BTNacademy

MODULE 4

HYDRATION AND FIBRE

4. MODULE 4: HYDRATION AND FIBRE

4.1. Module aims

Fibre

- To describe dietary fibre and explain its function in health, nutrition and dietary adherence
- To provide examples of foods high in fibre
- To give a recommendation for total fibre intake
- To outline the risks of low or excessive intakes
- To give practical tips on increasing low intakes

Hydration

- To give the role and importance of hydration
- To highlight how easy it is to become dehydrated
- To explain the role of salts in hydration and water balance
- To give practical tips for staying hydrated

4.2. Key principles from module 3

Briefly, before we begin, we wish to recap the key principles from last module:

- The micronutrients are things which we must consume to maintain good health and normal bodily function, but which are consumed in very small amounts and which are not used to make energy directly, though they may play a role in extracting energy from the macronutrients
- Vitamins are small organic compounds necessary for normal function which cannot be synthesised endogenously (though vitamin D can indeed be synth-esised on the skin)
- Minerals are inorganic elements which must be consumed to maintain proper function
- Each must be consumed in a certain amount per day, though the amount needed for consumption to avoid deficiency is not necessarily the same as the amount which should be consumed for optimal health. Likewise, consuming 'as much as possible' can be equally poor for health
- Vitamins A, D, E and K are fat-soluble, meaning that they can be stored in the liver and fat tissue for later use so clinical deficiency is rare but in general toxicity is more likely
- Vitamins B1, B2, B3, B5, B6, B7, B9, B12 and C are water-soluble and should be consumed every day where possible, though of course one day here and there won't make a difference

- Of the minerals calcium, phosphorus, magnesium, sodium, potassium, chloride and sulphur should be consumed in larger macro amounts than the trace minerals which include iron, manganese, copper, iodine, zinc, cobalt, fluoride and selenium. The relative amount of each we require does not mean that they aren't important
- Vitamins and minerals have diverse roles, but in general they work as antioxidants, as hormone-like cell modifiers or as co-enzymes which allow normal metabolic events to occur as they should. Many vitamins and minerals have alternative roles, but these are the most common
- The vast majority of micronutrient needs can be mindlessly consumed by people who do not have underlying issues which impact on absorption by simply eating a well-balanced diet that is varied often
- If you or a client don't eat a balanced and varied diet, we discussed means by which you can ascertain the likelihood of a deficiency, but also mention that if you are concerned a full blood panel should be able to tell you how likely this would be

We feel it is also important to recap that so far in this manual we have discussed the means by which you can calculate your energy, macro and micronutrient needs while also providing context for these recommendations based upon the latest research, as well as long-understood biological facts. We have broken food down into it's constituent parts and explained how and why each part should play a role in the diet of any individual looking for health and/or body composition improvement. In this module we will be discussing two topics which are paramount in creating a successful healthy eating plan, but which are often considered as side-thoughts.

Hydration and fibre are two facets of a dietary approach that are not only interesting, but of vital importance. Without sufficient fibre and with improper hydration you will not be in optimal health, and more than that, you will not be able to perform to your ability either in sport or the gym, or in places of work or education where mental sharpness is needed.

Recall the pyramid from module 1? Fibre and hydration appear on the 4th tier from the bottom. This is simply because of one thing – if macronutrient intakes and food choices are optimised, fibre should be more or less covered already. In fact it is fibre content which should dictate at least some of the food choices you make!

4.3. Introduction to hydration

What we will now turn our attention to is the thing which makes this transport, absorption and metabolism possible, the aqueous solution in which it all happens – water.

Water is essential for life, and maintaining hydration is important for physical and mental performance. The human body is largely made of water and generally the percentage ranges from around 75% in babies to 60% in adults, and slightly less in the elderly. This of course fluctuates due to certain hormonal conditions, hydration statuses and stages of the menstrual cycle.

Although we can live for up to 50 days and sometimes even longer without food, without water we will survive only a few days even in a cool climate. This is because bodily water is lost every day and without replacing it, the body is unable to perform its normal functions. The water your body stores is the medium in which the majority of nutrients, both organic and inorganic, are absorbed or transported to cells. Then when those nutrients are absorbed into the cell they are taken into the water-filled cytoplasm and involved in various metabolic processes which, themselves, require water to properly occur. No water, no life.

The body isn't just a homogenous sack, though, so we cannot just think of water as being 'in the body'. **Where your body's water is,** can be just as important as how much there is.

Water within the body can be considered to be in one of two separate compartments. The intracellular water is held within cell membranes and the extracellular water is, as you would expect, found elsewhere, outside of cell membranes. Around ⅔ of the water within your body is intracellular and the rest is found either within the plasma (in your blood) which transports things around your vascular system or the interstitial fluid which includes the water which surrounds all bodily cells and fills the lymphatic system. The lymphatic system is a complex network responsible for facilitating the passage of nutrients and metabolic products in between cells as well as helping move metabolic by-products to areas where it can be secreted. You may have heard of lymph nodes during medical examinations – these are areas where lymphatic fluid collects before draining into the urine or other areas for excretion.

