RAW CONSULTANT

Nutritional training package

Natures Menu

Natures Menu: Veterinary Division

1. Principles of Nutrition

Introduction

Within practice, we all understand that not every dog and cat can be fed the same diet. Many pets are sensitive to texture, temperature, taste and even the appearance of their food and some are more difficult to please than others! More and more, clients are beginning to understand that what they put into their pets reflects what they see on the outside with regards to overall health, vitality, energy (whether in excess or sometimes, not enough) and behavioural tendencies. However, bearing this in mind, some clients are also very aware of the price they pay for their pets' food, ease of use and nutritional balance. Traditionally, most practices have marketed dry biscuit complete foods and some tinned, tray and pouch varieties have also been available. But with an increasing understanding by clients regarding what they are feeding their pets and pet food 'exposé documentaries' hitting our TV screens more regularly, raw food is finding a significant place within the pet food market and is ever growing in popularity.

We all know that dogs and cats need to eat to survive, but what exactly is it they truly require? How does the body use the nutrients we are feeding them every day and are all of them needed? What proportions do animals require of each nutrient and what happens if the requirement is not fulfilled? This section aims to provide the learner with a comprehensive understanding of the principles of nutrition and to explain the various nutritional requirements of dogs and cats.

"Food" should contain the following:

- Materials for growth
- Energy materials that the body can use for heat and other forms of energy
- Substances which can facilitate, initiate or regulate either or both of the above

Components that contain the above are referred to as nutrients. Any nutrients which are required by the animal and cannot be synthesised within the body are called essential nutrients and must be contained within the diet. If any essential nutrient is missing, then a diet must be deemed inadequate or unbalanced. Cats and dogs require about 40 essential nutrients, each in the correct form and amount.

Macronutrients

These provide the bulk energy for an organism's metabolic system to function and are consumed in the largest quantity.

Macronutrients are:

- Proteins
- Carbohydrates
- Fats
- Water

In the following section, we will look at each macronutrient individually.

Proteins

Proteins are made up of long chains of amino acids which are linked together by peptide bonds. A peptide is a covalent chemical bond between two atoms that can be broken down by hydrolysis (the addition of water) to release energy measured in kilojoules. There are approximately 20 amino acids and these can be arranged in various combinations to give an almost infinite number of naturally occurring proteins. Amino acids are classified as essential (indispensable) or non-essential (dispensable). Essential amino acids cannot be synthesised and must be provided in the animal's diet *(see Table 1.)*, whereas non-essential amino acids can be synthesised from excesses of other dietary amino acids or dietary nitrogen.

Proteins are essential components of all living cells and have several important roles including:

→ Regulation of metabolism – as an enzyme form and some hormones
→ Structural role in cell walls and muscle fibres
→ Important in growth and repair
→ Source of energy

Proteins are metabolised daily and are needed to replace epithelial cell losses such as skin, hair and body tissues. An increase in protein metabolism will be present during several times in an animal's life stage, such as periods of growth, pregnancy, lactation and recovery from illness and substantial losses can occur in cases of severe burns or scalds to the animal's skin (serum loss/ooze).

Because proteins are essential to all living organisms, in dietary terms they are found in both plant and animal (meat) sources. Animal proteins however, have a more balanced amino acid profile, meaning

they have a greater proportion of essential amino acids and a better digestibility than plant proteins – which results in a greater biological value. This means that there is a higher proportion of the food protein that can be utilised for synthesising body tissues and compounds and less will be excreted in the urine and faeces. Good quality animal proteins have a higher biological value than plant based proteins.

Protein deficiencies can be the result of either insufficient dietary protein provision or the shortage of a particular amino acid. Either of these deficiencies can result in a number of symptoms including;

- Poor growth
- Weight loss
- Poor coat
- Anorexia
- Increase susceptibility to disease
- Muscle wastage
- Emaciation
- Oedema
- Death

With a deficiency of a single amino acid this can result in anorexia and a negative nitrogen balance (blood urea nitrogen/BUN).

Cats differ to dogs in that they have a higher maintenance protein requirement than many other mammals. They are highly sensitive to arginine deficient diets and require taurine as a dietary requirement as they are unable to synthesise it themselves, unlike dogs who require a lesser amount and are able to synthesise enough to suffice. A taurine deficiency can have severe implications on the health and development of cats, such as:

> Feline central retinal degeneration
> Dilated cardiomyopathy
> Reproductive failure in queens
> Impaired immune function
> Developmental abnormalities in kittens

