MODULE 3

MICRONUTRIENTS

BTNacademy

3. MODULE 3: MICRONUTRIENTS

3.1. Module aims

- To give the key facts on vitamins A, D, E, K, B and C
- To give the key facts on calcium, zinc, magnesium and iron
- To provide food-based options which should be included in a balanced diet to get sufficient amounts of these nutrients
- To list at-risk populations for deficiency, and offer options which could be recommended to them to avoid unbalanced nutrient intakes
- To explain why whole food nutrition is the key in healthy eating

3.2. Key principles from module 2

In the last module, we discussed the macronutrients. Here's a quick summary of what you learned:

- When eaten, proteins are broken down into amino acids, carbohydrates into monosaccharides and fats are digested as triglycerides which are 3 fatty acids bound to a glycerol backbone
- These are absorbed from the small intestine. Carbohydrates and proteins are taken to the liver which will either take them up and use them for something (its own energy, conversion to glucose if galactose, fructose or amino acids), store them as glycogen or allow them to be taken into the blood
- Fats, when digested use the lymph system to bypass the liver and enter the blood as chylomicrons before being transported around the body, the contents of each chylomicron being taken up by cells which need them. The near-empty chylomicron then enters the liver to be processed and repackaged
- Blood glucose and amino acid levels are controlled by insulin and glucagon
- The fats we eat affect our health differently, and so fat sources should be eaten in balance
- The carbohydrates we eat largely don't matter mechanistically, though a large fructose intake may be harmful, and of course we need to consider the impact food choices have on our dietary adherence
- Fats and glucose can be used for energy
- The fat you store is largely the fat you have eaten, but this does not mean that eating fat causes fat gain, or that eating a low-fat diet means fat gain cannot occur
- You learned how to estimate your need of fats, carbohydrates and protein

3.3. Introduction to micronutrients

In this module, we will be turning our attention to some other constituents of the foods we consume, the micronutrients. Micronutrients, as the name suggests, are nutrients which we consume in very small (micro) amounts. For example, carbohydrates can be consumed in amounts upwards of 500g per day, but the recommended intake of vitamin B12 is only 0.0015mg (1.5ug) per day. Micronutrients also do not provide energy, but they can indeed be used in the processes within the body which turn macronutrients into that energy – if this seems confusing, don't worry, it will all be explained throughout this module.

We will begin by giving a definition of the words mineral and vitamin, before exploring the general concepts surrounding each. From there we will describe and explain each of the 13 vitamins and the 15 minerals, showing how they are used, what happens if you have too much or too little and where you get them from. Finally, we will round off the module by giving you a real-world approach which is guaranteed to make sure you get enough of everything you need. Many of the micronutrients will be explained in quite a short format, primarily because consuming either too much or too little is very, very unlikely and to make this module enjoyable and readable, we wanted to only focus on what is important for practical purposes.

With that laid out, let's begin with the definitions.

3.4. What are minerals and vitamins?

It's important to cover what vitamins and minerals **are** because it's a subject that people rarely consider. This often occurs when scientific words enter common vernacular, but words have specific definitions and these definitions are important. Without understanding the definitions fully, you are never truly a master of a topic, so before we start listing things we will describe what exactly minerals and vitamins are.

3.4.1. Minerals

Minerals in nutrition are the chemical elements present in tissue once it has been burned. Dietary minerals could be consumed in the form of an inorganic salt like sodium chloride (table salt) or potassium chloride which you might find in a sports drink, or it could be part of an organic compound – like the magnesium contained in chlorophyll which is what makes your greens… green.

Minerals can be broken into two categories. There are six which we require in gram or near-gram amounts, and nine which are trace elements needed in tiny amounts. This is important, because although your body can somewhat regulate the minerals that we require in larger amounts, the trace minerals can become severely toxic if over-consumed.

3.4.2. Vitamins

Vitamins are organic compounds essential for an organism to function. You already know that organic means that it contains carbon, and you know that essential means that it cannot be endogenously synthesised, but this also tells you that a vitamin is categorised according to the organism and not because of any common trait that all vitamins share (other than their carbon atoms). Vitamin C, for example, is a vitamin in human nutrition as we cannot synthesise it, but it's not a vitamin for dogs because they can.

Like minerals, vitamins are also separated into two categories, the four fat-soluble and nine water-soluble forms. Water-soluble forms are very difficult to overdose on and cause any serious harm because they can be expelled easily enough through urine. Fat-soluble vitamins can indeed be overconsumed and may lead to health problems if this overconsumption is chronic. This tables gives you an overview of what we mean:

Fig. 36

Fat-soluble	Water-soluble
Excess stored in fat tissue and liver	Excess excreted urine
Decreased chance of deficiency	Increased chance of deficiency
Increased chance of excess	Decreased chance of excess

3.5. Nutrient needs: how do we define them?

Deficiencies in any of the above nutrients may lead to a decline of any biological function, from immune function to energy production to nerve signalling. As mentioned, some of them may cause serious problems if overconsumed as well, by either blocking/preventing the absorption of other minerals and therefore causing a deficiency, or simply by becoming toxic and having direct adverse effects. This is one of the main ways by which unbalanced dietary practices (typically those which hugely emphasise one nutrient or food group, or which eliminate another) may cause problems. We will explain this further in the sections on the specific nutrients, but consider that a diet which is intentionally very low sodium can lead to problems with muscle cramps and even heart function, while a diet which overemphasises organ meats can lead to a harmfully high intake of vitamin A.

It is because of this that, if nothing else, we hope you take from this module a further clarification of the importance of balance and variety within nutrition. We will summarise it by placing into context the real-world approach recommended for ensuring sufficiency, but before we do, we will explain in specific terms what the theoretical amounts are which you need to consume to be in perfect health. However, before that we need to show you how these figures are determined.

The recommendations we will give are those recommended presently by the World Health Organisation (WHO) and the Food and Agricultural Organisation of the UN (FAO). These two bodies had initially set out guidelines in 1974 but then in 2004 with the publication of "Vitamin and Mineral Requirements in Human Nutrition – Second Edition" they revised their recommendations and most of them had increased. This, the writers of the report claimed, was due to a multitude of reasons. Firstly, in the years between the reports the body of scientific literature had expanded dramatically, but on top of that the criteria for setting the RNI (Recommended Nutrient Intake) had also changed. Initially the RNI was supposed to be that which would meet the basic nutritional needs for 97% of the population, but the definition of 'meeting basic nutritional needs' is open to interpretation. Previously the criteria used to determine basic needs was considered in the context of widespread deficiency in developing countries, but the question then remains – what **is** deficiency?

It's highly unlikely that most individuals will ever die directly of a micronutrient deficiency. It does happen, of course – some micronutrient deficiencies can be fatal, but generally speaking death isn't the consequence, and as such we can't simply take 'you die if you eat less than this' as a minimum amount. What often happens is that a deficiency will lead to a clinical ailment. As an example, long-term vitamin C deficiency can lead to the bleeding condition scurvy and long-term vitamin D deficiency can cause rickets. Vitamin A deficiency which can be common in developed countries can lead to blindness, too. None of these conditions are fatal, but they are extremely damaging to someone's health – but again, is avoiding illness what we really want to do, or can we do better?

Vitamin and mineral intakes can be considered on a spectrum from fatal deficiency to wasteful, harmful or even fatal overconsumption. Somewhere along that spectrum there is a point where you will not die but may contract a clinical deficiency, somewhere there is a point where you are no longer at risk and somewhere along the spectrum is an intake which could be considered 'optimal'. The more up to date recommendations take in to account that the level which will 'avoid clinical deficiency' may not always be the intake level which will avoid all negative consequences of low intakes.