Plasma volume is the amount of water which is held in your blood. As it increases so does your total blood volume and it is for this reason that hydration and blood pressure are closely and crucially linked.

To maintain optimal health, it is not only necessary to ensure that total water content within the body is maintained within given parameters, it's also valuable to ensure that the water is in the correct places. The maintenance of this balance involves a few different systems including your heart/vascular system, brain/central nervous system, your kidneys/ renal system and your lungs/respiratory system.

4.3.1. Maintaining fluid balance

In terms of what you as an individual can do, water balance is maintained for the most part by consuming water, water based beverages and water containing foods such as fruits, yoghurts and some vegetables. This is important because every day you lose a significant amount of water even without exercising or profusely sweating.

During a typical day at a normal, comfortable temperature, a 70kg individual can lose around 1,400ml of water through urine, 100ml in sweat, 200ml in faeces and up to 600ml in your breath.

In day-to-day life, your hydration status is regulated very well by the sensation of thirst, which exists as a homeostatic mechanism, driving you to seek fluid. Later we will make recommendations for ideal water intakes, but for now let's explore what we really mean by hydration and water balance because as you will soon see, to be optimally hydrated is not simply a case of drinking a lot of water all of the time.

4.3.2. Osmosis and filtration

Two of the primary means by which your body maintains proper balance between the water in your blood and the water surrounding your cells are osmosis and filtration. This is important because if there is too much water in your blood then your blood pressure will rise which can have serious consequences. On the other hand, if there is too much extracellular water you will have unpleasant subcutaneous water retention and this can lead to damage in some tissues.

Note: As a quick primer before we continue, a solute is something which has been dissolved in a liquid, like sugar in water, as opposed to just mixed in like sand in water. Solute concentration simply denotes the amount of a given solute in a certain amount of liquid. For example, you can mix 1g of sugar into 100ml of water and have a comparatively low concentration solute, or you can mix 70g in and have a thick, syrupy, comparatively high concentration solution. Note that the concentration is specific to the solute, however, so while this mixture is a high sugar solution, it is a low salt solution.

4.3.3. Osmosis

There are many membranes within your body which are permeable to water-based solutions, with cell membranes being by far the most common.

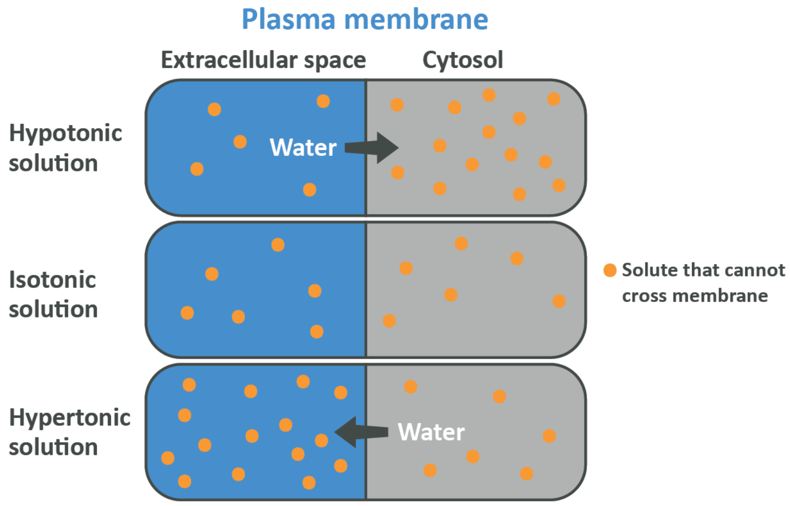
The cell membrane is the outer surface of the cell which allows it to maintain a specific internal environment which is optimised for its own function – consider this in the same way that a fish tank keeps the internal environment ideal for fish life by separating it from the external, air filled environment which isn't conducive to fish's survival. Cell membranes are permeable to water and many solutes, but this permeability is selectively controlled – they 'get to decide' what goes in and out. This means that cells which are permeable to water can maintain a different concentration of solutes on one side to the other and this creates what is known as an osmotic gradient. When this happens, there is a net movement of water between the high water (low solute) side to the low water (high solute) side. This can be considered like a process of diluting the side which has the high concentration.

This is called osmosis, and the difference between concentrations of a given solute on one side of a membrane vs. the other can be calculated as the osmotic pressure (expressed as mmHg, or millimetres of Mercury which is the manometric measurement of pressure). We won't go into specific osmotic pressures because they aren't needed, but it's an important concept to grasp.

Note: When a membrane is freely permeable to a solute (as in, it just goes in and out in this case without the cell being in control), it does not count towards the osmotic pressure of a given solution. This is because rather than water being forced to rush from one side to the other, the solutes themselves can evenly disperse on either side. As an example, urea (which is a waste product of cellular processes) will therefore be found inside cells at a higher concentration than the surrounding water, and is able to cross a membrane easily and disperse, but many proteins are not, meaning that the latter does but the former does not contribute to an osmotic pressure.

You may have heard the words hypotonic, isotonic and hypertonic before. In the context we are speaking about, a hypotonic solution has less solute than the environment within a cell, an isotonic one is the same and a hypertonic one has more. Here's a handy image to help you conceptualise what we are talking about.