Amino Acid	Essential?		Role	Common sources	Deficiency symptoms
	Dog	Cat			
Arginine	✓	✓	Ammonia excretion, blood vessel relaxation and hormone release	Animal proteins and gelatine	Signs of ammonia intoxication and cataracts. Often more severe in cats
Histidine	✓	✓	Precursor for neurological compounds such as histamine	Animals proteins and blood	Weight loss and refusal to eat, and cataracts in cats
Isoleucine	✓	✓	Stimulate protein synthesis and slow breakdown in muscle. Increases lean mass and helps prevent muscle wasting but effectiveness diminishes with age	Animal protein muscle meats, including beef, lamb and poultry	Rough coat, paw lesions and uncoordinated gait. Weight loss and lethargy
Leucine	✓	✓	Stimulate protein synthesis and slow breakdown in muscle. Increases lean mass and helps prevent muscle wasting but effectiveness diminishes with age	Animal protein muscle meats, including beef, lamb and poultry	Weight loss and lethargy
Lysine	✓	✓	Used in all protein synthesis for growth and repair. Very heat sensitive.	Animal proteins, especially muscle	Reduced food intake and weight loss. Excess lysine in puppies can cause signs of arginine deficiency
Methionine	✓	✓	Synthesis of the hair and skin protein, keratin. Accounts for up to 30% of adult dog's daily protein requirement	Fish, egg, wheat and maize	Dry, brittle, slow growing hair or hair loss
Cysteine	x	x	Technically non-essential as can be synthesised from methionine but if present in sufficient quantities will free up methionine for other functions.		
Phenylalanine	✓	✓	Thyroid and adrenal gland function, vital for tyrosine synthesis which is needed for pigmentation of hair and the iris	Most animal proteins: beef, pork, poultry and fish	Dogs: weight loss, reduced food intake and reddening of black coats. Cats: neurological dysfunction, unco-ordinated gait and hyperactivity

Tyrosine	x	x	Technically non-essential as can be synthesised from phenylalanine but if present in sufficient quantities will free up phenylalanine for other functions.		
Threonine	✓	✓	Precursor for metabolically active molecules such as pyruvate	Animal proteins: poultry, fish, lamb, pork and beef	Weight loss and refusal to eat, and nervous system problems in cats.
Tryptophan	✓	✓	Precursor of important metabolic molecules such as serotonin, melatonin and niacin	Poultry, fish and soy	Weight loss and refusal to eat
Valine	✓	✓	Stimulate protein synthesis and slow breakdown in muscle. Increases lean mass and helps prevent muscle wasting but effectiveness diminishes with age	Animal protein muscle meats, including beef, lamb and poultry	Weight loss and lethargy
Taurine	x	✓	Enables liver to synthesise bile salts and regulates calcium flow into and out of cells. Antioxidant and precursor for complex fats. Required for healthy reproduction, heart function, eyesight and hearing.	Animal proteins, especially organs such as heart, kidney and liver.	Feline central retinal degeneration (FCRD) and blindness, poor growth and reproduction and cardiac problems.

Table 1: Essential amino acids for dogs and cat

Although protein is an essential nutrient to both dogs and cats, a balance must be strictly implemented within a diet as excess protein can be converted to fat and stored as adipose tissue, eventually leading to obesity. In the past, there has also been anecdotal evidence suggesting that a diet too high in protein can have a severe effect on behaviour leading to hyperactivity and sometimes, aggressiveness. However, this has now been dispelled as a myth and feeding a good quality, high protein diet does not have any detrimental effects on behaviour.

Carbohydrates

Carbohydrates provide energy to the animal and consist of simple sugars (glucose) and complex sugars, such as starch, which are chains of the simple sugars. All animals have a metabolic requirement for glucose and providing the animal has enough precursors (amino acid and glycerol from proteins and fats) within their diet, they're able to synthesise enough without the need for any dietary carbohydrate.

Sugars and cooked starches are easily digestible and can provide an additional source of energy for the active animal. Dogs tend to like the taste of sugar whereas cats do not, hence why some brands of dog food contain added sugars to increase palatability. Many owners are not concerned with the nutritional contents of the food if the dog appears to enjoy eating it however, we must remember that those same people may eat from a fast food restaurant, knowing that its nutritional value is incredibly low but will only do this on occasion rather than every day.

Most carbohydrates are of vegetable origin, with the exception of glucose in the blood, glycogen in muscles and liver, and milk lactose. The value of disaccharides such as sucrose or lactose, is limited due to the activity of disaccharidases (sucrase and lactase) in the digestive tract. When an animal grows older, there is a natural decline in the production of the digestive enzyme lactase which can lead to diarrhoea if excessive consumption of lactose-containing products (dairy) is consumed. It is also important to ensure carbohydrates are fed in moderation as an excess can be converted to body fat, eventually leading to obesity. It is possible to estimate the carbohydrate content of pet foods using the nutritional analysis declared on pack. We call this the nitrogen-free extract (NFE) which is equal to 100-protein%-fat%-ash%-fibre%-moisture%.

Carbohydrates can be classified in a number of different ways. Figure 1 shows them divided by structure, whereas the following table differentiates them based on the way the body digests them:

Carbohydrate	Method of digestion	Example
Absorbable	Immediately useable by the body	Glucose
Digestible	Predominant form being of plant origin. Broken down by enzymes into absorbable carbohydrates	Starch
Fermentable	Utilised by bacteria in the gut and may be broken down into a usable form. Classed as prebiotics if specifically used by beneficial gut bacteria.	Pectin
Non-fermentable	Commonly known as fibre, passes through the body undigested and adds bulk to the bowel contents.	Lignin