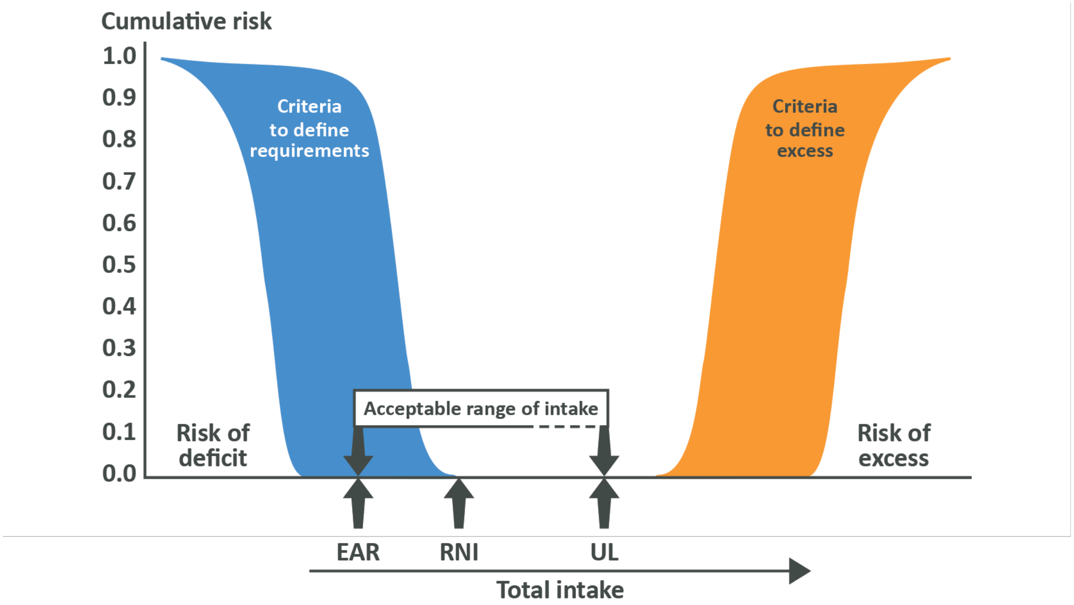
Each nutrient has, therefore, a few different numbers attached to it. There's the Estimated Average Requirement (EAR) which is 'the average daily nutrient intake level that meets the needs of 50% of the 'healthy' individuals in a particular age and gender group'. Then there is the Recommended Nutrient Intake which is the EAR plus two standard deviations (a standard deviation is the amount a typical individual in a group might differ from the average of that group) which basically means the EAR plus a bit, where the 'bit' is relative for the nutrient. This will 'meet the needs of almost all apparently healthy individuals in an age and sex specific population group'.

If relevant, a nutrient can also be given a TUL or Tolerable Upper Limit, which is the maximum amount which could be consumed by 97.5% of the healthy individuals in a given age and sex population without causing adverse health effects. For most nutrients, the intake/excretion level is regulated well within the body and therefore most nutrients (with some notable exceptions) are unlikely to be consumed excessively from foods – the problem comes when supplements are taken which provide unnatural intake levels. This will be explained nutrient to nutrient, however.

Some nutrients may also be given a protective intake level. This is a number above the RNI but below the TUL which, when consumed, may have additional beneficial effects.

Fig. 37

"Risk function of deficiency and excess for individuals in a population related to food intake, assuming a Gaussian distribution of requirements to prevent deficit and avoid excess".



(Vitamin and Mineral Requirements in Human Nutrition. (2004). 2nd ed. World Health Organisation, p.3).

Alongside the figures presented by the WHO, we will also provide the intake recommended by the UK Government at the time of writing this document in the Eatwell Guide. We recommend you stick with the UK Government set minimums as they reflect the most up to date information and the UK environment. Not all vitamins will have all of these values as the recommendation may not exist.

Recommendations for micronutrients are generally presented as population-based RNI's and are not intended to define the daily requirements for an individual. While a healthy individual consuming between the RNI and UL will minimise their risk for long-term micronutrient deficiency or overconsumption, this does not necessarily mean that it would be the correct recommendation for high-level athletes engaged in extreme forms of exercise (an hour or so per day, 3-5 days per week doesn't qualify you for this category) or individuals who do not meet the criteria for generally healthy (which amounts according to the WHO/FAO report to someone who presents with an absence of disease, absence of existing nutrient deficiencies or excesses and normal bodily function). Those with any internal health complaints should speak to a dietician qualified in the specific area relative to them. In the previous module, we gave recommendations which could be individualised a little bit according to a person's height and weight, but no such recommendation is possible with most micronutrients, simply as the information which would be needed to do so is largely not available.

If, however, you are generally healthy, not a high-level athlete, and haven't been either eating liver four times per day for the past year or avoiding anything that isn't water, white bread and jam, the following micronutrient recommendations should apply to you!

As a final point, the amounts expressed will be in a few different units, please use this table for reference so you know what on earth we mean by the different abbreviations.

Fig. 38

Unit	Abbreviation	Explanation
Gram	g	The weight of 1 millilitre of water. 1, 1000th of a kg
Milligram	mg	1000th of a gram. 0.001g
Microgram	ug	1000th of a mg, 1,000,000th of a g. 0.001mg or 0.000001g
International unit	IU	The conversion of IU to standard measures depends on the thing being measured. While IU may be mentioned for some nutrients, the amounts stated for the various intake levels can be given in any of the above units

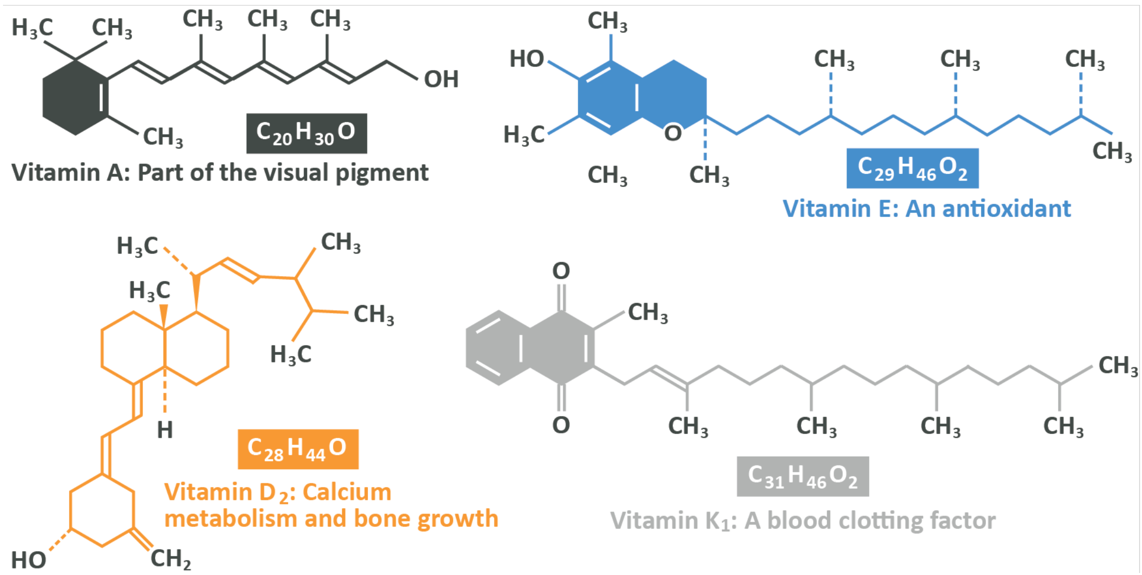
Let's start with the vitamins, specifically the fat-soluble ones.

3.6. The fat-soluble vitamins

Fat-soluble vitamins are ones which, when eaten in excess, are stored primarily in your liver and fat cells. Because of this, deficiency risk can be considered relatively low, as any days of low consumption can be 'made up' by vitamins stored within the body. With that said, of course, those with excessive levels of bodyfat may be at risk of deficiency in at least some cases, because their additional adipose tissue is able to 'suck up' some of the vitamins needed in the blood supply. Research has shown that individuals with obesity may be deficient in vitamin D despite a high intake, and this goes away with fat loss – as such, obese individuals especially should pay attention to regular intake, even if the relative risk is still reduced.

Fat-soluble vitamins are, as the name makes obvious, lipophyllic and hydrophobic. You encountered these terms in the last module when talking about fats and cholesterol. Because of this, you may have deduced that it is something to do with the molecular structure of the vitamins, and you would be correct.

Fig. 39



Above you see the structure of the 4 fat-soluble vitamins – vitamins A, D, E and K. They have what should now be a familiar structure involving a long carbon chain, with some carbons being formed into rings. This structure is known as 'non-polar' which means that none of the atoms within it have a particular positive or negative electromagnetic charge. Because of this structure, the molecules do not bind well with water and that means that they are not soluble in it or in your blood.

