamin)

Cobalamin was isolated in the middle of the 20th century through the anti-anaemic benefits of liver. It is the only vitamin that incorporates a mineral (cobalt) in its composition.

It is a coenzyme in many essential biochemical reactions, and also plays a primary role in the synthesis of proteins and the production of red cells.

Cobalamin is only found in animal products (liver, kidney, heart, lung, fish and meat) and deficiencies, caused through reduced absorption as a consequence of ageing, vegetarian diets, digestive diseases and certain forms of cancer, must be compensated for via the diet.

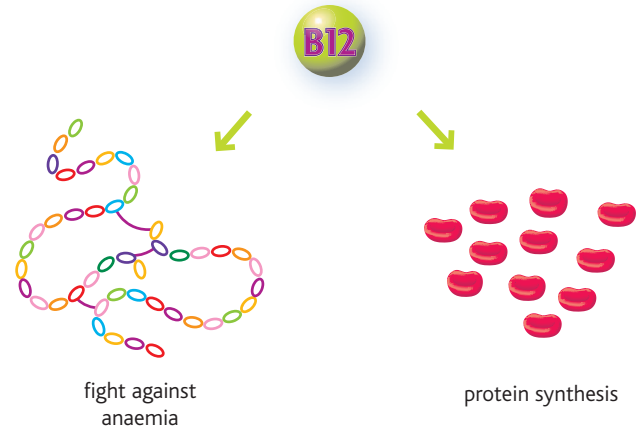


Figure 33. The roles of vitamin B12 in the body



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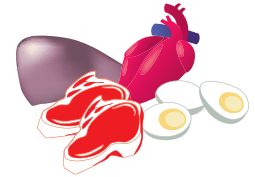


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Choline

Essential for healthy liver function



Background

Choline is not a vitamin in the true sense of the word because all animals are able to synthesise it to some degree. The body is able to synthesise choline in the liver, but production is not always sufficient to cover requirements and it must be added to the diet.

Role in the body

Choline works to build the cell membranes. It also plays a role in protecting the skin from dehydration.

Combined with phosphorus, choline becomes lecithin and forms part of the cell membranes and blood lipoproteins. Choline is also a component of acetylcholine, a very important mediator for nerve transmission.

Common sources

Choline is abundant in meat including liver and heart, eggs and soy.

Deficiency and excess

Choline is required to prevent the pathological accumulation of fatty acids in the liver.

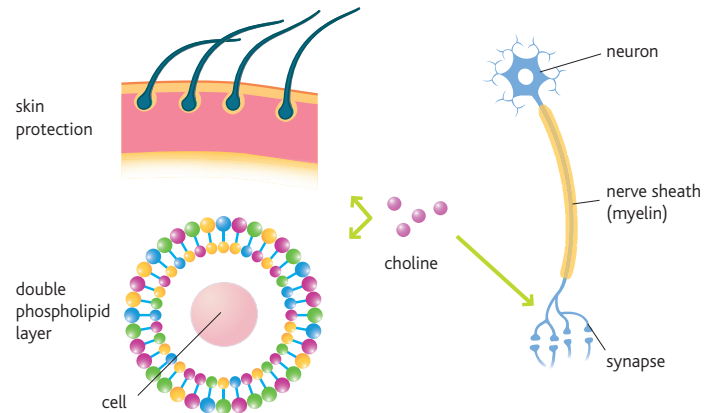


Figure 34. The roles of choline in the body



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Minerals



Minerals are inorganic nutrients within the diet. When a food is analysed for energy all nutrients other than minerals are removed. The remaining material is made up of dietary minerals, and is commonly referred to as "ash".

Those minerals required at relatively high levels within the diet are called macrominerals (Table 3). Microminerals (sometimes referred to as trace elements) are required in far lower amounts, but are as essential for the healthy functioning of the body (Table 4).

Minerals may be present naturally within the ingredients commonly used in prepared pet foods. However, they may also be added as purified salts such as iron sulphate, zinc oxide, manganese oxide, copper sulphate, sodium selenite, calcium iodate. Bioavailability of minerals varies between the salts and this factor must be considered when formulating mineral supplements for use in pet foods.

Each mineral is involved in several different functions, as summarised below.

Table 3. Essential macrominerals – key functions

Calcium	ossification of bones
Phosphorus	energy transfer
Potassium	cellular ion balance
Sodium	cellular ion balance
Magnesium	sensory impulses
Chloride	acid base balance

Table 4. Essential microminerals – key functions

Iron	synthesis of haemoglobin within red blood cells
Zinc	skin and coat health
Manganese	formation of cartilage and skin
Copper	synthesis of skin pigments
Iodine	functioning of the thyroid gland
Selenium	antioxidant





Calcium (Ca)

Vital for healthy bones and teeth



Background

Calcium is the fifth most abundant element in the Earth's crust and in sea water. Calcium intake must be balanced with phosphorus (P) for healthy bone growth and maintenance.

Role in the body

Calcium plays two fundamental roles in the body. Over 90% of calcium found in the body is retained in the bones and teeth where, along with phosphorus, it is responsible for making these structures rigid. Calcium also plays a role in transfer of information between the cells and in the transmission of nerve impulses.

Common sources

Calcium is found in the bones of mammals, birds and fish and is commonly added to pet food as bonemeal. Dairy products also contain significant amounts of calcium. Vegetables such as broccoli and cabbage are moderately good sources. Common mineral salts include calcium carbonate, calcium sulphate and calcium phosphate.