Fig. 46



4.3.4. The role of sodium and potassium in hydration and osmosis

Sodium and potassium are two inorganic molecules which carry a positive electric charge. Because of this charge they are often referred to as electrolytes (they aren't the only ones but are the most important for this discussion).

Sodium and potassium can pass freely across a cell membrane, but the cell then 'takes control' of the relative internal and external concentration of each for a very particular and important reason. Each cell is equipped with millions of sodium-potassium pumps which are small proteins on the cell membrane, able to pump 3 molecules of sodium out and 2 molecules of potassium into the cell repeatedly to maintain a given ratio – very high intracellular potassium and very low intracellular sodium with the extracellular environment reflecting the opposite. This ratio creates an electric charge necessary for a variety of functions, but also creates an osmotic pressure. The osmotic pressure in each direction must be kept equal, however, or the cell itself would either shrink or explode because of water rushing out or in respectively. This means that your intracellular and extracellular environments must be fine-tuned to maintain a given ratio of potassium and sodium, and in a broader sense it means that there is an optimal level of intra and extracellular water.

It can be considered that sodium is the key extracellular electrolyte responsible for extracellular water levels, and potassium is the key intracellular electrolyte responsible for intracellular electrolyte levels. If the body's potassium stores dropped leaving the cell with less potassium than it should have, then the osmotic pressure would result in the cells becoming dehydrated and your body would need to remove sodium to address the balance. The opposite is true too. If sodium levels dropped too low then the cells would be prone to hyper-hydration so sodium levels would need to be increased (this can happen thanks to stores on your bones, or by salt-cravings) or potassium levels reduced.

As you can see, balance between potassium and sodium is just as important as the balance between water intake and excretion.

4.3.5. Filtration

For water to leave the plasma and enter the interstitial fluid it must leave via capillary beds.

Note: Remember your heart pumps blood out through arteries to the body. The blood travels through these arteries, into smaller arterioles and finally to minuscule capillaries which spread out over tissues to maximise the surface area which can supply nutrients. This spread-out area is called the 'capillary bed'.

Capillaries have a very thin, permeable wall and so things diluted in the blood can pass out of them quite easily, and things can also be diluted into the blood from the tissues at this point before being passed to various areas in the body which excrete them.

After the capillaries have been in contact with their target peripheral tissue, they merge again into venuoles, then veins, then the blood returns to the heart.

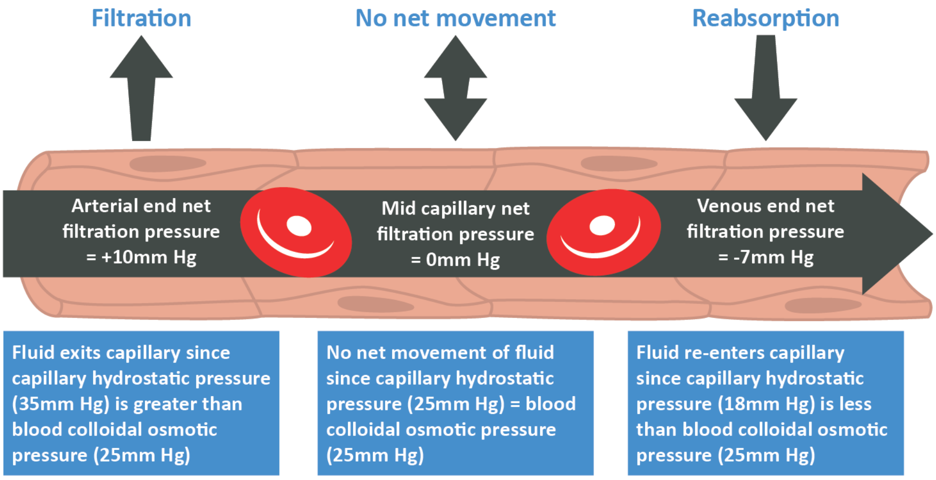
The pumping of the heart creates hydrostatic pressure (expressed as mmHg also) in the capillaries carrying blood to tissues, and this means that at the arterial end of the capillary bed the fluid is forced out, effectively increasing interstitial water. Because red blood cells and some other proteins necessary in blood are comparatively large, they are unable to leave the capillaries, meaning that only the water and smaller solutes therefore increasing the protein concentration within the capillary (there is less plasma water left in the capillary, so the concentration is higher). Think of this like a hose with a hole in – if you narrow the end of the hose, the water comes out of the hole at a higher pressure. At the other end of the bed, closest to the veins, the hydrostatic pressure is less as a lot of liquid has been removed but concentration within the capillary is now high, which will then cause water to re-enter the vascular system via osmosis and be returned to the heart.

Blood reaches the bed at high pressure and water leaves. At the other side of the bed the pressure is less, but the concentration gradient is large so water re-enters.

As you may have already deduced, the amount of water which travels from one side of a membrane to another is determined by the cumulative pressure between all different osmotic pressures **and** hydrostatic pressure. The pressures may come from both sides of the membrane, and water will travel in the direction where the pressure is most strong.

How this works in a capillary bed is summed up in the picture below.