This insolubility means that, much like dietary lipids, once these vitamins are absorbed into the cells of the small intestine they are packaged into chylomicrons alongside triglycerides and cholesterol, then transported around the body for use or deposited back in the kidney for storage. As such, these vitamins should always be consumed alongside some dietary fat (or preferably a mixed meal) so as to facilitate their absorption and transport. If the fat content of the diet is too low, in fact, deficiency of these nutrients can occur even if intake is relatively high due to malabsorption.

Note: In ***fig. 39*** you see vitamins K1 and D2, but there are other forms of these vitamins with slightly different structures and in fact, each vitamin could be considered to be a group of similar molecules with the same (or very similar) functions in the body, rather than one discrete thing – vitamin A is a collection of things, rather than one particular molecule.

If fat-soluble vitamins in excess of need are consumed, they are stored mostly in the liver and fat cells for later release.

3.6.1. Vitamin A

Found in two forms in foods: retinoids and carotenoids. Retinoids are found in animal products, especially liver, cod liver oil, eggs and whole fat dairy, whereas carotenoids are found in red, yellow and orange vegetables including sweet potatoes and carrots, as well as dark leafy greens like kale.

Retinoids are 'pre-formed' vitamin A but carotenoids must be oxidised and cleaved in two before they can be 'used'. While both are absorbed and travel around the body, retinol can be used immediately (and if not, it's stored in the liver after being delivered there by chylomicron remnants) and carotenoids tend to be stored in fatty tissue in their inert form. If intake becomes low, the carotenoids can then be oxidised for use but this process is quite tightly regulated according to vitamin A levels present in the body. As such, retinol is quite easy to 'overdose on' whereas carotenoids cannot realistically become toxic with overconsumption, though they can cause a harmless yet undesirable orange pigmentation to appear in your face, hands and other features, if chronically eaten in excess. If retinoid intake is excessive, toxicity can result in liver damage, headaches and vomiting.

Vitamin A has numerous functions including regulating proper immune function, reproductive function and proper growth of cells, but it's most prominent function is to do with eyesight. Vitamin A is vital for the resynthesis of Rhodopsin, a pigment on rod cells which are the tiny receptors on your eye. If this becomes chronic, blindness will result, but the immediate symptomology will be 'night blindness' where a person struggles to see in dim light.

Deficiency is most likely in populations consuming most of their vitamin A as carotenoids (so, from plant sources) because although around 90% of the retinoids present in a food will be absorbed, this number is far lower for carotenoids, and this is even lower if the accompanying meal is very low-fat. As such, vegans should be very careful to ensure their fat intake doesn't drop too low, as is common in plant-based diets.

In fact, there is a conversion equation for 'retinol equivalents' or RE, which show the difference between 1iu of retinol and 1iu of carotenoids. In order to get 1iu of retinol, you need to consume just under 6iu of beta carotene (the most common carotenoid in commonly consumed foods), meaning that plant based vitamin A requirements are around 6 times that of animal based ones. The recommendations below are given in RE, so a higher level will be required if your only intake is from plant sources.

Fig. 40

Population	WHO AER	WHO RNI	UK RI	Upper limit
Male adults (19-65)	300ug	600ug	700ug	3000ug per day or 7500ug per week
Female adults (19-65)	270ug	500ug	600ug	3000ug per day or 7500ug per week
Pregnant women	370ug	800ug	Speak to your doctor*	3000ug per day or 7500ug per week
Lactating women	450ug	850ug	Speak to your doctor*	3000ug per day or 7500ug per week

* During pregnancy, vitamin A intake is a balancing act. While more is needed to avoid deficiency, which may cause issues either during gestation or during breastfeeding, having too much is just as dangerous. Current recommendations are for supplementation to be avoided during pregnancy, along with liver and liver products, but a blood test will be able to indicate individual needs.

Note: For reference, liver contains around 4,500ug RAE per raw 85g, a 180g sweet potato with skin has around 144ug (1730ug beta carotene) and 100g of carrots has 345ug (4142ug beta carotene).

3.6.2. Vitamin D

Found in two primary forms, D2 (ergocalciferol) and D3 (cholecalciferol). D2 is a plant-origin form which may be consumed in the diet, most commonly from mushrooms which have been exposed to sunlight (or in modern food manufacturing, intentionally enriched via ultraviolet light) whereas D3 can be attained via foods such as milk and eggs, or synthesised by your skin upon exposure to sunlight, thanks to a cholesterol-like precursor called 7-dehydrocholesterol.

D2 and D3 are structurally different molecules, but they are metabolised in a very similar way and can be considered to be more or less interchangeable for practical purposes.

While dietary vitamin D **can** be used to meet needs, the amount of vitamin D present in foods can be relatively low, and as such the main source of non-supplemental vitamin D for humans is that which is synthesised from sunlight. Because of this ability to synthesise vitamin D endogenously, strictly speaking we should not consider it a vitamin at all, going by the definitions established above, but nonetheless it's a crucial micronutrient.

Upon ingestion or synthesis of vitamin D, it is metabolised in the liver to 25-hydroxyvitamin D or calcidiol, which is in turn sent to the kidneys where is it converted into 'active vitamin D' known as 1,25-(OH)2D or calcitriol. The suffix –ol indicates that in fact this active form is a hormone, and in fact vitamin D is a seco-steroid (which simply means that it has a 'broken' carbon ring in its structure, one of the rings appears smaller than the others and only has five sides.

Because it's a steroid hormone, it is able to travel in the blood and enter cells, bind to special receptors and affect the way that DNA code is used. Recall from the last module, that DNA code tells the cell how to make protein, well, vitamin D is able to affect the way that proteins are made. Those proteins then go on to have profound effects.

Vitamin D is required primarily to maintain normal blood levels of calcium and phosphate, which are themselves needed to maintain normal bone health, and it does this by altering the way that calcium-transporting proteins, amongst others are made. As we discussed in the last module, all tissues in the body break down and rebuild themselves constantly as a means of repairing damage and staying 'new', and bone is no exception. Without adequate intakes of calcium and phosphate, bone density will reduce and without vitamin D these two minerals cannot be absorbed, even if intake is theoretically adequate. This is why deficiency in vitamin D causes rickets – a bone deformity which typically manifests as bow leggedness, caused by insufficient sunlight exposure (thus vitamin D) during childhood and adolescence. It is also worth noting that genetic defects and other health conditions may also be responsible.

Aside from that, vitamin D and the gene expressive effects it holds are also involved with immune function, muscle function, heart function, brain development and your respiratory system, while additionally having the ability to reduce cancer risk. Alongside rickets, deficiency is also associated with depression and low mood (especially prevalent in the winter in the Northern Hemisphere).

Research into vitamin D is increasing in recent years, with many further exciting potential effects being shown, including but not limited to improved body composition, improving fall risks in the elderly and increased testosterone levels in men. It's disease and developmental abnormality risk mediating properties are only just being elucidated, but early evidence is showing that vitamin D supplementation may even be protective against chromosomal abnormalities.

Skin synthesis of vitamin D is able to meet minimum requirements after around 30 minutes of constant exposure to relatively strong sunlight on the arms and face, but this process is hampered by some key factors:

- Outside of the band around the equator stretching from the latitudes 42 degrees North and 42 degrees South you aren't likely to get sunlight strong enough for most if not all of the year. Note that Lands' End has a latitude of 50 degrees North and John O'Groats is at 58, so the UK falls outside of that range. Outside of this range, at least in Winter, synthesis can be close to if not zero due to low light levels
- As we age we experience thinning of the skin, which makes this process less effective
- Clothing and sunscreen use both impact the amount of UV rays which come into contact with the skin. Of course, in colder months in countries outside of the abovementioned band, clothing is worn more which results in even less exposure
- Skin pigmentation affects vitamin D synthesis. The darker your skin, the less likely it is that UV light will reach the required dermal layer

Overconsumption of vitamin D is very, very unlikely but it is indeed possible with very large dose supplementation.