Deficiency and excess

Dietary calcium levels, either below or in excess of required dietary levels, can result in skeletal abnormalities. Lactation and growth require higher dietary levels of calcium than other lifestages. Signs of deficiency include compromised growth, while excess calcium results in bone abnormalities and osteochondrosis.

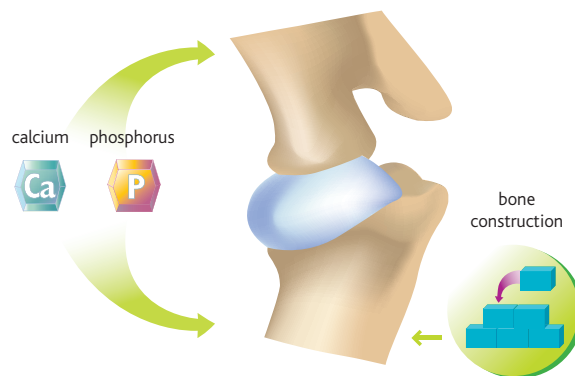


Figure 35. The roles of calcium (Ca) and phosphorus (P) in bone construction





Phosphorus (P)

Bone structure, constituent of cell membranes



Background

The word phosphorus means 'light bearing'. The substance was discovered in 1669 by a German alchemist who released phosphorus in the form of a vapour that glowed in the dark.

Role in the body

Phosphorus has multiple roles, each equally important. A large proportion (over 80%) of phosphorus found in the body is retained in the bones and teeth where, together with calcium, it is responsible for making these structures rigid. It is a constituent of cell membranes and is required for energy production. Phosphorus is a structural component of DNA and RNA, the molecules that carry the cell's genetic code.

Common sources

Phosphorus is found in the bones of mammals, birds and fish and is commonly added to pet food as bonemeal. Meat is also rich in phosphorus.

Deficiency and excess

Phosphorus deficiency can result in slow growth, poor appetite and bone deformities. The maximum amount of phosphorus in a diet is usually governed by the level of calcium and maintenance of the calcium:phosphorus ratio. However, ageing cats may demonstrate sub-clinical renal insufficiency and may be more susceptible to the effects of excess phosphorus.

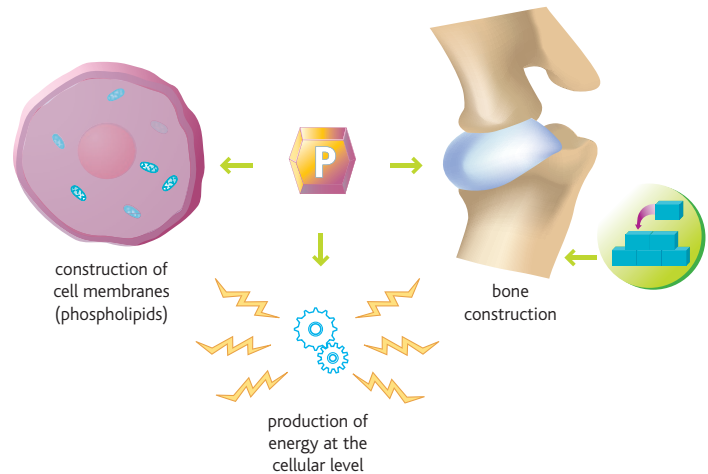


Figure 36. The roles of phosphorus (P) in the body



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Potassium (K)

Cellular function and energy metabolism



Background

Potassium is an alkaline mineral that oxidises rapidly in air and is very reactive with water. This mineral was first isolated from potash (a type of stone), hence its name. It is the eighth most abundant mineral in the body.

Role in the body

Potassium is the most abundant cation (positively charged ion) found inside the cell. It is essential for the correct functioning of the cell, and together with sodium this mineral is responsible for maintaining the acid base balance. Potassium is also responsible for nerve impulse transmission and plays an important role in energy metabolism.

Common sources

Potassium is commonly found in vegetables, meat, fish and eggs. Common mineral salts include potassium bicarbonate, potassium chloride and potassium sulphate.

Deficiency and excess

Although potassium deficiency is rare, restlessness and muscle paralysis have been reported in potassium-deficient puppies. Diarrhoea can cause significant potassium losses resulting in deficiency if the condition persists. Potassium upper limits should be reduced in diets designed for cats and dogs with heart or renal failure. Urinary acidification can result in increased potassium loss, which should be compensated for in the diet.

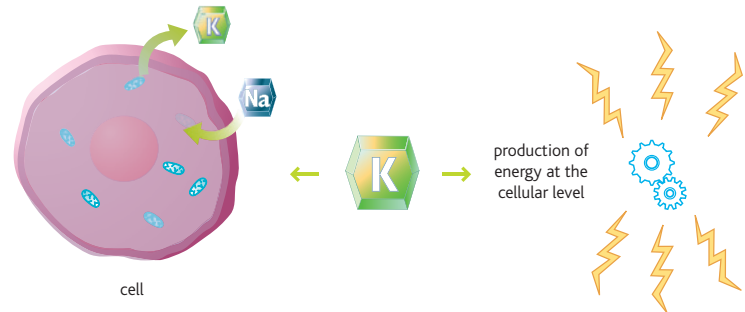


Figure 37. The roles of potassium (K) in the body



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Sodium (Na)

Cell equilibrium, regulation of thirst and urine output



Background

Sodium is a soft silvery white highly reactive mineral, first isolated by Sir Humphrey Davy in 1807.