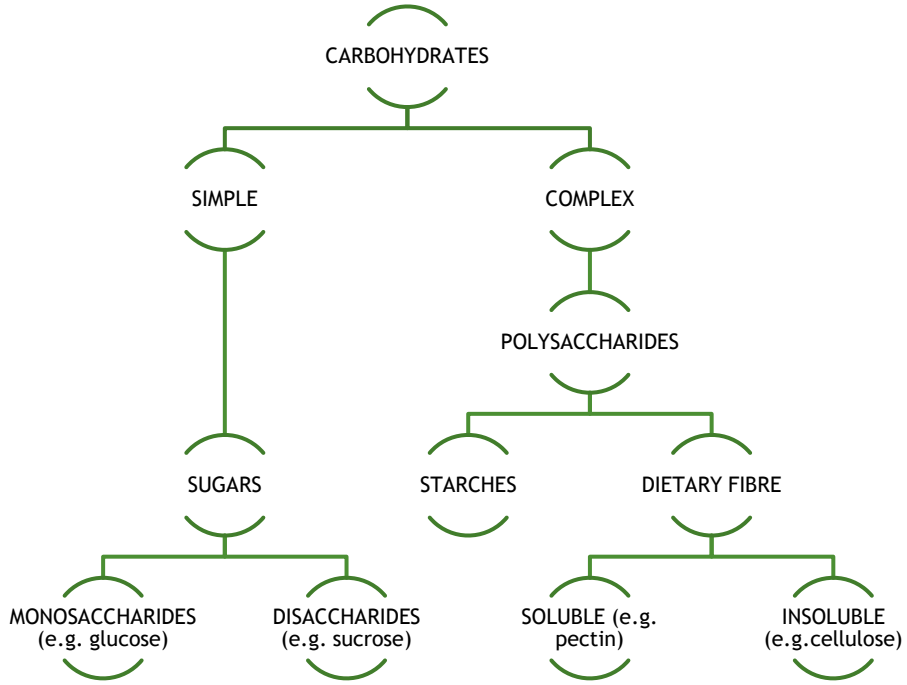

Figure 1 Carbohydrate classification by structure

Dietary Fibre

Dietary fibre can also be referred to as roughage and is a form of carbohydrate. It is not necessarily an essential nutrient for dogs and cats, although it does play an important enough role for it to be mentioned within this unit and no doubt if it was excluded from the diet altogether, we would notice some significant consequences in practice!

Dietary fibre is the term used for the group of indigestible polysaccharides e.g. cellulose, pectin and lignin. They are usually associated with plant material and make up the cell walls of plants including vegetables and fruit. They travel through the digestive tract relatively unchanged, hence we see carrot appearing in the same form in the faeces as it was when it was eaten albeit slightly discoloured due to the strong digestive juices. A limited amount of dietary fibre can be beneficial

in providing faecal bulk, regulating bowel movements to prevent food from festering within the digestive tract and can help prevent constipation and diarrhoea.

Fibre is classed as being soluble or in-soluble. Soluble fibre dissolves in water and is fermented in the colon into gases and active by products, some of which can be prebiotic. Soluble fibre tends to slow down the passage of food through the system. Insoluble fibre does not dissolve in water and ferments in the large intestine. It too can be prebiotic and provide bulking to the faeces as it absorbs water as it passes through the digestive tract, making the stool easier to pass. Insoluble fibres tend to accelerate the passing of food through the system.

A combination of soluble and insoluble sources can be used to help improve glycaemic control in dogs with diabetes mellitus and in the dietary management of some 'fibre-responsive' diseases such as chronic diarrhoea.

The Glycaemic Index

Although not often mentioned when discussing animal diets, it is worth understanding the meaning of the glycaemic index (GI) to improve your background knowledge of nutrition.

The glycaemic index is the ranking of carbohydrates on a scale of 1 – 100 depending on how they raise the blood sugar of animals after digestion. Foods with a high glycaemic measure are those that are rapidly digested and cause fluctuations in the blood sugar. Foods with a low glycaemic index are slower to digest and absorb; they gradually raise the blood sugar and insulin evenly and are generally thought to have health benefits. Low GI diets reduce insulin levels and insulin resistance, as well as being helpful for weight loss diets due to the nature of their slow digestion they reduce the feeling of being hungry.

Examples of the glycaemic index can be found below:

Scoring system

Low GI	Med GI	High GI
0 – 55	56-69	70+

Food examples

Low	Medium	High
Salmon	Sweet potatoes	White potatoes
Beef & Lamb	Blueberries	White bread
Spinach	Brown rice	White rice
Chicken	Oats	

The glycaemic index is worth bearing in mind next time you are recommending a diet for a clients' pet, whether or not the pet is deemed fit and healthy.

Grains

Typical grains found in pet foods are: wheat, corn, soy, rice and barley. Grain-free pet foods have recently become more popular but grain-free does not mean carbohydrate-free, as carbohydrates are also present in other ingredients such as potatoes and sweet potatoes. While dogs and cats have no absolute dietary need for carbohydrates, suitable quantities of healthier, digestible carbohydrates can provide a readily available energy source for some active dogs. Brown rice, sweet potato and oats are great options and gentle cooking further enhances digestibility. Gluten is a protein found in some cereal grains and is also a concern for some dog owners. It is responsible for the elastic texture of dough and can often be used in pet foods as a binding agent. Irish setters in the UK can suffer from an inherited gluten-sensitive enteropathy.

Fats

Fat in the diet provides the most concentrated source of energy. Oils, fats and lipids can all be terms used when describing dietary fat, with 'oil' being used for fats that are liquid at room temperature and 'fat' being used for fats that are solid at room temperature. Lipid is used to refer to both liquid and solid fats in more a scientific or biochemical term.