Toxicity results in, amongst other things, elevated levels of calcium in the blood which may lead to calcification of soft tissues including kidneys, heart, lungs and blood vessels. For shorter-term hypercalcaemia you would be likely to experience loss of appetite, weight loss, weakness, fatigue, vomiting, constipation and irritability. During pregnancy it can cause unborn infants to have congenital heart problems, elfin faces and cognitive developmental issues.

Fig. 41

Population	RNI	UK RI	TUL
Adult males (19-50*)	5ug**	10ug	100ug***
Adult females (19-50*)	5ug	10ug	100ug***
Pregnant women	5ug	10ug	100ug***
Lactating women	5ug	10ug	100ug***

* From 50+ this intake level doubles to 10ug

** Vitamin D is often stated in IU. 1ug of Vitamin D is equivalent to 40IU, so 10ug is 400IU

*** There is a NOAEL (No Observed adverse effect level) intake of 250ug per day in men, but this lower figure acts as a large safety buffer. In fact, some potentially beneficial doses exceed this lower band, but do not meet the higher one.

Note: For reference, 85g sardines has 6.5ug, half a pint of whole milk has around 4 and an egg has around 1 and a half.

The above levels should be sufficient to maintain proper calcium levels and maintain normal function, but it should be noted that a higher intake of vitamin D may offer more benefits. Vitamin D is one of the vitamins whereby the intake to avoid deficiency may not be as high as the intake level which is 'optimal' and various bits of research have concluded intake ranges of between 20-80iu per kg of bodyweight per day can improve certain health markers. We tend to recommend those looking to supplement vitamin D to improve their overall health should look to this range, though we strongly advise never exceeding 10,000iu or 250ug.

3.6.3. Vitamin E

Vitamin E comprises a group of 8 similar homologues (things which are kind of the same but different) grouped into tocopherols and tocotrienols, each of which is broken into A, B, Y and D forms (alpha, beta, gamma, delta). This is important, because it is alpha-tocopherol (A-T) which is the most easily absorbed form, and much like in the case of vitamin A where retinoid levels are recommended, intake recommendations are expressed as an amount of A-T as opposed to vitamin E in general. The only truly practical purpose for knowing this is if you were going to supplement with vitamin E, in which case a cheap version would either comprise another form, or a synthetically formed dl-a-tocopherol which must be consumed in a higher amount than usual (dl-A-T is about 75% as potent as naturally occurring A-T, for example).

A-tocopherol is present in large amounts in sunflower and palm oil, nuts, avocados, egg yolks, whole grains and green leafy vegetables, and as such deficiency is relatively rare.

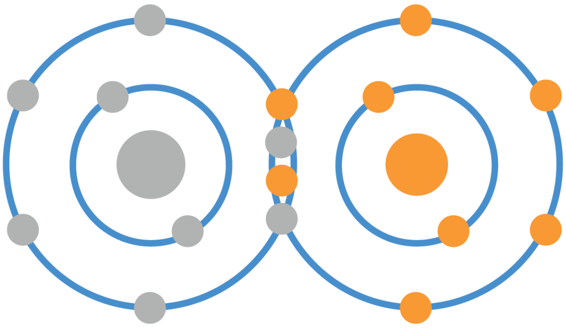
Upon ingestion vitamin E is transported via chylomicrons to the liver, before being packaged into other lipoproteins and ultimately transferred to cells where it is stored within the lipid bilayer of tissues.

The primary role vitamin E plays within the body is as a lipid-soluble antioxidant. Antioxidants are often a hot topic within mainstream nutrition, with antioxidant supplements and enriched foods becoming more and more popular. In reality they need not be supplemented in unnaturally high amounts (and in fact doing so could be harmful), but that doesn't mean they aren't important. In fact, adequate antioxidant intake is hugely beneficial to disease risk minimisation.

3.6.4. What is an antioxidant?

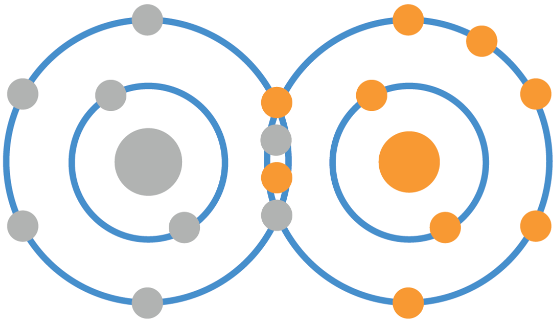
As you know, atoms have a certain amount of electrons on their outer ring which they 'prefer' to maintain, as this keeps them stable. Within the body, oxygen is one of the main molecules for metabolism, and in its naturally occurring state oxygen is in the O2 form, meaning that two oxygen atoms are linked together, like so:

Fig. 42



Here you see that the inner ring has 2 electrons, then the outer ring has 6, with each atom sharing 2 of its 6 electrons with the other. It is possible, however, for one of these oxygen atoms to gain an extra electron, like so:

Fig. 43



This can happen due to either normal physiological conditions or environmental factors. For example, during the normal processes in cells which result in ATP, oxygen undergoes a process which adds electrons to it in the production of water, but occasionally it doesn't get all it needs.

To become water, an oxygen molecule needs to get an additional 4 electrons. If it only gets one it becomes a superoxide anion, gets 2 it becomes hydrogen peroxide, and if it gets 3 it becomes a hydroxyl radical. This are commonly referred to as a free radicals, or radical oxygen species (ROS), and in too great a number they can become bad news.

These radicals can be created through unusual conditions including exposure to excessive radiation, stress, inflammation, smoking, alcohol, drugs, chemicals or even a poor diet. These radicals are not all oxygen-based, but the majority of free radicals you are likely to come into contact with are ones which have been produced endogenously through the manufacture of ATP.

These free radicals are highly unstable because of the additional electron(s), and this can cause problems. One of the main mechanisms for this occurring is that they can 'steal' an electron from one of the lipids on the lipid bilayer of the cell membrane. Free radicals can also oxidise proteins within a cell, and both of these processes can obviously harm the cell.

Crucially however, these reactive oxygen species can oxidise DNA, causing the kind of mutations that could lead to cancerous growth.

Furthermore, as you know, the oxidation of PUFA found in VLDL and LDL lipoproteins is one of the primary issues which can lead to atherosclerotic plaque.

The first defence against free radicals (oxidants) are antioxidants, which can effectively 'donate' an electron to them and render them inert, and therefore neutralise the issue. Antioxidants, therefore, are extremely important (even if, as we said, taking supra-physiological doses of them as supplements probably won't be of huge benefit, and as you'll see, you can get all you need from eating normal food, rather than spending your life savings on rare and endangered berries from the Guatemalan jungle).

Once incorporated onto the lipid bilayer of cells, vitamin E can neutralise reactive oxygen species effectively, converting itself into forms which are then collected and excreted in bile.

Levels of Vitamin E are relatively well regulated at high intakes, because to be transported to peripheral tissues in lipoproteins the molecules must be transported to the relevant areas by specialised binding proteins, and this process is self-adjusting according to intake. With that said, deficiency and toxicity are definitely possible.

Vitamin E deficiency can result in muscle and neurological problems, as well as a greater risk of diseases associated with oxidative stress including cancer, neurodegenerative diseases and atherosclerosis. As mentioned above, it is unlikely that someone would become deficient in the Western world, with deficiency generally only appearing in humans during times of famine or in the presence of conditions which impair absorption. With that said, it's worthy of note that those on very low-fat diets, or very low food intakes in general for the purposes of fat loss may be at some small level of risk.

There is very little data which can be collated to provide vitamin E recommendations, because incidence of deficiency is so rare. In fact, the means of determining intake which is most often utilised is by recommending an amount relative to the average population intake of PUFA (seeing as prevention of PUFA oxidation is probably the primary benefit of vitamin E), with the ration being 0.4mg of a-tocopherol per gram of PUFA.

UK guidelines of 2550 and 1940kcal per day for men and women respectively, each with an intake of PUFA at 6% of intake (so 17 and 13g each) have therefore led to a recommendation of 7 and 5mg of vitamin E for men and women. High intakes of Polyunsaturated Fatty Acids (PUFA) may justify a higher intake, and doses often 100-200mg of the synthetic all-rac-a-tocopherol are common, with no adverse effects. In fact, only doses of over 1000mg per day have ever shown toxicity (which presents as pro-oxidative action). Due to this ambiguity, no WHO RNI is established, and we will not be providing a table like the other vitamins.