Fig. 47

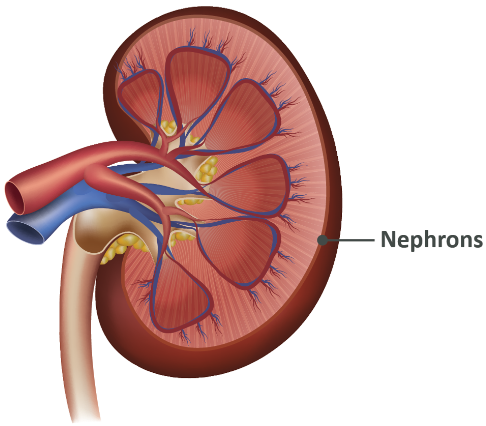


4.3.6. The role of the kidneys

Of all the organs and bodily systems involved with fluid and electrolyte balance, it is by far the kidneys that play the largest role.

The functional part of the kidney is a small yet complex structure known as the nephron, with each kidney having somewhere in the range of 1-1.5 million, of these units located along the outer edge of the main kidney body.

Fig. 48

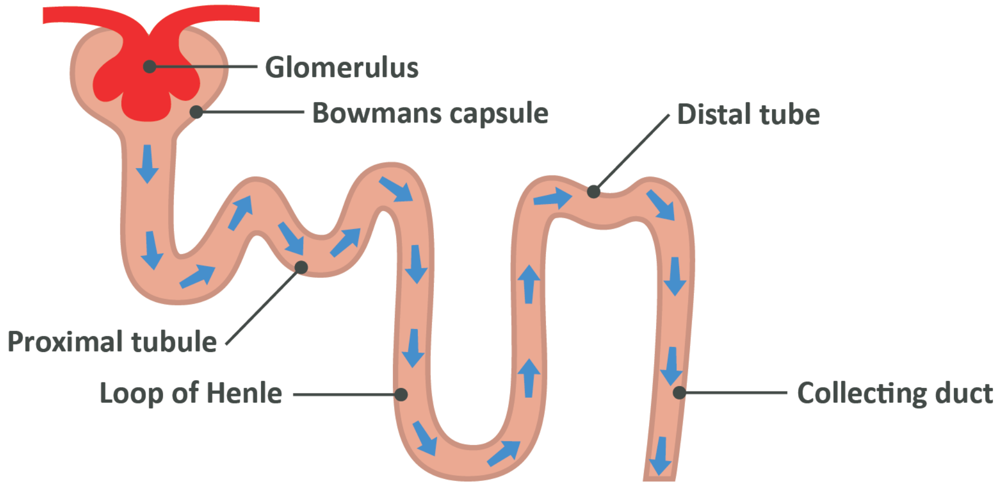


Each nephron (see previous diagram) is broken down into five compartments:

- Bowman's capsule
- The proximal convoluted tubule
- The loop of Henle
- The distal convoluted tubule
- The collecting duct

Note: Proximal means closest to, distal means furthest from, here these terms denote distance from Bowman's capsule.

Fig. 49



Around 25% of the blood pumped from the heart is sent directly to the kidneys, which should show you how important this process is, seeing as the kidneys make up far less than 1% of the body's actual weight. This blood reaches the nephron via the capillaries which converge into a complex referred to as a glomerulus.

Glomerular capillaries are a little different to the above capillary beds, which would be more typical in muscle tissues or the lungs for example. In the glomerulus both sides are arterial with an afferent arteriole carrying blood in and an efferent arteriole carrying it away which is smaller in diameter. This setup functions to keep the pressure in the glomerulus around three times as high as it is in other capillary beds, which is key, as around 130ml of blood per minute is filtered through the kidneys, or around 187 litres per day. Because of this pressure, the filtrate which leaves the blood doesn't get re-absorbed at the other side of the capillary bed but instead makes its way through the nephron for processing.

Of course, you don't urinate 187 litres of water per day, and that is due to the nephron's ability to re-absorb water and solutes. At various points through the tube, capillaries which surround it will re-absorb water and solutes via osmosis and put them back into the bloodstream for use, so only around 1400ml of water per day is filtered from your blood and removed. After they have been re-absorbed, the plasma and solutes dissolved in it simply return to normal blood flow.

Blood goes to the nephron, is non-discriminately filtered and then the things that the body needs are re-absorbed with the rest being urinated out.

In fact, it is by altering the rate at which electrolytes and water are re-absorbed in the nephrons that your body can precisely alter the amount of water and electrolytes which become present in the plasma. This is how your body regulates your blood pressure and is also how you maintain proper fluid balance between intra and extracellular compartments.

As a final consideration, it must be remembered that when sodium is being re-absorbed from the nephron this necessarily increases the concentration in the local capillaries to a higher level than that within the nephron itself, and vice versa when sodium reabsorption is restricted. This creates an osmotic pressure which impacts the way that water travels across membranes.

In very basic terms, as far as reabsorption from the kidneys goes, water follows sodium and if sodium reabsorption is increased or decreased, so is water reabsorption to suit. We will come back to this.