Dietary fats are mixtures of triglycerides which are three fatty acids joined by a unit of glycerol. Fats can be classified into three groups:

- Saturated – no double bonds between carbon atoms
- Unsaturated – one or more double bonds present
- Polyunsaturated – more than one double bond

Most fats will contain all of the above but vary significantly in proportions.

Fats have a number of benefits when included in a diet. They can increase palatability by improving flavour and texture of the food but most importantly, they contain essential fatty acids (EFAs) and are carriers of the fat-soluble vitamins A, D, E and K. There are currently three essential fatty acids which are recognised as: linoleic, α - linolenic and arachidonic acid. Linoleic and α – linolenic are the parent essential fatty acids from which the more complex, longer chain essential fatty acids can be made (derived EFAs). The cat, however, is unusual in that it is unable to convert the parent EFA into longer chain derivatives. Therefore, cats require a dietary source of arachidonic acid from animal origin such as chicken, duck or fish.

Essential fatty acids play an important role within the body and are used to maintain kidney function, assist in reproduction, form cell membranes and are involved with the synthesis of prostaglandins. Total removal of fat from the diet, which many owners may consider in order for their pet to lose weight can have detrimental effects on overall health such as;

- Dull, scurfy coat
- Hair-loss
- Fatty liver
- Anaemia
- Impaired fertility in breeding animals

Therefore when advising a diet for animals, the complete removal of fat is not a true answer as a balanced amount of fat is required for life.

Saturated long-chain fatty acids are used exclusively for energy whereas the role of polyunsaturated fatty acids (PUFAs) is more diverse. PUFAs are more commonly recognised when they are grouped as omega-3 or omega-6 based on their chemical structure, specifically the location of the first double bond. The ratio of omega-3 to omega-6 in a diet is often referred to but as yet there is insufficient evidence to determine an optimal ratio for cats and dogs.

	PUFAs	Role	Common Sources	Deficiency or Excess
Omega-3	Alpha-linolenic acid (ALA) Eicosapentaenoic acid (EPA) Docosahexaenoic acid (DHA)	Improving skin and coat, anti-inflammatory agent, normal embryonic development, sustain cognitive function in geriatrics	ALA: Flaxseed oil EPA and DHA: marine fish oil, phytoplankton and single cell algae	Excess can lead to impaired immune function in dogs
Omega-6	Arachidonic acid (AA) Linoleic acid (LA)	Synthesis of prostaglandins therefore essential for normal reproduction	AA: Animal fats, beef tallow and poultry skin LA: vegetable oils, sunflower oil	Deficiency can cause poor reproductive performance, dry skin and dull coat

It is also worth mentioning that diets high in polyunsaturated fatty acids can become rancid when exposed to air due to oxidation. This can lead to the destruction of other nutrients, particularly vitamin E, therefore storage of animal feed is of high priority to prevent degradation and should be stored in air-tight containers or frozen.

Micronutrients

Micronutrients are, as the name suggests, required in small quantities to facilitate a range of physiological functions and are classed as vitamins and minerals. It is very important to obtain the correct balance of micronutrients within the diet to prevent severe deficiencies and illness occurring, as you will learn from the text below.

Minerals

Minerals are inorganic compounds collectively known as 'ash' and they are divided further into macro minerals and micro minerals (sometimes referred to as trace elements). Electrolytes are minerals in their salt form as found within the body tissues.

Essential macrominerals

Essential macrominerals are Calcium (Ca), Phosphorus (P), Magnesium (Mg), Potassium (K), Sodium (Na) and Chloride (Cl). We shall briefly discuss each macromineral and gain an understanding of symptoms associated with deficiencies and excesses. Although it is important to have the correct balance within the diet, we will also learn that it is important for the body to be able to regulate the correct ratios between different minerals.

Calcium and Phosphorus

Calcium and phosphorus are very closely related and therefore, usually discussed together. They maintain the structural rigidity of bones with approximately 99% of calcium and 80% of phosphorus stored within the skeletal tissues. An increase in these minerals is required during growth, late pregnancy and lactation. The metabolism of calcium and phosphorus is closely linked with vitamin D and within the body calcium is involved with blood clotting and nerve and muscle function. Phosphorus is involved in nearly all the metabolic processes which take place. While bone is high in calcium, many meats are high in phosphorus with tripe offering a lower phosphorus protein source.

The calcium to phosphorus ratio (Ca:P) is of great importance especially during growth and if the balance is incorrect, it can have a marked effect on bone development due to a condition known as "nutritional secondary hyperparathyroidism" where the body increases reabsorption of the minerals from the bones to replace the deficit in the blood, leading to skeletal deformities. Low calcium (hypocalcaemia) can cause eclampsia in pregnant bitches and queens, as the body cannot compensate for the loss of calcium in the blood from the production of milk. Very high levels of calcium and phosphorus or a very high ratio of calcium and phosphorus have also been associated with serious health problems. Hip dysplasia, osteochondrosis syndrome, enostosis and wobbler syndrome have been linked to excessive calcium consumption in growing dogs, often caused by owner supplementation.