In short, 7 and 5 mg are the minimum recommendations for men and women respectively, though a higher intake based upon a higher calorie intake or higher PUFA intake is wise, with around a ratio of 0.4mg of a-tocopherol per gram of PUFA being a reasonable starting place. Overdosing is unlikely without high-dose supplementation, but intakes of over 1000mg have been shown to cause harm.

Note: For reference 25g of almonds has around 7.3mg of Vitamin E, one whole avocado has around 2.7 and a large handful of raw spinach has somewhere around 7mg.

3.6.5. Vitamin K

Vitamin K is the final fat-soluble vitamin, the primary role of which surrounds blood clotting (in fact it's vitamin 'K' because the German word for coagulation starts with a K). As per all of the other fat-soluble vitamins so far, vitamin K refers to a number of different active molecules which have similar but subtly different structures. The group includes phylloquinone, phytonadione and others, but very little information exists to elucidate the actual metabolic differences between the different forms upon ingestion.

After ingestion, it takes the usual route which lipids take via lymphatic fluid and then blood to the liver, where it helps to manufacture a number of coagulation products including 'factors II, VII, IX and X' and carboxyglutamate (Gla) which arrest and prevent bleeding by forming blood clots and proteins C and S which do the opposite, by inhibiting blood clotting. Despite this seemingly juxtaposed set of functions, deficiency in vitamin K manifests primarily as a tendency towards excessive bleeding. Vitamin K also seems to be important for certain proteins involved with bone mineralisation, but the actual mechanisms here aren't very well documented.

After the vitamin K dependent procoagulants (proteins which **pro**mote **coagulat**ion) are synthesised in the liver, they are secreted in their inactive forms into the blood. In the presence of Gla and calcium these proteins are able to bind to platelets in the blood as well as cells on the inner lining of blood vessels, then when coagulation is initiated these start to form a clot. Protein C effectively blocks this from happening too early, and protein S helps make C more able to perform its job.

Vitamin K deficiency, as mentioned, can lead to excessive bleeding, with this presenting the greatest problem during the first 6 months of infancy. This deficiency is known as haemorrhagic disease, or more recently and more specifically vitamin K deficiency bleeding (VKDB). Maternal drugs which impact on absorption are the primary causes of vitamin K deficiency in infants though other underlying illnesses such as cystic fibrosis may also play a role. Primary sites for bleeding in infants include the intra-abdominal cavity, inside the cranium and within the GI tract, and all can be fatal.

Because of this, it is now common practice for infants to be given vitamin K supplementation if healthcare professionals suspect there is a risk due to low cumulative milk consumption (either breast or formula), very early births and other complications during labour. It has even been suggested that getting enough vitamin K via breastmilk is either very difficult or impossible, and as such an oral or intramuscular supplement is often prescribed.

In adults, vitamin K deficiency which results in bleeding is almost unknown outside of situations caused by underlying pathology, though a low intake can manifest as excessive bleeding when cut, due to a large amount of 'unfinished' procoagulant proteins in the blood which are unable to bind to calcium properly.

Excretion of vitamin K happens readily, with large amounts of that which is consumed being removed either in the urine or in faeces via bile, and as such oral dosing of the natural form doesn't seem to have an upper limit which is toxic. With that said, excessive intakes of synthetic forms given as supplements to infants have been known to lead to liver damage, which suggests an excessive intake does indeed exist, though this is as yet undetermined. What is known is that doses often 20mg or greater do not seem to cause harm, despite being an order of magnitude above the RNI, and it is unlikely that any harm would come at intakes of 1mg or less.

The best dietary sources of vitamin K are green leafy vegetables, olive and rapeseed oils, fermented foods including cheese and animal liver. Additionally, significant amounts of vitamin K are synthesised in the colon by various microbes which live there, including bacteroides, enterobacter and veillonella, all of which are 'fed' by a diet rich in vegetable matter.

Fig. 44

Population	RNI	UK RI
Infants (0-6 months)	5ug*	N/A
Adults	1ug per kg of bodyweight	1ug per kg of bodyweight

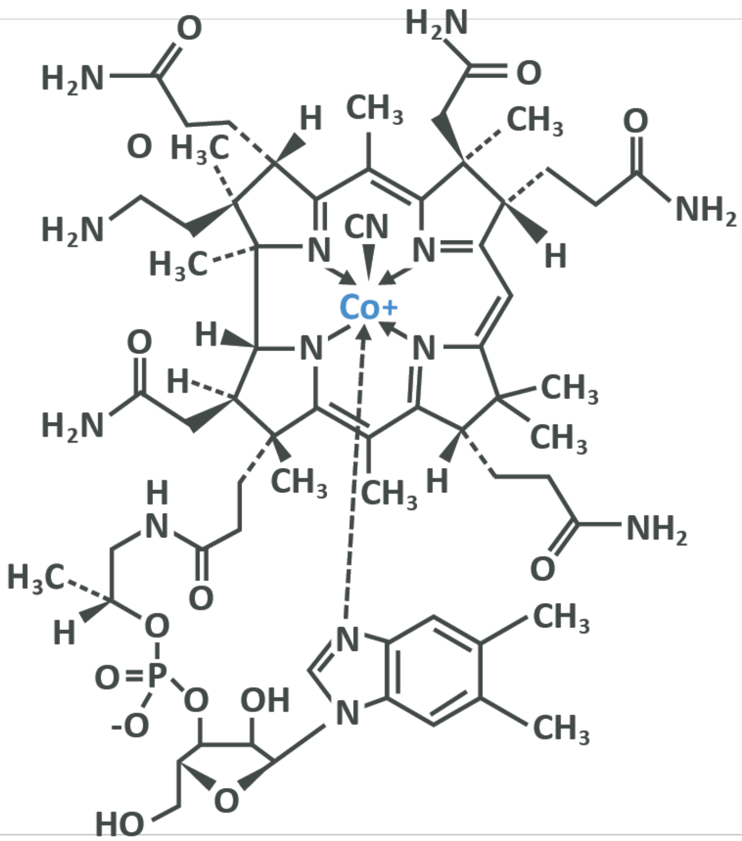
* As noted above, this may be difficult to get from breastmilk alone, as infants exclusively given vitamin K from breastmilk tend to get on average 7-13% of their needs daily. This seems to be independent of maternal vitamin K intake, and as such, supplementation via oral or intramuscular administration is often given.

Note: For reference, an 80g portion of raw kale has 444ug of vitamin K, spring onions have over 100ug and brussells sprouts have around 100ug.

3.7. Water-soluble vitamins

Water-soluble vitamins are water-soluble due to their molecular makeup. Unlike hydrophobic fat-soluble vitamins which have a non-polar structure, water-soluble vitamins have polar structures which means that atoms within them do indeed have an electromagnetic charge or a 'polarity' and this allows them to combine with the polar molecules which also make up water. The incredibly complex structure you see below is vitamin B12.

Fig. 45



Water-soluble vitamins are digested via your small intestine straight into your blood much like amino acids and glucose. From here they are transported to the cells that need them, and excessive amounts in your blood are generally excreted readily in urine. There are no long-term storage sites for water-soluble vitamins – you either use them or they are removed.

This means that toxicity from overconsumption is almost impossible and side effects are non-existent outside of those seen from extremely high supplemental intakes which may cause gastric upset (such is the case for vitamin C). Unfortunately, this also means that if you consume a very low amount for a relatively long period, your body will not have any additional stores to 'tap in to'. As such, daily intake is more important, and deficiency is a bit more of a realistic prospect.

The water-soluble vitamins can be further grouped together into the B vitamin complex and vitamin C. The B vitamins all have very similar functions in the body and are found in foods which have a lot of overlap between them, and as such have been historically considered together despite being chemically distinct. We will very briefly lay out the functions of the B vitamins, with the exception of B12 and folic acid which need to be considered in a little more detail, before covering vitamin C.