Role in the body

This mineral is essential for healthy functioning of cells. Together with potassium it maintains acid base balance and is also responsible for maintaining pressure between the inside and outside of the cell. It also plays a major role in cellular energy metabolism and is involved in nerve impulse generation and transmission.

Sodium is also important for regulation of water balance, the sensation of thirst and urinary concentration.

Common sources

Sodium usually occurs naturally in the form of sodium chloride (table salt). Vegetables are usually low in sodium, while unprocessed meats are around three times higher. Other common mineral salts include sodium phosphate and sodium carbonate, sodium bicarbonate and sodium tripolyphosphate (STPP).

Deficiency and excess

Sodium deficiency is rare in cats and dogs. Symptoms include restlessness, increased heart rate, reduced water consumption and increased urine output. Very high levels of sodium intake have been shown to cause vomiting and dry mucous membranes.

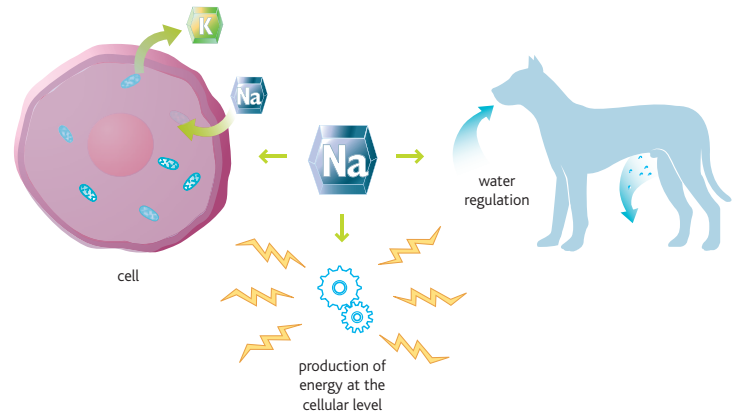


Figure 38. The roles of sodium (Na) in the body



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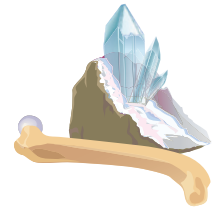


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Magnesium (Mg)

Healthy bone structure, functioning of the nervous system



Background

Magnesium constitutes around 2% of the Earth's crust, making it the eighth most abundant element. The free element metal is not found naturally as it is highly reactive. It is the second most abundant intracellular cation and is involved in more than 300 metabolic processes.

Role in the body

Magnesium plays a role in energy metabolism, DNA and RNA metabolism, protein synthesis, muscle and nerve cell membrane function. Magnesium is also, like calcium and phosphorus, an important constituent of bones and teeth.

Common sources

Magnesium is found in the bones of mammals, birds and fish and is commonly added to pet food as bonemeal.

Deficiency and excess

Magnesium deficiency can result in the appearance of nervous problems including hyperextension of the joints, paralysis, hypertension and loss of appetite. Excess dietary magnesium has been linked with struvite bladder stone formation in cats.

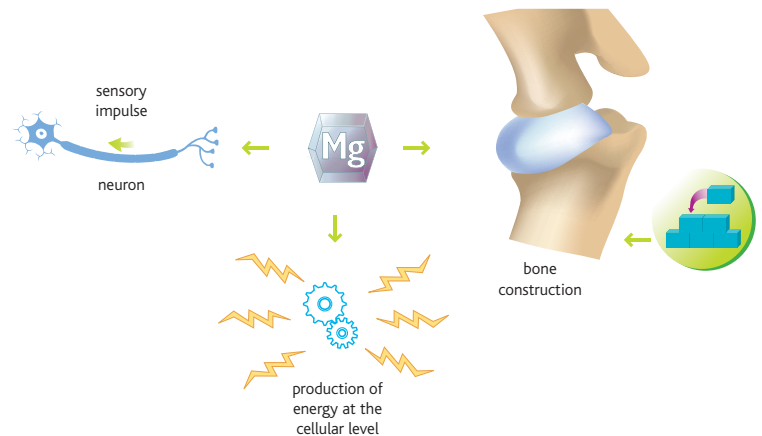


Figure 39. The roles of magnesium (Mg) in the body





Chloride (Cl)

Acid base balance



Background

Chloride is the most prevalent negatively charged ion in the extracellular fluid of animals.

Role in the body

Chloride is important in maintaining the concentration of extracellular fluid and plays a role in acid base balance.

Common sources

Chloride is found in limited concentrations in most foods. Therefore, diets must be supplemented with chloride-containing salts e.g. sodium chloride (salt)

Deficiency and excess

Signs of deficiency include weakness, failure to grow and symptoms of potassium deficiency.

Excess chloride can result in altered calcium and potassium levels in the blood and metabolic acidosis.