To summarise:

- Your blood is full of solutes, most importantly for this discussion sodium and potassium, but also proteins like red blood cells and white cells, amino acids, fatty acids, glucose and a ton of other things
- You drink water and it is absorbed into your blood, increasing plasma water levels and blood pressure, and decreasing relative plasma solute levels
- This plasma is sent to various capillary beds around the body in the blood. The plasma water and solutes (but not the larger proteins) are forced through the capillary walls and 'bathe' the cells nearby with water and nutrients such as glucose and triglycerides
- Due to osmosis, some solutes will enter and others will leave the cells. If the solution within the cell is at a higher concentration than the solution in the interstitial fluid, some water will also enter the cell. If the opposite is true then the cell will lose water. This is how cells stay hydrated
- Water is taken up from the interstitial fluid (along with any waste which the cells have secreted into it) back into the plasma at the other end of the capillary bed and sent back to the heart
- Being that a certain water level within every cell is ideal, we should therefore be able to deduce that the amount of water and solutes in the plasma must be kept within certain parameters. If blood concentration becomes too high because there is too little water or too many solutes, the cell will dehydrate and if the opposite is true it can burst
- The kidneys can excrete certain amounts of water, or indeed prevent the excretion of water, and the same goes for various solutes, especially sodium and potassium. This keeps the total level of all three tightly regulated

But how does the kidney know what to do? Why does it excrete more or less water when it needs to? And what about sodium and potassium?

4.3.7. Vasopressin

Vasopressin (also known as antidiuretic hormone or ADH) is a hormone released from the hypothalamus which is a gland located in your brain. Much like how bile is produced in the pancreas and stored in the gall bladder for rapid use, ADH is produced in the hypothalamus and stored in the pituitary gland (also located in the brain).

In order for ADH to be released, an increase in plasma sodium concentration must be detected. From an evolutionary standpoint, this makes sense because historically sodium was very hard to come by, and therefore the only reason that plasma concentration would increase would be because of a decrease in plasma water. Unfortunately, with a healthy plasma water level this effect can also be mimicked with an excessive sodium intake. Regardless of why it occurs, plasma sodium level increases mean that the extracellular water becomes hypertonic and osmosis then means that the cells which make up the pituitary (specifically the posterior or 'back' half) dehydrate and shrink, which then creates a signal to release ADH.

ADH then travels in the blood to the kidneys where it serves two primary functions. First it increases the amount of water which can be re-absorbed from the nephrons by directly increasing the permeability of the capillaries there. To repeat and clarify, vasopressin **directly** works on how water is re-absorbed. This is distinct from the next system we will talk about.

As a secondary effect, vasopressin is able to increase the rate at which sodium is excreted by reducing sodium reabsorption to some extent, and as a tertiary effect it increases subjective thirst. This is why you feel really thirsty when you eat very salty foods.

The key effect, however, is to increase the amount of water in the blood and in so doing, increase blood pressure. This has historically been a crucial part of survival, but of course in the modern world where an elevated sodium intake is almost the norm this can lead to artificially elevated blood pressure and the associated problems. If potassium intake is also high, and therefore intracellular potassium is relatively high, this effect is somewhat mediated (osmotic pressure inside and outside of the pituitary cells would be even) but regardless, an elevated sodium intake risks activating this system in a way it did not evolve to be activated.

This is not the only means by which the body regulates water and blood pressure, however. Next, we will take an overview of the Renin Angiotensin Aldosterone System (RAAS).

4.3.8. The Renin Angiotensin Aldosterone System (RAAS)

This system works via hormonal action which happens in a cascade. While the main job of vasopressin is to increase the reabsorption of water and its secondary effect is to increase sodium excretion, the purpose of the RAAS is primarily to control plasma levels of sodium. By increasing sodium reabsorption, water reabsorption happens on its own via osmosis.

Recall that glomerular filtration happens quickly because the pressure is higher here than in normal capillary beds, and that this process is so important that 25% of all blood leaving the heart undergoes this process. From these two facts alone, it should be obvious that glomerular pressure is extremely important. It's so important, in fact, that cells surrounding the afferent arteriole near the Bowman's capsule of the nephron can detect when blood pressure drops.

When the glomerular pressure drops lower than what it would ideally be, glomerular filtration rate would of course be reduced and this could potentially lead to a build-up of dangerous metabolites or other things within the blood. This needs to be rectified and it's for this reason that the RAAS kicks in. When pressure drops, the kidney produces an enzyme called renin which enters the bloodstream.

This is the main reason that renin is produced – basically, there's not enough water, there is a reduction in blood pressure, and therefore this system logically starts to initiate a mechanism to stop excreting water and making it worse. There are two other reasons that the RAAS becomes activated.