Magnesium

Approximately 60% of the body's magnesium is found in skeletal tissue but it is also found in soft tissues. It plays an important role in heart and skeletal muscle and the nervous tissue which all depend on a balance between magnesium and calcium. Magnesium is very important in the metabolism of sodium and potassium and has a key role in enzyme reactions related to energy metabolism. A deficiency will produce symptoms of muscle weakness and in severe cases, convulsions. However, dietary deficiency is very rare as magnesium is widely found within food. An excessive intake (which can be associated with inappropriate supplementing) can lead to an increased occurrence of feline lower urinary tract disease (FLUTD) in cats and has been linked to struvite bladder stone formation. Brown rice and fish are both great sources of dietary magnesium.

Potassium

Potassium plays an important role in acid base balance and osmoregulation. Both nerve and muscle functions require potassium and it is also involved with energy metabolism. As with magnesium, naturally occurring deficiencies are rare as potassium is found in a wide variety of foods although, it is related to protein intake, therefore ensuring the protein is of a high quality will help prevent a low intake of potassium over a period of time. Deficient amounts of potassium can cause muscle weakness, poor growth and lesions of the heart and kidney. Diarrhoea can cause significant potassium losses and result in deficiency if persistent whilst urinary acidification can result in increased potassium loss and may need to be compensated for in the diet. Cardiac and renal diets should have reduced potassium upper limits. Banana and sweet potato are both great sources of dietary potassium.

Sodium and Chloride

Together, sodium and chloride are the major electrolytes of the body water. They help maintain acid base balance and osmoregulation. Chloride is an essential component of bile and hydrochloric acid which is found in the stomach as digestive juices. Common salt (Sodium chloride - NaCl) is the most useful form and is widely added to foods meaning that naturally occurring deficiencies are rare; however some symptoms of a deficiency include the inability to maintain water balance, decrease water intake, impaired growth, dry skin and hair loss. Excess consumption of sodium chloride causes an increase in thirst (as we all know after eating a large plate of salty chips!). Sodium and chloride are also both naturally present in a wide variety of foods, including meat and vegetables so it is relatively easy for pets to meet the minimum nutritional requirements.

Micro minerals or Trace Elements

As the name suggests, trace elements are only required in very small amounts. They include Iron (Fe), Copper (Cu), Zinc (Zn), Iodine (I), Selenium (Se), Manganese (Mn).

Iron

Iron has an essential role in many enzymes which are involved in respiration as well as being an essential component of the oxygen carrying pigments, haemoglobin (in blood) and myoglobin (in muscle). Deficiency causes anaemia associated with weakness and fatigue. Like most trace elements, if ingested in copious amounts it is toxic and can lead to anorexia and weight loss. A rich source of Iron is both red and white meats as well as brown rice and spinach.

Copper

Copper facilitates the intestinal absorption of iron and its incorporation into haemoglobin, it is an active element in many enzymes and plays an important role in reducing damage by free radicals. It is also involved in the synthesis of collagen, myelin and melanin. Copper deficiency impairs the absorption and transport of iron causing anaemia, even when iron intake is at a normal level. Bone disorders can also occur with a copper deficiency and is thought to be a reduction in the activity of a copper-containing enzyme, leading to diminished stability and strength of bone collagen. Strangely, excess copper intake can also cause anaemia which is thought to arise from copper and iron being in competition for absorption sites in the intestines. Toxicity is rare but certain breeds are predisposed to copper storage disease, such as Bedlington terriers. Liver and peas are both good sources of dietary copper.

Zinc

Zinc is essential within enzymes related to protein and carbohydrate metabolism and is important for a healthy coat and skin. It is also required for the transport of vitamin A in the blood and plays an important role in reproduction. Zinc is required by all animals but its requirement is affected by other components within the diet. For example, high dietary calcium content or a vegetable based protein diet can dramatically increase the zinc requirement. Zinc deficiency can cause symptoms such as poor growth, anorexia, testicular atrophy, emaciation and skin lesions. The link between zinc and skin and coat condition is of importance in the companion animal as a marginal deficiency may occur whilst the animal appears healthy but develops a poor skin and coat. Excessive intake may interfere with the absorption and utilisation of iron and copper, and can cause seizures in cats. Beef and spinach are both great sources of dietary zinc.

Iodine

As an essential component of thyroid hormones, iodine plays an important role in regulating basal metabolism and this is its only known function. Goitre (enlargement of the thyroid gland) is the principle sign of iodine deficiency but do bear in mind that other factors may also produce goitre. Clinical signs associated with hypothyroidism include skin and hair abnormalities, dullness, lethargy and drowsiness. There can also be abnormal calcium absorption and reproductive issues with foetal

reabsorption. Excessive iodine intake can display similar symptoms to that of a deficiency with the iodine directly affecting the thyroid gland. Seaweed is naturally very rich in iodine.

Selenium

Selenium is closely interrelated with vitamin E, such as the presence of one nutrient can prevent a deficiency of the other nutrient (see section on vitamin E later). Together they prevent damage to cell membranes caused by free radicals. Selenium does have a unique function in that it is an obligatory component of glutathione peroxidase, the enzyme which protects cells against damage from oxidising substances. A deficiency has many symptoms including degeneration of skeletal and cardiac muscles in dogs and reproductive disorders and oedema in other species. It can be toxic in excess amounts and the balance between the correct level and an excess level is very fine. Home supplementation of foods by owners can prove very dangerous with regards to excessive intake. Tuna and grass-fed meats provide a source of dietary selenium.