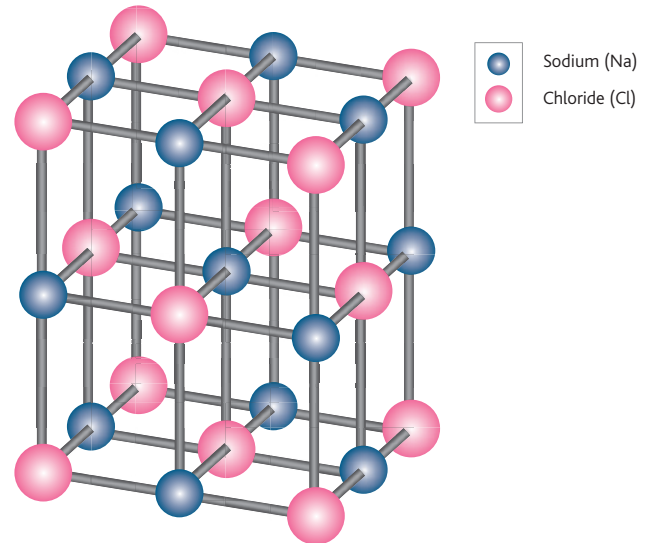


Figure 40. The structure of sodium chloride



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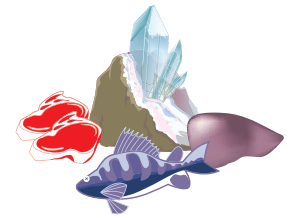


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Iron (Fe)

Oxygen transport



Background

Iron is the most prevalent trace element in the body comprising about 0.005% of total weight.

Role in the body

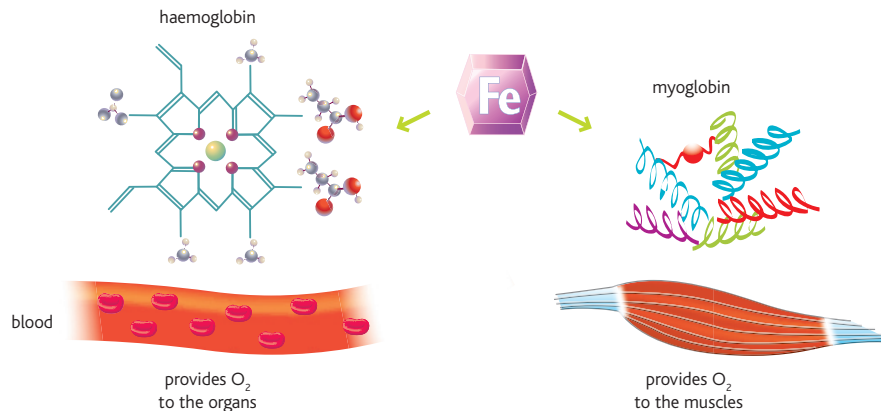
Iron is a vital component of haemoglobin, the molecule that transports oxygen around the body in red blood cells, and of myoglobin, which does the same job in muscle. Iron also has many enzymatic functions, especially with respect to cellular respiration.

Common sources

Liver, meat, fish, and green vegetables such as broccoli and spinach are rich natural sources of iron. Carbonate and oxide sources of iron are poorly available forms of this mineral.

Deficiency and excess

Iron deficiency can result in poor growth, pale mucous membranes, diarrhoea and anaemia. High levels of iron can cause marginal deficiencies in manganese, copper and zinc. Very high levels of iron can result in vomiting and diarrhoea.



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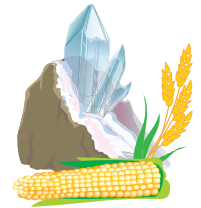


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Zinc (Zn)

Skin and coat health, reproductive function



Background

Zinc is a transition metal found throughout the body. It is present in most tissues in relatively low concentrations.

Role in the body

Zinc is the co-factor for around 200 zinc-containing enzymes involved in cell replication, carbohydrate and protein metabolism, and membrane structure. It is essential for the transport of vitamin A in the blood and plays an important role in reproduction. It is also crucial for collagen and keratin synthesis and is therefore a fundamental element involved in skin and coat health, and wound healing.

Common sources

Whole grain cereals and meat are rich natural sources of zinc. Zinc can also be found in mineral salts such as zinc sulphate and zinc oxide.

Deficiency and excess

Zinc deficiency can result in poor growth and skin lesions on areas of wear such as foot pads. Excess zinc can also cause seizures in cats. If the zinc level in the diet is high the copper and iron levels should be increased above minimum requirements to avoid marginal deficiencies due to competing absorption sites within the body.

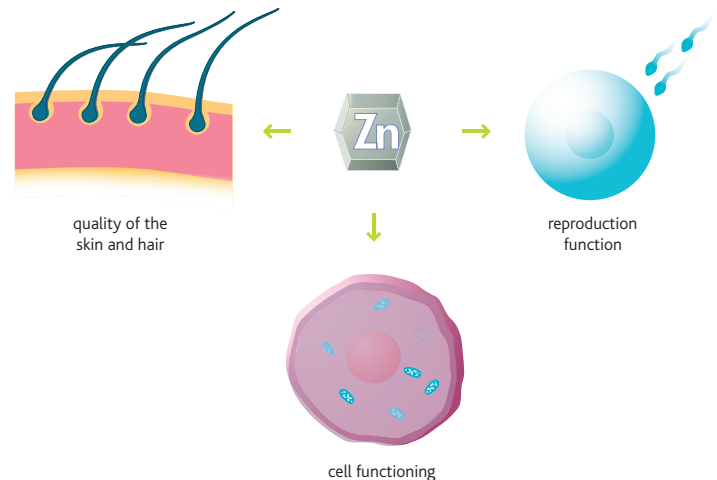


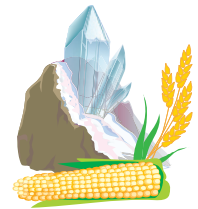
Figure 42. The roles of zinc (Zn) in the body





Manganese (Mn)

Bones and cartilage



Background

Manganese occurs in small amounts within animal tissues. An adult dog may have a total body content of only 3-15mg manganese.