- **The Sympathetic Nervous System (SNS).** The SNS is the nervous system which, briefly, creates the 'fight or flight' or stress response to stimuli. When you're stressed/in danger this kicks in to perform a host of tasks including elevating heart rate, increasing alertness and raising blood glucose in an effort to help you run or stand your ground when in danger. The SNS activates renin release to initiate the RAAS because an increase in blood volume and the narrowing of the blood vessels both result in an increase in blood pressure and an easier transport of nutrients to working muscles. This has large implications for individuals with chronically stressful lives, as it provides a direct mechanism for how stress can lead to increased blood pressure and increased blood pressure, as you have learned in previous modules, can lead to damage in the arterial walls which makes for more efficient binding of LDL cholesterol. This is one of the precise mechanisms by which stress can cause heart attacks
- If a decrease in sodium is detected in the distal convoluted tubules, or an increase in potassium, then renin will be released. This again makes sense because, relating back to osmosis, if sodium levels are low and potassium levels are high, that would create an osmotic pressure that could in fact result in over-hydration of the body's cells, leading to cell damage

In short, renin release (the first stage of the RAAS) is caused by reduced blood pressure, the SNS during times of stress, by a decrease in plasma sodium or an increase in plasma potassium. It's crucial to know that these do not all have to happen at the same time, and they don't cancel each other out, so if blood pressure drops but sodium doesn't drop (so you're low on water but not low on sodium) renin will still be released.

As a final note on renin, it's release is proportional to the magnitude of the driver for release. If blood pressure only drops a little, only a little is released for example. So, what then?

Renin's role in the blood stream is to activate a hormone precursor called angiotensinogen which is produced by the liver. Angiotensinogen secretion happens all of the time in order to make it readily available but it's completely inert until renin is released to activate it and make angiotensin 1, which is then converted to angiotensin 2 in the lungs by another enzyme called Angiotensin Converting Enzyme (ACE). ACE inhibitors are medications which can be taken to reduce blood pressure, and this is their mechanism of action (that ACE is produced in the lungs is also why ACE inhibitors make you cough).

Angiotensin 2 has a few different roles. Firstly, it increases vasopressin secretion, secondly it increases thirst sensation and thirdly it acts to constrict blood vessels in order to increase blood pressure. It's fourth and main role, however, is to cause the adrenal glands (a pair of glands which sit on top of your kidneys) to produce aldosterone. To recap:

- The liver produces angiotensinogen
- The kidneys produce an enzyme called renin which converts this to angiotensin 1. Renin release happens because your blood pressure drops too low in the glomerulus, because your SNS is activated, because your potassium level is too high or because your sodium level is too low
- Angiotensin 1 goes to the lungs and is converted to angiotensin 2 by an enzyme called angiotensin converting enzyme or ACE
- Angiotensin 2 tells the pituitary to release vasopressin, tells you to drink water, constricts your blood vessels and tells the adrenal glands to produce aldosterone
- Aldosterone is the end-product of the RAAS, which has an effect on the nephrons
- In the nephron, aldosterone causes the reabsorption of sodium to increase, thus increasing the osmotic pressure pushing water into the surrounding capillaries and therefore indirectly increasing plasma volume. At the same time, aldosterone causes potassium to be excreted in the urine
- The increase in plasma volume and sodium content then increase blood pressure, which reduces the need for renin to be released, preventing blood pressure elevating higher

4.3.9. Summary of water and electrolyte homeostasis

- The body tightly controls its water balance and thus blood pressure through the renin angiotensin aldosterone system and the action of anti-diuretic hormone also known as vasopressin
- Water homeostasis is largely down to the actions of the kidneys which filter and then re-absorb water and electrolytes from the blood. They re-absorb more of what the body needs and excrete what it doesn't
- With lowered blood volume, and therefore blood pressure, glomerular filtration is not able to do its job efficiently which is a problem
- With imbalanced electrolyte levels, osmosis can either dehydrate or damage the cells of the body. Cells keep a high internal potassium level and high external sodium level which creates an even osmotic pressure and if this pressure becomes uneven there is an issue
- A reduction in hydration manifests itself in the blood as a reduction in blood volume and decreased blood pressure, as well as an increased concentration of sodium

- When blood pressure drops in the glomerulus (the entrance part of a nephron in the kidney), renin is released into the bloodstream. This can also be released if plasma sodium level drops, potassium level increases or indeed if you are highly stressed
- This ultimately results in angiotensin 2 being present in the blood
- If plasma sodium concentration increases above the level it usually is, either due to increased sodium or reduced water, the pituitary also releases ADH which increases water uptake and sodium excretion in the kidneys
- Angiotensin 2 is vasoconstrictive (causes closing/shrinking of localised blood vessels). It also acts on the filtration rate in the kidneys, helping them retain more sodium (therefore water) and thus increases blood pressure
- Thirst levels increase with angiotensin 2, making you drink
- The net result of the RAAS system and ADH is elevated blood pressure. They are also able to regulate the relative levels of sodium and potassium in the blood to maintain an optimal ratio between them

4.3.10. Reducing blood pressure

Throughout the previous section, we have given the mechanism by which the body increases blood pressure. We have noted that this has historically been incredibly beneficial because throughout our evolutionary past a reduction in blood pressure simply denoted a reduction in blood plasma volume which itself indicated dehydration. As such this increase in blood pressure was an effort to reduce dehydration.

Of course, in the modern world this may not be the case. It's very possible for sodium levels in the blood to be far higher than potassium levels within the cells, which can lead to a decrease in intracellular water, therefore an ADH mediated increase in blood pressure. If this occurs, 2 peptide hormones called ANP and BNP (atrial natriuretic peptide and brain natriuretic peptide) are released into circulation. These increase sodium and water excretion in the kidney and prevent the release of renin, thus lowering blood pressure. If this system is not able to keep up or an individual is particularly susceptible, however, hypertension can result.