The B vitamins are all either cofactors or precursors to them, with the majority being co-enzymes. Co-enzymes, for example, are molecules which must be bound to an enzyme for that enzyme to be able to carry out the effect that it does, and as such the B vitamins can be considered generally to have the function of allowing cellular metabolism to occur efficiently.

3.7.1. Vitamin B1

Also known as thiamine. Needed as a coenzyme for the proper metabolism of pyruvate to acetyl CoA, meaning that it is key in the release of energy from glucose (the process of cellular respiration was covered in module 2). It's also involved in proper DNA production and is needed for your nerves to work properly. Deficiency is seen in people with diets that rely on milled rice and raw fish (milled rice is void of these nutrients, and raw fish contains compounds which prevent absorption). As such, it is still endemic in Asia.

The only other situations outside of limited food consumption or cases of related health complaints where deficiency is likely is in exclusively breastfed infants whose mothers are deficient, or in chronic alcoholism.

Deficiency can lead to a disease called beriberi. The WHO RNI is 1.1mg for women and 1.2mg for men, 1.4mg for pregnant women and 1.5mg for those who are lactating. The current British recommendations are 1 and 0.8mg per day for men and women respectively. Toxicity is not possible due to extremely rapid excretion times for overconsumption.

Good sources include vegetables, eggs and whole grains.

3.7.2. Vitamin B2

Also known as riboflavin. Deficiency is incredibly uncommon outside of situations of severely limited food intakes, or other clinical or genetic issues which prevent absorption. Riboflavin is needed during the processes which produce energy including the electron transport chain which extracts ATP from NADH+.

Deficiency can lead to hypo or ariboflavinosis, categorised by a sore throat, bruising in the back of the throat, and issues with immune function. Toxicity is not possible due to limited intestinal absorption.

The WHO RNI is 1 and 1.3mg per day for females and males respectively, rising to 1.4mg for pregnant and 1.6mg for lactating women. In the UK the recommended intake is 1.3mg per day for men and 1.1mg per day for women.

Good sources include milk, eggs and rice.

3.7.3. Vitamin B3

Also known as niacin. Niacin is used within respiration performed by cells and is also needed during the processes involved with DNA repair. Additionally, it's needed in fatty acid and steroid synthesis. Deficiency can lead to a condition called Pallegra, which involves diarrhoea, dermatitis and dementia. If untreated this leads to death.

Toxicity is unlikely but possible, so taking extremely large doses should be avoided – the TUL for Niacin is 35mg per day. Taking a large dose can also lead to skin flushes and heat (therefore sweating and vascularity), which is why it's often found in pre-workout supplements.

The WHO RNI for Niacin is 14 and 16 mg per day for women and men respectively, rising to 18 mg for pregnant and 17mg for lactating women. The UK recommended intakes are 13 and 17mg for women and men, respectively.

Good sources of Niacin include meat, fish, milk, wheat, sweet potatoes, squash, corn and eggs.

3.7.4. Vitamin B5

Also known as pantothenic acid. This is required for the oxidation of fatty acids and carbohydrates for energy due to its involvement with CoA. Deficiency is very unlikely, but can lead to postural hypotension, unusually elevated heart rate during exercise, constipation and hand and feet numbness.

Toxicity is unlikely.

The WHO RNI for B5 is 5mg per day for males and females, 6mg for pregnant women and 7mg for lactating women. The UK recommended intake is 5mg per day for both sexes.

Good sources include meat, poultry, green vegetables, sweet potato, cauliflower, eggs and wholegrains.

3.7.5. Vitamin B6

B6 is heavily involved in amino acid metabolism, steroid hormone breakdown and recycling, and energy production as well as haemoglobin synthesis (haemoglobin allows red blood cells to carry oxygen). Deficiency is extremely rare and symptoms are difficult to isolate as deficiency in B6 usually happens alongside deficiency in other nutrients. Immune function dysregulation, skin issues and potential decrease of brain glutamate metabolism are associated with extremely low intakes.

Deficiency is very, very rare, happening only in those on excessively restricted diets (it appears on eating disorder wards) or those who are on haemodialysis.

Toxicity is rare, but symptoms of neurotoxicity have been observed in situations where very high dose B6 has been used in the treatment of pre-menstrual syndrome (PMS), carpal tunnel and some neurological conditions. As such a theoretical TUL of 100mg has been adopted.

The WHO RNI is 1.3mg for males and females, though this rises to 1.5 and 1.7mg for females and males respectively after age 50. In pregnant and lactating women, the numbers are 1.9 and 2mg respectively. The UK recommended intake level is 1.4mg for men and 1.2mg for women.

Good sources include vegetables, beans, peanuts, eggs, potatoes and milk.

3.7.6. Vitamin B7

Also known as biotin, this plays a vital role in the metabolism of all three macronutrients owing to its function as a coenzyme of critical carboxylases, which are enzymes that add COOH groups to things during metabolic reactions.

Deficiency can be seen in those who consume a large amount of raw eggs (raw eggs have biotin-binding proteins call avidin which block absorption), babies fed formulae which haven't been properly formulated to contain enough nutrients and people with short-gut syndrome. Otherwise deficiency is very rare, though if it does occur it is detectable by dermatitis, conjunctivitis, alopecia, lethargy and developmental delays in infants.

Toxicity is not a problem due to limited intestinal absorption.

The WHO RNI for Biotin is 30ug per day for men and women including pregnant women, rising to 35ug during lactation. The UK the recommended intake is 30ug.

Good sources include eggs, almonds, cheese, mushrooms, sweet potatoes and spinach.

3.7.7. Vitamin B9

Also known as Folate, derivatives function in the transfer of carbon from donor molecules to others in metabolic reactions, and are used in DNA production, in the formation of the neurotransmitters that allow your nervous system to communicate, in the production of white cells and red blood cells and in amino acid metabolism.

Deficiency is surprisingly common, not least of all because the natural forms of folate are highly unstable and may become less active during harvesting, transport, storage, processing and cooking of foods. Synthetic supplemental folic acid is far more bioavailable and stable. Deficiency can lead to megaloblastic anaemia (enlarged red blood cells) and elevated levels of homocysteine (a by-product of other metabolic processes). Elevated homocysteine levels can lead to a number of issues including thrombosis and fractures.

Finally, a deficiency in folate present in pregnant women can lead to severe birth defects including spina bifida.

The WHO recommends 400ug per day for men and women, rising to 600ug in pregnant women and 500ug in those who are lactating. In the UK the recommended intake is 200ug per day.

The general recommendation is for women who are pregnant or planning on becoming pregnant take a 400ug folic acid supplement every day. Speak to your GP if you are, or are planning on becoming pregnant and they will be able to advise about this.

Good food sources include dark green leafy vegetables, flaxseeds, mango and avocado, though a lot of dietary folate is consumed via fortified cereals and breads.

It's unlikely that dietary folate intakes would ever reach toxicity, but supplemental folic acid should not be taken in amounts over 1mg. In fact, doses of higher than 1mg can disguise deficiency of vitamin B12 because elevated folate levels can reduce the size of the megaloblastic red blood cells caused by B12 deficiency. This is a potential issue for those susceptible.

3.7.8. Vitamin B12

B12 aids folate in cellular reproduction. B12 is also crucial in homocysteine utilisation and metabolism and it is essential to the production of healthy red blood cells. A deficiency of vitamin B12 can lead to subacute combined degeneration which is a permanent and debilitating degeneration of the posterior and lateral columns of the spinal cord. This results in loss of function in extremities, cognitive issues and worse.

Alongside this B12 deficiency can lead to megaloblastic anaemia and the associated weakness and fatigue. This can be masked by excessive folate intake, which will then leave the former condition to manifest unbeknownst to the individual until it is too late, which is an all-too stark reminder to be careful when super-dosing vitamins or consuming an unbalanced diet.

B12 is extremely well-sourced from animal products, but there are no plants which synthesise it meaning that vegans are at severe risk of deficiency. Marmite, kimchi and some other fermented foods are the only vegan sources and therefore, unless these are eaten daily, a vegan should supplement with this nutrient.

The WHO RNI is 2.4ug per day for men and women, rising to 2.6ug for pregnant and 2.8ug for lactating women. The UK recommended intake is 1.5ug per day. Excessive intake will not cause toxicity as excretion is very rapid.