Role in the body

Manganese plays an active role in the correct functioning of the mitochondria, and is important for the formation of bone and joint cartilage and neurological function. Manganese also plays a structural role in many enzymes.

Common sources

Cereals and mineral salts are good sources of manganese. Meat does contain manganese but in lower amounts than other sources.

Deficiency and excess

A deficiency of manganese can result in shortening and bowing of the front legs during growth. In adult dogs lameness, enlarged joints and poor locomotion have also been reported. Manganese deficiency can also have profound effects during reproduction including delayed oestrus, poor conception rates, still births and low birth rates. Prolonged manganese excess can result in iron deficiency.

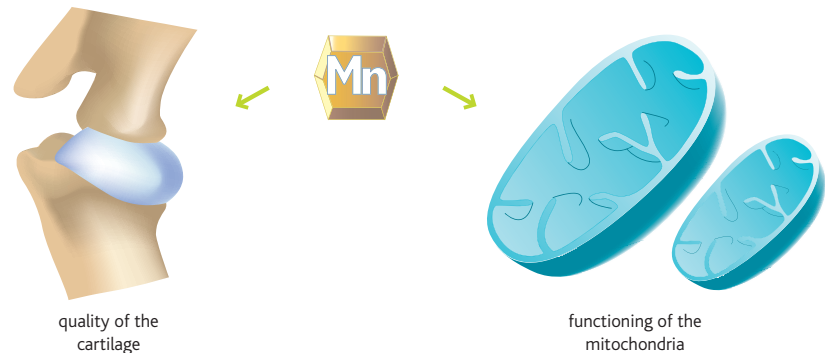


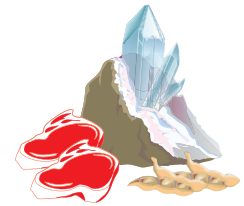
Figure 43. The roles of manganese (Mn) in the body





Copper (Cu)

Prevention and treatment of anaemia, hair pigmentation



Background

The bodies of dogs and cats contain a very small amount of copper. In 1984, Meyer reported a total body content of copper to be 7.3 mg per kg body weight in young dogs.

Role in the body

Copper facilitates the intestinal absorption of iron and its incorporation into haemoglobin. It is an active element in many enzymes. Copper plays an important role in reducing cellular damage caused by free radicals. Copper is also involved in the synthesis of collagen in the tendons and the myelin within the nervous system. Copper also participates in the synthesis of melanin, which is a hair pigment.

Common sources

Foods that have a high copper content include meat (lamb, pork, duck) and protein rich grains (peas, lentils, soy). Copper may also be added to pet food in the form of mineral salts, however copper oxide is a poorly available form of this mineral.

Deficiency and excess

Copper deficiency can result in anaemia, loss of hair pigmentation and hyperextension of the lower limb. Copper is stored in the liver and although toxicity is rare, certain breeds are pre-disposed to copper storage disease e.g. Bedlington terriers.

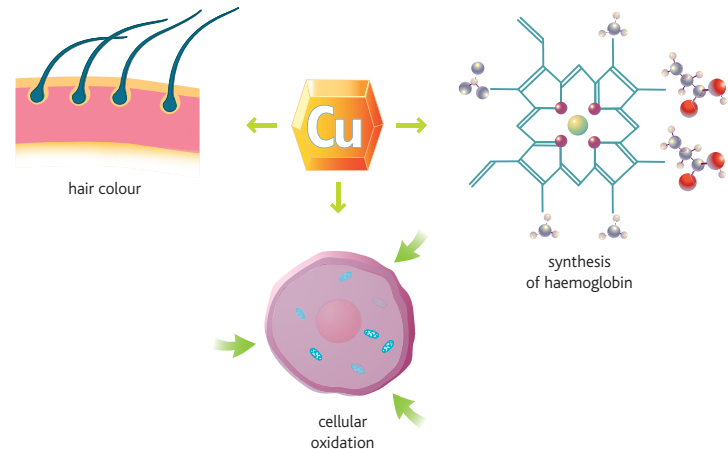


Figure 44. The roles of copper (Cu) in the body



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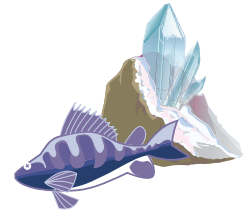


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Iodine (I)

Synthesis of thyroid hormones



Background

Iodine is by far the heaviest mineral that is essential for cats and dogs.

Role in the body

Iodine is required in very small amounts. It is an essential constituent of the thyroid hormone which is important for growth, development and the regulation of metabolic rate.

Common sources

Sea salt, seaweed flour and fish are common sources of iodine.

Deficiency and excess

Signs of deficiency include goitre, hair loss, dry coat and weight gain due to altered thyroid gland activity. In cats, excess iodine has been shown to decrease thyroxine levels leading to similar symptoms to those seen in deficiency.