Hypertension (high blood pressure) affects a huge proportion of the modern Western World with around 30% of UK residents having blood pressure which exceeds the current assumed safe limits. Hypertension is, like all health issues, multifactorial with factors leading to it including:

- Increased bodyweight (including large amounts of muscle mass). Increased mass means more blood circulation requirements, which necessarily mean higher blood pressure
- A sedentary lifestyle
- Age (risk increases as you get older)

- Genetics/family history
- Smoking
- Race (Black populations are more likely to be diagnosed)
- Stress
- Drinking too much alcohol
- Too much sodium or too little potassium in the diet

Through a number of different mechanisms, an elevated salt intake can lead to elevated blood pressure and there does seem to be a genetic variance between people. Regardless, a large body of epidemiological and controlled research suggests that an intake of over 2.3g of sodium (around 6g of salt) is correlated to an increased risk of illness. That is not to say that the less salt you eat, the better, though. As you have seen, sodium is a vital part of hydration and in fact this is why it is included in all sports drinks. A minimum intake of 1.5g of sodium has been set by the Institute of medicine, which suggests that rather than worrying about reducing salt completely, people should instead reduce their intake of extremely salty processed foods while feeling no guilt whatsoever in lightly salting unprocessed, home cooked meals.

Similarly, as you have seen during this module, the relationship between potassium and sodium is a close one. In research, when potassium intake is increased, the risk of hypertension and all other negative factors associated with a higher sodium intake are greatly reduced. Potassium is found in abundance in vegetables and fruits (especially bananas) so if you are consuming a diet high in vegetables you are more likely to be able to get away with consuming the higher end of the sodium spectrum. The same goes if you are highly active as you will see below.

As an aside, provided sodium and potassium are balanced and sodium intake is not excessive, sodium should not cause unwanted subcutaneous water retention which is an extremely commonly cited reason for people to reduce sodium to as low levels as possible.

4.3.11. Sodium and athletes

As far as athletes go, insufficient sodium intake is potentially just as big of a problem (if not bigger) than excess sodium intake. A sodium insufficiency is known as hyponatremia. It manifests with similar symptoms to dehydration because, as you know, a decreased sodium level can activate renin release and the subsequent angiotensin 2 which makes you thirsty. That angiotensin 2 can result in the excretion of potassium (via aldosterone), which combined with the decrease in sodium can have extremely wide reaching effects including:

- Nausea and vomiting
- Headache
- Confusion
- Loss of energy and fatigue

- Restlessness and irritability
- Muscle weakness/cramp
- Seizures
- Coma
- Death

Hyponatremia is most often seen in athletes who are performing long-duration exercise while drinking plain water. This causes a loss of sodium through sweat, facilitated by further water intake but not replenished via consumption. Though this course is not a sports nutrition course specifically, it would be unwise of us not to mention this. While we will cover dehydration next in some amount of detail, you do not just lose water through sweat and urine, and if you aren't consuming electrolytes you can run into a lot of problems even if your water intake is exactly where it should be.

This should also be extrapolated out to the general population. If you drink too much water you stand just as much chance of causing yourself harm than drinking too little. You CAN drink too much water.

Of course, this is not to say that you necessarily need to consume electrolyte supplements or sports drinks and in fact these should only be reserved for those performing very long-duration exercise. Most people can get more than enough sodium through salt consumption and potassium through vegetables and fruits. Another good tactic will be discussed in the final section.

Note: Here we have given the UK Government recommendations along with some notes that active people, or those consuming a lot of potassium may be able to consume a little more salt than other individuals. Those who have impaired renal function are generally more susceptible to increased salt intakes and because elevated sodium intake can increase calcium excretion via the kidneys, those with osteoporosis may also do well to keep their salt in check. Likewise, those with existing hypertension of course must be more careful. If you are within these groups or find that any of the above risk factors apply to you, then we ask that you strictly adhere to the guidelines and seek the advice of a medical professional if you have a clinical reason to think that even this salt intake may be problematic.

4.3.12. Dehydration

Maintaining a proper level of water within the body is vital. Water allows all metabolic processes to occur, allows for the removal of potentially harmful metabolic by-products and environmental toxins, helps maintain your temperature and provides a medium for the transport of the nutrients we need to survive. If the level of water within the blood drops, not only does kidney function suffer, our entire body is unable to function optimally.

While the kidneys will seek to re-absorb as much water as possible, at some point you need to drink because water is lost through various means. If water losses exceed water intake, dehydration will ensue. Dehydration can be classified as mild, moderate or severe as diagnosed by the percentage of water that has been lost.

- **Mild:** Less than 5% water lost = no clinical symptoms, elevated thirst
- **Moderate:** 6-9% of water lost = significant thirst, sunken eyes, dry lips/mouth, weakness, light headedness, low blood pressure
- **Severe:** Over 10% of water lost = significant thirst, rapid heart rate, cold hands/ feet, reduced skin firmness, low blood pressure, confusion

You can also use a urine chart like the below to determine whether you are properly hydrated.