Manganese

Manganese is involved with many enzyme related functions and is required for carbohydrate and lipid metabolism and cartilage formation. A deficiency can cause defective growth and reproduction, and disturbances in lipid metabolism. In adult dogs lameness, enlarged joints and poor locomotion have also been reported. Prolonged manganese excess can result in iron deficiency. Pumpkin and sesame seeds provide a great source of dietary manganese.

Other trace elements

A number of other trace elements have been found to be necessary for normal health in mammals and these include chromium, fluoride, nickel, molybdenum, silicon, vanadium and arsenic. They are required in such small amounts that specific recommended levels have not been identified in companion animals and deficiencies are pretty much non-existent due to their small requirements. As with the majority of trace elements, excessive intake can be toxic but the levels of toleration differ from element to element.

Vitamins

Vitamins are organic compounds that help regulate the body processes. Nearly all vitamins cannot be synthesised by the body and so must be provided in the diet. They are divided into two main groups:

- Fat soluble vitamins = vitamin A, D, E and K
- Water soluble vitamins = B complex vitamins and vitamin C

Water soluble vitamins require a daily intake as they are not stored within the body and any excess consumed is excreted in the urine. Whereas fat soluble vitamins are stored within the body, making a daily intake less critical however, due to their storage toxicity is more likely due to excess build

up. Vitamins are sensitive to light, heat and oxidation so care should be taking during any processing and storage of pet foods to minimise degradation and maintain the nutritional quality for the full shelf-life.

Fat Soluble Vitamins

Vitamin A

Vitamin A (known as retinol) in nature, is found to a large extent in the form of its precursors, carotenoids. This is the yellow and orange pigment found in most fruit and vegetables giving them the recognisable colours we know. Of these carotenoids, ß- carotene is the most important, as this is the component of visual pigments within the eye (transmit light) and is therefore highly important for vision. It is also concerned with cell differentiation and the maintenance of normal cell structure and it is therefore vital for sustaining a healthy skin and coat, mucous membranes and normal bone and teeth development.

Deficiency of vitamin A may cause anorexia, weight loss and abnormalities of the squamous epithelium. This last symptom is of importance within the veterinary practice as this can lead to seborrhoeic coat conditions, xerophthalmia leading to corneal opacity and ulceration, increased susceptibility to microbial infections and crusting of the nares. Dogs can synthesise vitamin A from ß- carotene, however, cats are unable to and therefore it is of high importance that a cat's diet contains a source of preformed vitamin A which is mostly found in animal fat.

Excess vitamin A is stored within the liver meaning toxicity can lead to liver damage. Hypervitaminosis A causes a crippling bone disease resulting in bony exostoses and ankyloses of joints, particularly in the cervical vertebrae and long bones of the forelimb. Cats can be highly susceptible to hypervitaminosis A due to prolonged supplementation of the diet with cod liver oil tablets or being fed excess amounts of fresh liver.

Vitamin D

Metabolites of vitamin D stimulate calcium absorption within the intestine and can also stimulate reabsorption of calcium from the bones (in conjunction with the parathyroid gland). The dietary requirements for vitamin D are very closely linked with dietary concentrations of calcium and phosphorus (as discussed earlier). Humans and herbivores can synthesise the vitamin from lipids within the skin, provided they have exposure to sunlight and are otherwise healthy and well nourished. However, this process is absent in dogs and cats so there must be an adequate dietary source of vitamin D.

Deficiencies are rare but can be seen with a calcium:phosphorus imbalance. Rickets may occur in younger animals and osteomalacia in the older animal. Toxic effects are related to hypercalcaemia if excess intake is prolonged and can result in calcification of the soft tissues, lungs, kidneys and

stomach, along with deformities of the teeth and jaws with eventual death. A rich dietary source of vitamin D is beef liver or fish oils.

Vitamin E

Vitamin E works closely with selenium to protect cell membranes against oxidative damage. A dietary requirement will be increased when the diet is already high in polyunsaturated fats as these are easily oxidised. Cats can suffer from a deficiency in vitamin E when they are fed a diet high in oily fish which can lead to a painful disease called pansteatitis where the body fat becomes painfully inflamed (also known as 'yellow fat disease').

Dogs suffering from a deficiency can show signs of skeletal muscle dystrophy, reproductive failure, retinal degeneration and discolouration of adipose tissue. Toxicity in both cats and dogs is rare as high doses are well tolerated but excessive vitamin E can prolong blood-clotting time in cats. Grapeseed extract is rich in vitamin E and safe for pets but beware as the skin and flesh of grapes can be highly toxic to dogs.

Vitamin K

Vitamin K is responsible for regulating several blood clotting factors and healthy animals can synthesise enough with bacterial synthesis in the intestine therefore, a deficiency in vitamin K is highly unlikely. If bacterial synthesis is impaired or supressed by vitamin K antagonists (such as warfarin), hypoprothrombinaemia and haemorrhage may occur. This vitamin has a low toxicity but very large amounts may cause anaemia and other blood abnormalities. Broccoli and spinach are great sources of dietary vitamin K.