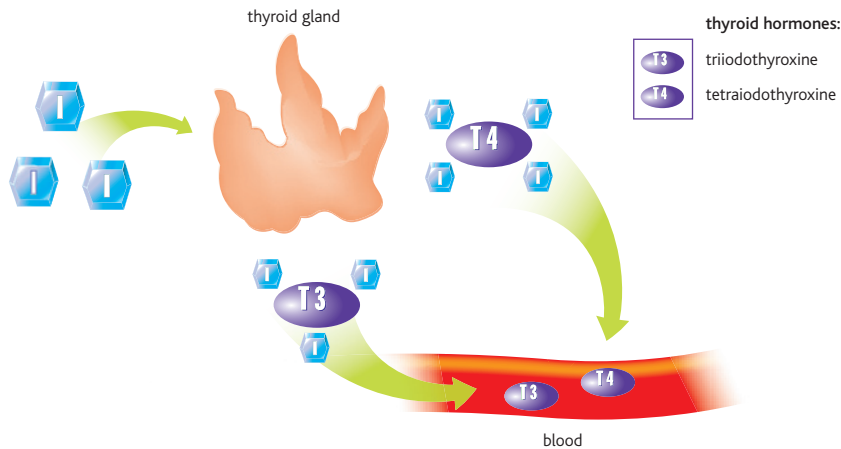


Figure 45. The roles of iodine (I) in the body



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Selenium (Se)

Reduction in cellular damage, immune response



Background

Selenium is an essential micromineral, first classified in 1817. It is widely distributed in animal tissues, yet is present in only very small amounts in any given organ or tissue.

Role in the body

Selenium plays a vital role in reducing cellular damage caused by free radicals. Selenium also plays a support role in immune response.

Common sources

Selenium is found in inorganic mineral salts and fish. Low quantities can be found in meat, liver and kidneys.

Deficiency and excess

Selenium deficiency can result in refusal to eat, depression, difficulty breathing and coma. Selenium excess can occur in diets containing high levels of fish. Symptoms include refusal to eat and poor bodyweight gain.

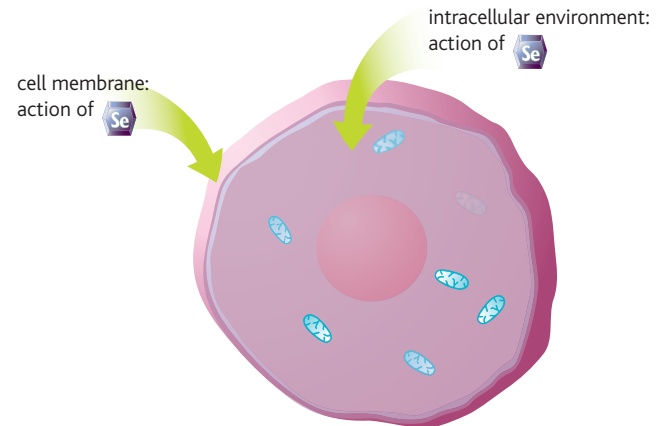


Figure 46. The antioxidant role of selenium (Se)



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The benefits of manufactured pet foods

As has been shown in the content of this book, essential nutrition is a complex subject. Although they do share some common traits, there are many notable physiological differences between dogs, cats and humans. These differences mean that their dietary requirements are different. Most of the differences are due to the unique and specialised adaptations of cats and dogs.

One way to ensure that all essential nutrient requirements are met is to feed a manufactured diet. Wet, dry and semi-moist diets are all carefully designed to provide the right nutrients in the right amounts according to lifestage, be that puppy, kitten, adult or senior. Decades of scientific research and expertise are incorporated into most reputable brands of manufactured pet food offering owners a reliable and consistent product of guaranteed quality and a high level of safety.

Many cats and dogs around the world are still fed home prepared diets made up from human foods and table scraps. Diets that are suitable for humans rarely deliver enough nutrients for dogs or cats without excessive overfeeding. It is very hard to make a complete and balanced pet food at home. Most home prepared diets are incomplete and may impair the health and vitality of pets. They have been linked to increased risk of obesity and other health issues.

Home prepared raw food diets may have the additional risk, both to pets and owners, of being contaminated with parasites and bacteria. Some common human food ingredients can be toxic to cats and dogs, examples of these include chocolate, grapes, raisins and onions.

Table 5: Difference in nutrient composition of home prepared and manufactured pet food

Home prepared food	Dogs need	Cats need
3 parts rice 2 parts chicken breast 1 part cooked vegetables	1.5 x more zinc 36 x more vitamin E 10 x more vitamin B	12 x more vitamin E
2 parts rice 1 part steamed fish	2 x more fat 3 x more zinc 11 x more vitamin E 2 x more vitamin B12	2 x more fat 2 x more zinc 2 x more vitamin E 2 x more vitamin B12



Healthy weight maintenance

Up to a third of dogs and half of the cat population are reported to be overweight. The health risks associated with excessive weight include joint problems, cancers, respiratory dysfunction, osteoarthritis, diabetes and cataracts. The overriding factor contributing to obesity is overfeeding.

In order to keep pets at a healthy bodyweight it is important that owners follow the recommended feeding guide for their pet's lifestage and lifestyle, making minor adjustments according to the individual pet.

Recognising and acknowledging that their pets are overweight is often a barrier for owners. The WALTHAM® S.H.A.P.E™ (Size, Health And Physical Evaluation) guide is an easy to use, scientifically accurate, flow diagram based system, validated for use by untrained owners, that allows body condition scoring of the pet. The guide also provides useful advice based on the outcome of the scoring.