Good sources include almost animal products including eggs and dairy, fortified breakfast cereals and marmite.

3.7.9. Vitamin C

Also known as ascorbic acid. Its main role is as an antioxidant, though it is also used in collagen synthesis. It also enhances iron uptake and thus is frequently prescribed with iron supplements. 25mg of vitamin C with meals can increase iron availability by 65% (this is present in a very small serving of most vegetables) and therefore those supplementing with iron should take this with meals.

Vitamin C is necessary for collagen synthesis and production, so it can be very important in recovery and injury cases as collagen is a key ‘ingredient’ in connective tissue. Extreme deficiency is well known for causing the excessive bleeding condition known as scurvy, categorised by bleeding gums, loose teeth and bruising.

Although vitamin C is useful for fighting off illness, there is no good evidence to suggest that super-dosing it is good for reducing cold symptoms, and it’s unlikely that consuming a large amount improves injury recovery due to rapid excretion times after overconsumption. In fact, large-doses of vitamin C can cause GI distress.

The WHO RNI is 45mg per day, rising to 55mg and 75mg for pregnant and lactating women respectively. The UK recommended intake is 40mg. The suggested TUL is 1000mg.

Good food sources include citrus fruits, peppers, berries, dark green leafy vegetables, white potatoes and blackcurrants.

3.8. The minerals

Minerals are chemical elements required by organisms to perform vital functions. Plants absorb these minerals from the soil, and when these are later consumed by animals they are stored within its flesh. Upon consuming animal products, plants or indeed water, humans can ingest all of the minerals they require.

Minerals can be broadly separated into macrominerals and trace minerals, called so because the macrominerals are required in large amounts and the trace minerals in far smaller amounts. We will start with the macrominerals.

3.8.1. Magnesium

The human body at birth contains around 760mg of magnesium, rising to around 5g at 4-5 months of age and 25g in adulthood. 30-40% of this is found in muscles and soft tissue, 1% in extracellular fluid and the rest being found in bones.

Soft tissue magnesium is a coenzyme involved in energy metabolism, protein, DNA and RNA synthesis and is used in the transfer of electrical signals around the body. It's also important for maintaining cell membrane integrity and has a role maintaining potassium and calcium levels in cells (which are used to transfer information and perform numerous functions including muscle contractions and motor unit innervation). Because of this, magnesium can be considered vital for maximal exercise performance.

Deficiency can result in muscular weakness, lethargy, nausea, unwanted weight loss and sleep issues. On top of this, hyperirritability, muscle spasms/cramp and even cardiac arrhythmia can result from prolonged deficiency. In the short-term, magnesium loss is associated with poor exercise recovery. Maintaining healthy magnesium levels is associated with a protective effect against both depression and ADHD.

Undergoing repeated strenuous exertion, especially in the heat, can make us very susceptible to these problems if we don't pay attention to what we eat, as magnesium can be lost in sweat.

Serum magnesium levels have also been positively related to maximal muscle contraction ability, since the reactions involving the build-up and the breakdown of ATP, ADP, and creatine phosphate are Mg dependent. The effect of magnesium levels on the high-energy phosphates have been repeatedly investigated in the quadriceps muscles in states of varying hypomagnesaemia in man, and a significant lowering of contraction ability/force generation has been found, as compared with normal, non-magnesemic controls in men.

A WHO report recommended that magnesium intake could be considered as a function of mg per kilogram of bodyweight, or as a recommendation of mg per calorie consumed. They did contest, however, that recommendations at present are based potentially upon some amount of estimation.

What is noteworthy is that in theory magnesium absorption is well controlled and therefore toxicity is unlikely, though due to reduced absorption with high intakes, diarrhoea can ensue.

The WHO Recommendation is 4mg per kilogram for males and females, dropping to 3.5mg per kilogram after age 65. Due to magnesium's functions within exercise, athletes have been known to supplement it at higher doses but a lot more evidence is needed before it could be concluded that high-dose magnesium supplementation has any benefit to exercise performance.

However, magnesium is one of the most common deficiencies in the Western World, and a 200-400mg supplement of magnesium (there are many forms, but citrate is one of the most effective) is not a bad idea for those most at risk of deficiency, including those on restricted calorie intakes and athletes. As always, though, before using supplementation consider whether deficiency is **actually** likely, we will discuss how to do this at the end of this module.

3.8.2. Potassium and sodium

Potassium accounts for around 0.2% of the weight of a human body, and its ions are present in a huge amount of proteins and enzymes used for normal function. Potassium performs a colossal amount of functions, but the key reason you need to be aware of it is because of its impact on total body water homeostasis. Potassium is present in green leafy vegetables, and is also found in large amounts in low sodium salt alternatives.

Sodium is most commonly consumed in table salt (sodium chloride). Much like potassium it is one of the prime minerals relevant to health and nutrition, and although it has been commonly demonised for causing high blood pressure, this needs to be taken into context with a few different factors.

In nerve cell membranes, a ‘sodium/potassium pump’ transports 3 sodium ions outside of the cell and 2 potassium ions back in. Ions carry an electrical charge, and this exchange leads to a disparity between the charge inside and outside of the cell. This creates what is known as an ‘action potential’ and is the main way which nerves are able to communicate.

As mentioned, though, the key reason you need to consider sodium and potassium in an applicable sense is because of their role in body water level management. This will be explained in far greater detail in the module on hydration, but for now consider that the recommended intake for potassium is 3.5g, and the recommended upper limit for sodium consumption is 2.4g per day. Though a maximum intake of sodium is given, this should NOT be taken as meaning that less is better or that the ideal amount is zero or as little as possible. Both of these minerals are crucial for survival.

Like we mentioned, however, this will be covered in detail when we talk about hydration.

3.8.3. Chlorine

Chlorine is crucial for the production of the hydrochloric acid which plays a role in stomach digestion. Aside from this, it’s a key player in cellular functions including allowing things to cross the cell membrane. The recommended daily intake is 3.4g which will be consumed almost entirely from sodium chloride (table salt).

3.8.4. Calcium

Calcium is probably best known for its role as a component of bones, though it is also vital for heart function, digestive health and the contraction/relaxation of muscles. On top of this an adequate calcium intake is needed for the proper function of blood cells. Deficiency in calcium can lead to cramping and muscle spasms as well as bone weakness. The Recommended daily intake for calcium is 1000mg, though the upper limit of 2500mg should not be exceeded as this can cause constipation and impair iron and zinc absorption.

The majority of calcium you consume will be via dairy, though calcium can be consumed from vegetable products such as broccoli and kale. It's worthy of note that many vegetable sources of calcium contain oxalic acid which can block calcium absorption, though, and as such a vegan client may wish to look at tofu or fortified milk alternatives.

3.8.5. Phosphorus

The final macromineral is phosphorus, which is a component of bones just like calcium but on top of that it is used to make phosphate, which is a critical part of DNA, ATP and other molecules. Generally, the majority of phosphorus you consume will be via protein-containing animal products such as meat, poultry, fish and dairy. Plant based phosphorus is harder to absorb, so again this is a mineral which vegans may need to be aware of. Phosphorus RNI is 550mg/day.

3.9. The trace minerals

The following are needed in miniscule amounts, but that shouldn't be taken as a detraction from their importance. Without these, you'll be in a bad place!

3.9.1. Zinc

Dietary zinc is important for the skeleton and under-consumption can lead to osteoporosis. Primarily, though, zinc is a cofactor for over 100 proteins and enzymes, being vital for many enzymes that are involved in the synthesis of RNA and DNA, meaning it's vital in gene transcription and recovery as-well as being vital in the hormone receptors for vitamin D, oestrogen and testosterone.

Zinc is also a vital component in superoxide dismutase, a key antioxidant enzyme and regulation of other antioxidants. Zinc also effects carbohydrate metabolism, causing (if deficient) impaired glucose tolerance, due to a reduced ability to secrete insulin from the pancreas in response to oral glucose load. Low zinc can also be a factor of low testosterone due to its essential role in testosterone and sperm manufacture. Recommended amounts are 15mg per day, but no more than 40 as this can impair absorption of other minerals. Primary sources are oysters, meat, poultry, whole grains and nuts. While deficiency is not common, vegan diets do lead people to be at risk.