Water Soluble Vitamins

Vitamin B-complex is used to form many co-enzymes involved with normal metabolic function, especially energy metabolism and synthetic pathways. They are now referred to as their individual names, rather than a combination of letters and numbers although, where applicable, these have been noted in the title for reference.

Thiamine (Vitamin B1)

Thiamine is involved with the metabolism of carbohydrates and its dietary requirements are dependent on the carbohydrate content of the diet. A deficiency in cats can occur when they are fed a fish diet which contains high levels of the enzyme thiaminase. The vitamin is destroyed through high temperatures and some forms of processing. Deficiency symptoms include anorexia, neurological disorders, weakness, heart failure and eventual death. The vitamin has very low

toxicity with excess levels of consumption. Peas and yeast extract are both great sources of dietary thiamine.

Riboflavin (Vitamin B2)

This vitamin is essential in a number of oxidative enzyme systems and cellular growth cannot occur without it. Deficiency signs include eye lesions, skin disorders and testicular hyperplasia. Toxicity with this vitamin has not been reported. Beef liver and root vegetables provide a good source of riboflavin.

Niacin (Vitamin B3)

Niacin is a component of two important co-enzymes required for oxidation-reduction reactions which are necessary for the utilisation of all major nutrients. Its requirement is influenced by the dietary level of the amino acid tryptophan, which can be converted into the vitamin. Cats however, are unable to perform this conversion and therefore a dietary source of niacin is essential. A deficiency can cause a disease known as pellagra in humans, known as 'black tongue' in cats and dogs. This causes inflammation and ulceration of the oral cavity with thick, blood-stained saliva and foul breath. Niacin is non-toxic in excess. Tuna and yeast extract are both great sources of Niacin for cats.

Pantothenic Acid (Vitamin B5)

This is a constituent of co-enzyme A which is essential for carbohydrate, fat and amino acid metabolism. The vitamin is widespread in animal and plant tissue, such as sweet potato, chicken and fish, making deficiencies very rare. Toxicity with increased consumption has not been reported.

Pyridoxine (Vitamin B6)

Vitamin B6 is involved with a wide range of enzyme systems associated with nitrogen and amino acid metabolism therefore, there is an increased requirement for the vitamin when the diet is high in protein. Deficiency symptoms include anorexia, weight loss, anaemia and irreversible kidney damage in cats. Pyridoxine is non-toxic in excess. Salmon and chicken are good dietary sources of pyridoxine.

Biotin (Vitamin B7)

Also known as vitamin H, biotin is required for a number of reactions involving the metabolism of amino acids. It is important for the maintenance of keratinised structures e.g. the skin and hair. Deficiencies are rare as the daily requirement is fulfilled with bacterial synthesis, however, a deficiency can develop with prolonged use of oral antibiotics which can supress bacterial synthesis. Feeding raw egg whites can also affect the biotin levels as they contain a binder called avidin therefore, if eggs are to form part of the daily diet they should be cooked. Deficiency symptoms

can include dry, scaly skin, dull brittle hair, hyperkeratosis, pruritus and skin ulcers. Liver and kidneys are good sources of biotin.

Folic Acid (Vitamin B9)

This is important in a number of reactions within the body and is also an essential component of DNA. It is required for the normal maturation of red blood cells within the bone marrow and deficiencies will cause anaemia and leucopenia, although this is rarely seen due to bacterial synthesis providing much of the daily requirement. Folic acid supplementation in gestating bitches helps reduce the incidence of cleft palate in newborn puppies. Yeast, liver and green vegetables such as spinach are good sources of folic acid.

Cyanocobalamin (Vitamin B12)

This is closely linked to folic acid and is involved with fat and carbohydrate metabolism and the synthesis of myelin. Deficiencies can cause pernicious anaemia and neurological symptoms. Animal protein is rich in cyanocobalamin, particularly organ meats such as liver and kidney.

Choline

Choline is a constituent of phospholipids which in turn, are an essential component of cell membranes. It is also the precursor of acetylcholine which is a neurotransmitter chemical. The body is able to synthesise choline in the liver so dietary deficiency is highly unlikely but production is not always sufficient to cover requirements so a dietary source is recommended. Liver, heart and eggs are rich sources of choline.

Ascorbic Acid (Vitamin C)

Vitamin C is involved with many intracellular reactions and protein synthesis. Most mammals can synthesis vitamin C from glucose, with the exception of humans and guinea pigs. Some believe that an increase in dietary levels can be helpful in times of stress or increased activity although no specific dietary requirements are necessary when dealing with companion animals.

Water

Water is required to maintain life and can be consumed by drinking, contained within the food that is eaten or found as metabolic water which is released during the breakdown of fats, proteins and carbohydrate. Water performs many vital roles within the body and the balance of body water is regulated within very narrow limits. Water losses occur in several ways such as panting, urinating, faecal content, through the skin, respiration and via fluid losses such as milk production. Life may continue for a few weeks without food, but without water, it may cease within days or even hours

dependent on environment. A plentiful supply of fresh drinking water should always be available for animals.

Energy Calculations

Energy density of the food

Protein, fat and carbohydrate provide energy in the diet, expressed in kilocalories (kcal) or kilojoules (kJ). Fat provides around twice as much energy per gram compared to protein and carbohydrate. Both inadequate and excessive energy intake will be detrimental to the health of the pet.