Risk factors

The main reason for the development of obesity is an energy intake in excess of energy expenditure. A number of factors may be involved in reaching this state:

Genetics: some breeds of dog appear to be more susceptible to weight gain

Age: middle age (halfway through expected lifespan for dog size) is a risk factor

Neutering: typically leads to decreased activity and therefore weight gain

Gender: in some dog studies, females appeared to be more at risk than males

Lifestyle: indoor lifestyle is a risk factor

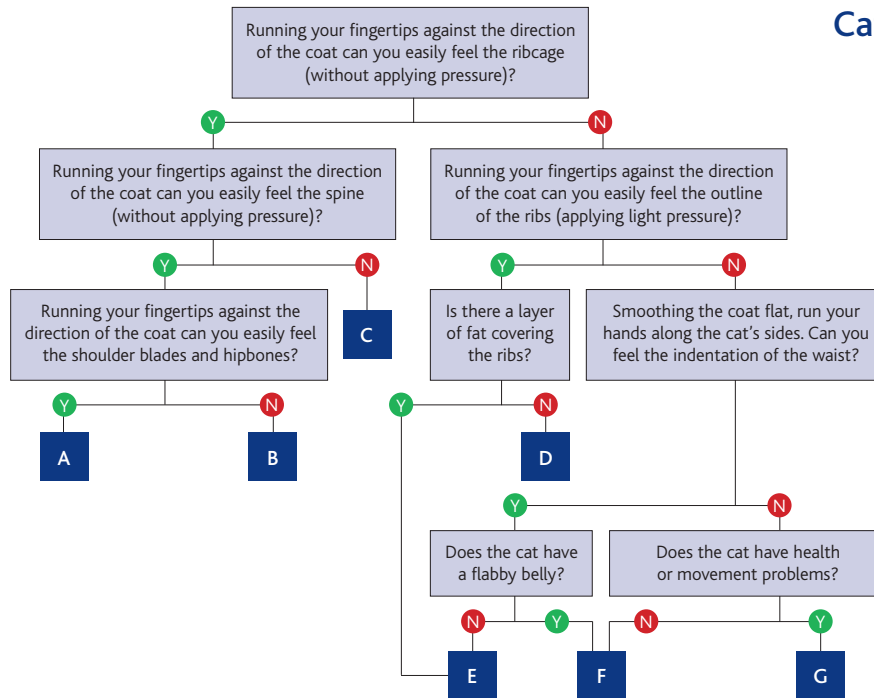
Owner factors: overweight owners associated with overweight pets

Pet-owner relationship: more intense in owners of obese cats



Healthy weight maintenance

Cat S.H.A.P.E.™ guide



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Healthy weight maintenance

Cat S.H.A.P.E.™ guide

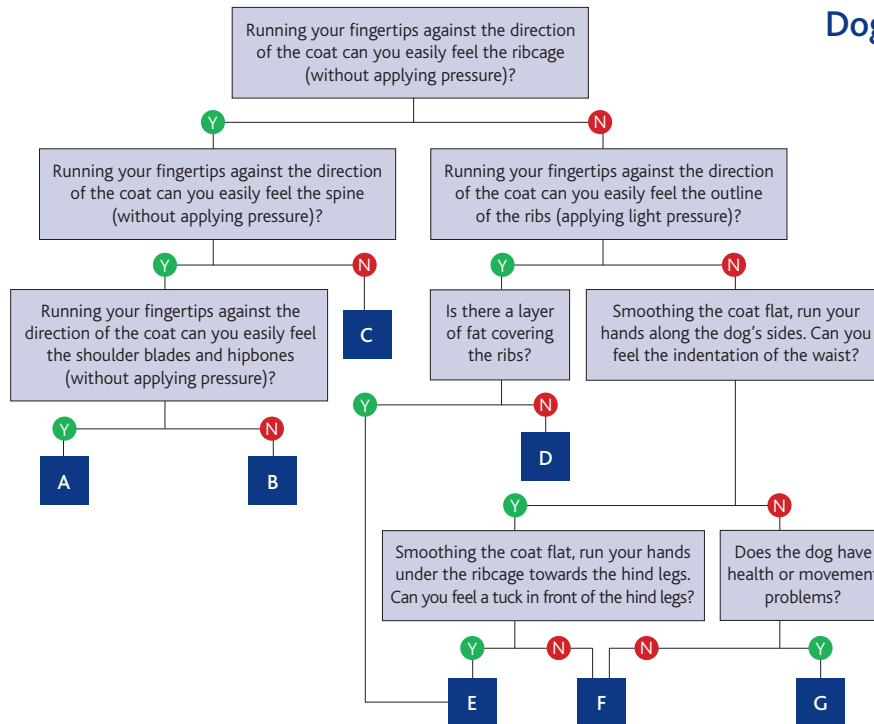
S.H.A.P.E.™ Score	Description
A	Extremely thin – your cat has a very small amount or no total body fat. Recommendation: seek veterinary advice promptly.
B	Thin – your cat has only a small amount of total body fat. Recommendation: seek veterinary advice to ensure your cat is being offered the appropriate amount of food. Reassess using the S.H.A.P.E.™ chart every 2 weeks.
C	Lean – your cat is at the low end of the ideal range with less than normal body fat. Recommendation: increase food offered by a small amount. Monitor monthly using the S.H.A.P.E.™ chart and seek veterinary advice if no change.
D	Ideal – your cat has an ideal amount of total body fat. Recommendation: monitor monthly to ensure your cat remains in this category and have him/her checked by the veterinarian at your next visit.
E	Mildly overweight – your cat is at the upper end of the ideal range with a small amount of excess body fat. Recommendation: seek veterinary advice to ensure your cat is being offered the appropriate amount of food and try to increase activity levels. Avoid excessive treats and monitor monthly using the S.H.A.P.E.™ chart.
F	Moderately overweight – your cat has an excess of total body fat. Recommendation: seek veterinary advice to implement safely an appropriate weight loss plan including increasing activity levels. Reassess using the S.H.A.P.E.™ chart every 2 weeks.
G	Severely overweight – your cat has a large amount of excess total body fat that is affecting its health and well being. Recommendation: seek veterinary advice promptly to introduce a weight loss plan to reduce your cat's weight, increase activity levels and improve overall health.