3.9.2. Iodine

Iodine is a trace mineral with big implications for our health, especially of the thyroid. It's essential for synthesis of thyroid hormones and a deficiency can lead to development of a goitre. Although most people would assume deficiency is relegated to developing nations (due to adding it to table salt), recent research has found deficiency in places like the UK and France where adding regular table salt to food has fallen out of favour due to table salts high sodium levels. Adding in small amounts of table salt or low-sodium salt (rich in potassium) to your diet should cover your iodine need, but check the label to ensure the salt has been iodised. The recommended intake is 150ug, with no more than 1.1mg (1100ug).

3.9.3. Iron

The main function of iron in health is that it is required for numerous proteins and enzymes including haemoglobin, meaning that a deficiency can easily lead to anaemia and the associated weakness/lethargy. Key sources of iron are red meat and seafood, with vegetarian options including nuts, beans and dark chocolate. Plant based iron is often in smaller doses, and is also harder to absorb, though, making this another key nutrient for the attention of vegan clients.

Furthermore, females during their menstrual cycle have a greater need for re-synthesising red blood cells and therefore require an elevated iron intake. The recommended amount for men is 8.7mg per day but for women it is 14.8, with potentially higher amounts needed for those with particularly regular or heavy periods (though the TUL is set at 45mg). If you are concerned regarding your iron levels, speak to a doctor.

3.9.4. Copper

Dietary copper is used in the production of many redox enzymes, including those used during the processes of the electron transport chain and therefore vital for energy production. The recommended intake is 2mg per day, but no more than 11mg. Common food sources include seeds, nuts, green vegetables, mushrooms, beans, liver and lentils. Deficiency is very rare, however.

3.9.5. Manganese

Another important coenzyme involved with proper bone function, joint health, skin health and fertility. Deficiency is rare as food sources include nuts, seeds, wholegrain bread, wholegrain rice, vegetables and even brewed tea. 2mg is the recommended amount, but taking in over 350mg can lead to manganism, related to neurological issues including irritability, mood swings and compulsive behaviour. Long-term manganism can lead to symptoms similar to idiopathic Parkinsons disease.

3.9.6. Selenium

Selenium is vital for the proper functioning of enzymes with antioxidant effects. One of these, glutathione peroxidase, can effectively protect against the kind of oxidative stress associated with atherosclerosis and as such a deficiency in selenium could potentially increase risk. It’s found in large amounts in brazil nuts, dairy, eggs, meat, grains and seafood. Selenium RNI 75ug for men, 60 for women.

3.9.7. Molybdenum

Molybdenum, found in legumes, whole grains and nuts, is vital for the proper functioning of enzymes involved with the oxidation aspects of energy production in the electron transport chain. The recommended amount is 75ug but no more than 2mg (2000ug).

3.9.8. Chromium

Chromium is used in the body during glucose and lipid metabolism, but as yet the amount needed for optimal health and the TUL are ill-defined. The recommended amount is around

120ug for now. It's found in broccoli, meat and whole grains amongst other leafy vegetables.

3.9.9. Cobalt

While technically a trace mineral, this can be synthesised by gut bacteria along with vitamin B12 and is in fact often considered to be part of the vitamin

3.10. What do we actually do with this information?

As you can see, there is a **huge** amount of information here. We have broken down the key information surrounding each vitamin and mineral, and we have extrapolated on this where it may be either relevant, important or interesting, but at the same time it is very possible to look back over all of this information, all of the recommended intakes, and wonder where on earth you are supposed to start.

We hope we have given you the impression that every one of these micronutrients is important, and have shown you how a deficiency, or even a sub-optimal intake for any of them can be hugely problematic, harmful or potentially fatal, but at the same time we want to confer one more piece of key knowledge: **it is not necessary to track all of this.**

While tracking your macronutrient and/or calorie intake can be a very valid means of ensuring your food intake is 'on point', there is almost no realistic way to ensure you get all of the micronutrients you need every day by tracking. The amount of information you would have to check and retain is enormous, and more than that, it isn't always even necessary.

The fat-soluble vitamins can be stored for use later, as can many of the minerals which may be stored in bone or other tissues. This doesn't mean that it's **ok** to only eat them occasionally, but at the same time you don't need to consume them all every day without fail. On top of that, nutrient deficiencies don't happen overnight – you aren't that delicate. If you spend a week on holiday eating junk food you will not come home with scurvy or osteoporosis.

With that being said, it **is** important to ensure that in general, on average, you are indeed getting all of the micronutrients you need to be in top health. Adhering to the UK recommended guidelines is what we advise, with a potentially higher intake for vitamin D and maybe a larger intake of magnesium if you are in an exercising population.

3.11. How do you ensure that you are getting all you need?

Look across all of the nutrients and you will spot a trend. There is a lot of crossover in the foods which you will see nutrients pop up in:

- Dark green leafy vegetables
- Whole grains
- Legumes
- Nuts
- Seeds

- Red meat
- Dairy
- Organ meats
- Eggs

Effectively, you will consume enough of everything so long as you are eating a well-balanced and highly varied diet. If you are concerned or just want to be sure, a great tool is chronometer.com which allows you to track micro as well as macronutrients. Using this every day is not necessary or recommended, as we mentioned, but adding in a typical 2-3 days of food to see where your numbers average out is a very good way to double check that there's nothing glaring.

If you find that one of the nutrients is always low, this is where you can make deliberate dietary adjustments to suit.

Again, to re-address the point and drive this home – eating a diet which is calorie appropriate will ensure you achieve the weight loss/gain you desire, making sure your protein intake is adequate, fat intake is appropriate and carbohydrate intake is where it should be will also go a long way towards granting you the body composition you require (possibly alongside resistance training) and then by always being mindful of dietary balance, variety and colour (the colour of a food is a quick method of guessing it's nutritional content in that two fruits/vegetables of different colours will offer at least **some** different nutrients) will go a very, very long way towards making you as healthy as possible and avoiding deficiency, either low level or clinical.

3.12. Who should pay a little more attention?

With the above in mind, we do need to mention that those who do not consume a well-balanced diet may need to pay more attention than others. Those who are lactose intolerant do not consume a balanced diet by definition as they do not consume dairy, meaning calcium should be something they are mindful of.

- Vegans will not be able to get vitamin B12 from many foods, and on top of that plant based calcium, iron, zinc and many others may fall short of needs
- Those consuming low carbohydrate diets or shunning grains put themselves at a greater risk
- Those who avoid table salt in all forms may need to be careful
- Pregnant women or those who are lactating, as you have seen, may require a lot more of certain nutrients than they ordinarily would
- Those who have had gall bladder removal and therefore cannot consume large amounts of dietary fat at meals may need to consider additional fat-soluble vitamins
- Individuals on a very low calorie diet are at obvious risk of consuming fewer nutrients

- Athletes or those under intense physical stress will place their body under higher demand which may warrant additional nutrients. Speak to a doctor for a blood test if you are concerned
- Anyone with any medical conditions may be at risk. Ulcerative colitis can block absorption of certain nutrients, the medications for epilepsy and others can create malabsorptive states
- People eating restrictive diets due to taste (many people do not eat nearly enough vegetables) may need to consider supplementation until this can be rectified. If this is you, start slowly by gradually increasing the range of vegetables you like

In none of these situations is it impossible or even practically difficult to achieve an optimal nutrient intake, but that's not to say it will happen by accident. If for any reason you do not consume all of the food groups, macronutrients or otherwise, if you are using medications or if you have any reason to think that you are at an elevated risk of deficiency compared to the majority of the public, our advice is to speak to your GP. Nutrient deficiencies are relatively easy to diagnose with a blood test, and doing so can help you to adjust your nutrient intake either through foods or with supplements.

For the rest of us, consuming a diet which is varied, wholesome and rich in as many whole, unprocessed foods as possible (this is not to discount the benefits of some fortified foods, but rather to emphasise the importance of consuming a large amount of unprocessed and whole foods in their unrefined state) will almost certainly ensure you get all that you need.

In the next module, we will be discussing hydration and fibre.

3.13. References

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