Gross energy (GE) – is the maximum amount of energy that can be released from a diet and is assessed by bomb calorimetry. Although a food may be high in energy, it is of no use if the animal it is being fed to cannot utilise the nutrients to metabolise and release the energy contained.

Digestible energy (DE) – the energy available from a food after it has been digested in the intestines and absorbed by the animal. It is calculated by subtracting faecal losses from the gross energy.

Metabolizable energy (ME) – this is the energy which is utilised by the tissues within the body. It is calculated by subtracting urinary losses from the digestible energy.

The values of DE and ME vary greatly depending on the food itself and what species of animal is consuming it, in our case, dogs and cats. There will also be inter-species variation due to individual metabolic efficiency.

Predictive equations are often used to calculate the metabolizable energy of pet foods from the average analysis of protein, fat, fibre and carbohydrates (NFE). The modified Atwater factors were developed to account for the lower digestibility of processed pet foods but for raw pet foods the original Atwater factors are more appropriate to use as they retain a higher digestibility:

	Modified Atwater	Original Atwater	
		Dog	Cat
Kcal ME/100g =	3.5x(%crude protein + %NFE) + 8.5x %crude fat	4x(%crude protein + %NFE) + 9x %crude fat	4x(%crude protein + %NFE) + 8.5x %crude fat

More recently the NRC (National Research Council) 4-step predictive equation has become favoured over the Modified Atwater Factors for processed pet foods as it has demonstrated greater accuracy for dry processed pet foods and equivalent accuracy for processed wet pet foods. However, as most clinical studies suggest raw pet foods retain a higher digestibility compared to processed pet foods, it is recommended to continue using the original and unmodified Atwater factors as the best predictive equation for metabolizable energy in raw pet foods.

The 4-step NRC Predictive equation is as follows:

1.	**CALCULATE GE**	
	GE (kcal) =	(5.7 x protein%) + (9.4 x fat%) + (4.1 x (NFE% + %fibre))
2.	**CALCULATE ENERGY DIGESTIBILITY (%)**	
Dogs:	% energy digestibility =	91.2 – (1.43 x fibre% in DM)
Cats:	% energy digestibility =	87.9 – (0.88 x fibre% in DM)
3.	**CALCULATE DIGESTIBLE ENERGY**	
	DE (kcal) =	(GE x energy digestibility)/100
4.	**CONVERT INTO METABOLIZABLE ENERGY**	
Dogs:	ME (kcal) =	DE – (1.04 x protein%)
Cats:	ME (kcal) =	DE – (0.77 x protein%)

**This calculation is not suitable for milk substitutes and liquid preparations for enteral nutrition and may be inaccurate for foods with a crude fibre content of more than 8%.*

Energy requirements

Calculating calorie requirements is not as daunting as it sounds. Every animal requires a level of energy to be consumed on a daily basis to maintain normal function and health. It is key to understand that there are many factors which will influence the daily energy requirements such as lifestage, if the animal is highly active (e.g. working dog), lives outside during cold conditions, is unwell or hospitalised for health reasons. Energy requirement disease factors can be found through further reading.

Since almost one quarter of owners admit to exercising their dog for less than three hours a week[1], the effect of activity levels cannot be overlooked for an accurate estimation of energy requirements. In order to take account of these factors and tailor our calculations to individuals we must consider the maintenance energy requirement (MER). This is not only the amount of energy required to perform basic bodily functions at rest but also includes calories required for exercise, growth and recovery from disease.

[1] Slater M R, Robinson L E, Zoran D L et al. Diet and exercise patterns in pet dogs. JAVMA 1995; 207 (2): 186-190.

As there is not a linear correlation between energy requirements and bodyweight, this calculation takes into account metabolic weight or body surface area. This is especially important in dogs as there is such a wide range of healthy bodyweights across the many varied breeds. In dogs the following calculation is most often used:

$$\mathbf{MER = a \times BW^{0.75}}$$ *(where a = activity factor and BW = ideal body weight in Kg)*

In order to compensate for different activity levels and growth and reproduction stages, the activity factor (a) can be estimated using the following tables (adapted from the FEDIAF Nutritional Guidelines):

DOGS

Activity level/ Age	Low: <1hr (eg walking on lead)	Medium: 1-3hr (eg playing, off lead)	High: 3-6hr (eg working dogs)
1-2 years	125-130	130-140	140-175
3-7 years	95-110	110-130	130-150
>7 years	80-95	95-120	120-140

Please note these are only estimations and adjustments should always be made to suit the individual with a goal of maintaining a healthy body condition. Great Danes are known to have higher energy requirements than estimated by these calculations and often require a factor of between 200-250, while obese-prone adults may require a factor of 90 or below. Never feed puppies ad libitum as overfeeding can lead to skeletal deformities, please refer to our puppy feeding guidelines found in module 3.

CATS

Owing to the small variation in adult body weights, the energy needs of cats can be expressed per kg bodyweight instead of per kg metabolic weight. But typically, metabolic weight is still used to calculate MER using the following formula:

MER= a x $BW^{0.67}$ (where a = activity factor and BW = ideal bodyweight in Kg)

Neuter Status	Activity Factor (a)
Intact	100
Neutered (and/or indoor)	52-75