NB: Some breeds and different life-stages may have different ideal S.H.A.P.E.™ scores. Consult your veterinarian if you are unsure.



Healthy weight maintenance

Dog S.H.A.P.E.™ guide



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Healthy weight maintenance

S.H.A.P.E. TM Score	Description
A	Extremely thin – your dog has a very small amount or no total body fat. Recommendation: seek veterinary advice promptly.
B	Thin – your dog has only a small amount of total body fat. Recommendation: seek veterinary advice to ensure your dog is being offered the appropriate amount of food. Reassess using the S.H.A.P.E. TM chart every 2 weeks.
C	Lean – your dog is at the low end of the ideal range with less than normal body fat. Recommendation: increase food offered by a small amount. Monitor monthly using the S.H.A.P.E. TM chart and seek veterinary advice if no change.
D	Ideal – your dog has an ideal amount of total body fat. Recommendation: monitor monthly to ensure your dog remains in this category and have him/her checked by the veterinarian at your next visit.
E	Mildly overweight – your dog is at the upper end of the ideal range with a small amount of excess body fat. Recommendation: seek veterinary advice to ensure your dog is being offered the appropriate amount of food and consider increasing activity levels. Avoid excessive treats and monitor monthly using the S.H.A.P.E. TM chart.
F	Moderately overweight – your dog has an excess of total body fat. Recommendation: seek veterinary advice to implement safely an appropriate weight loss plan including increasing activity levels. Reassess using the S.H.A.P.E. TM chart every 2 weeks.
G	Severely overweight – your dog has a large amount of excess total body fat that is affecting its health and well being. Recommendation: seek veterinary advice promptly to introduce a weight loss plan to reduce your dog's weight, increase activity levels and improve health.

NB: Some breeds and different life-stages may have different ideal S.H.A.P.E.TM scores. Consult your veterinarian if you are unsure.

Dog S.H.A.P.E.TM guide



Dominique Grandjean (DVM, PhD, HDR) is a Professor at the National Veterinary School of Alfort (France), where he works as head of the canine breeding and sport medicine unit. As a faculty member in Alfort he has over the last 25 years focused most of his work on dog nutrition. He is also a colonel veterinarian for the Paris Fire Brigade (military unit defending Paris and suburbs), in charge, among other tasks, of the canine search and rescue teams. Dominique is also national and regional technical advisor of the civilian security for cyrotechnics and biological hazards.

As a researcher his work focuses on the consequences of stress in the sporting/working dog, with a deep involvement in sled dog long distance races since 1980, and in search and rescue dogs since 1990. His unit (Unité de Médecine de l'Élevage et du Sport – UMES) also includes a physiotherapy service and a dedicated sub-unit for canine collectivities veterinary problems. Dominique has published more than 100 scientific papers on working dog physiology, nutrition and medicine, and a total of 26 books all related to this area.

Dr. Richard Butterwick is Head of Nutrition at the WALTHAM® Centre for Pet Nutrition. After graduating from the Department of Agricultural Biochemistry and Nutrition, Newcastle University, UK in 1985 Richard was awarded a PhD in 1989. Richard then spent a short sabbatical lecturing pre-clinical studies at the Samora Machel Veterinary School, Lusaka, Zambia, before joining the Department of Paediatric Endocrinology at Saint Bartholomew's Hospital, London where he was part of a clinical research team working on growth disorders in children. In 1991 Richard went on to join the WALTHAM® Centre for Pet Nutrition where he worked on the research and development of veterinary clinical diets, with emphasis on the management of obesity, gastrointestinal disease, neonatal and post-operative nutritional support.

Since then he has led a number of research programmes, covering a broad spectrum of nutritional areas in dogs and cats, including energy requirements and obesity, digestive function and health, growth and development, and oral health. Richard has published widely in the field of dog and cat nutrition and is a member of a number of professional bodies.



The last 50 years have been witness to unprecedented advances in the knowledge of cat and dog nutritional requirements. We all know that good nutrition is essential for a healthy life, but it is not always easy to find out what those essential nutrients are and why they are essential for health.

This book reviews each essential nutrient required by cats and dogs and helps to define what is meant by a complete and balanced diet.

Comprehensively illustrated nutrient information sheets provide all the information you need to help you understand the value of every essential nutrient, and how these are supplied through commonly used pet food ingredients.

Edited by:
Prof. Dominique Grandjean & Dr. Richard Butterwick

Written by:
Prof. Dominique Grandjean
Dr. Ralph Merrill
Dr. Catherine Buckley
Dr. Penny Morris
Mr. Chris Charlton
Dr. Abigail Stevenson

Contact:
Dr. Ralph Merrill, WALTHAM® Centre for Pet Nutrition,
Waltham-on-the-Wolds, Leicestershire LE14 4RT

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