Fig. 50

Urine colour	Possible meaning
Clear	Good hydration, over-hydration or mild dehydration
Pale yellow	Good hydration or mild dehydration
Bright yellow	Mild or moderate dehydration or taking vitamin supplements
Orange or amber	Moderate or severe dehydration
Tea coloured	Severe dehydration

Note: Exercise requires cells to work harder which results in a larger amount of metabolic by-products that must be removed. Even if the plasma level is where it should be after a hard training session (especially an endurance sport), this can lead to darker urine than you would expect simply due to increased solute concentration. As such, post exercise rehydration should be assessed via regaining lost bodyweight and other subjective means such as headaches, dry lips and a feeling of thirst rather than urine colour.

Moderate and severe dehydration obviously severely impact health and daily function, but are unlikely to happen outside of extreme cases including, but not limited to:

- Prolonged exercise in heat
- Prolonged periods where liquids are withheld or unavailable
- Sickness/diarrhoea
- Diuretic use

Mild dehydration can, however, impact your health without necessarily creating any clinical symptoms. Low-level dehydration can lead to poor mental performance, fatigue, perceptions of hunger and some degree of irritability. A dehydrated person is less productive and probably not feeling as good as they could be.

Of course, it can also severely impact on sporting performance.

As loss as small as 2% of body mass can lead to a decrease in performance related to an inability to regulate temperature, increased heart rate and far higher rate or perceived exertion. These issues exacerbate as dehydration progresses until more severe general symptoms appear. It is not possible to train yourself to be able to perform while dehydrated. While mild dehydration will not create permanent problems with your health, it's best to be avoided.

4.3.13. How can we ensure adequate hydration?

This is the big question. While we have covered a great deal of physiology, biology and theoretical knowledge here, we also need to make some practical recommendations.

As we noted previously, dehydration of up to 5% will not result in clinical symptoms but will result in thirst. We also mentioned in passing the danger of drinking too much water and why this should be avoided.

'Drink to thirst' is and always will be the best advice, though this is not a perfect system because people typically will ignore thirst drivers. Though mild dehydration will not cause harm, it can cause hunger pangs and lead to lethargy which aren't things to actively seek out to say the least. Our recommendations therefore are to consider having a drink alongside your meals, and to keep a small water bottle within easy reach during the day. You don't need to drink to a schedule or make sure you have X amount during the day, but you do need to cultivate a habit of hydrating when you actually get the urge to do so, rather than ignoring it.

4.3.14. A ballpark estimate of need

While it's not necessary to stick to a specific amount, it is practically useful to have a rough idea of what you might need. Are we talking 2 glasses or 2 gallons?

The Eatwell Guide recommends an intake of 8 glasses of water per day which offers a reasonable visual/practical idea of what your liquid consumption should look like. To put a number on it, a reasonable calculation is to multiply your weight in kg by 28 and consume this number in millilitres per day of rest. For example, an 80kg individual might require 2240ml or roughly 2.25 litres.

This is of course imperfect and not set in stone. We cannot appreciate your genetic propensity for sweating or your environment, and of course some of the water you consume during the day is contained in your food and not measurable, but this ballpark figure is something which gives you some amount of perspective. If you are exercising that day, consuming water to thirst during the session (consider using a sports drink for intense exercise over 1 hour in duration) is also important.

If you are going to exercise for prolonged period, especially in heat, it can be wise to weigh yourself before and after, then consume the kilograms you have lost in water over the next few hours, alongside a meal which contains at least some amount of salt. If you're very dehydrated, a sports drink can be useful here.

As we discussed above, tonicity relates to the relative concentration of a solution. An isotonic sports drink is ideal for rehydrating after a highly depleting workout, so this is what we recommend if you have lost a lot of water.

Further information on this topic is beyond the scope of this course. However, if it interests you, we would encourage you to look at our sports nutrition modules in the BTN Practical Academy.

4.3.15. Considerations to make it easier

Drinking water isn't rocket science, but some people genuinely do struggle to get into the habit of paying attention to their natural thirst. So how would someone increase their fluid intake easily without setting an alarm on their phone?

- Firstly, it's a good idea to start the day with a glass of water. After sleeping you are mildly dehydrated and this gets you off to a good start. You may find that it helps you wake up, and of course it's an easy habit to get in to. You can drink a glass while waiting for the coffee to brew
- Add something calorie-free to your water to make it taste better if you don't really enjoy it. Adding fresh fruit, mint or cucumber to water adds a nice twist, and if you want to, a sugar free cordial works just as well
- In fact, tea, coffee, diet sodas, juices, smoothies, foods and even beer also count to your overall fluid intake. The only things which don't count are espresso shots or hard spirits as the high concentration of alcohol and caffeine act to increase urination. However, we don't advocate getting all your liquid from beer
- Always drink during or at least after exercise. If you're exercising first thing in the morning make sure you are hydrated before going in to the session
- Invest in a water filter if your tap water tastes bad
- Reduce your intake of processed foods to keep your sodium intake within reasonable limits, but don't think this means you should avoid salting your food. You're also not going to have a heart attack if you consume a few very salty foods on occasion
- Consider salting food with a Lo-Salt or a similar product, as these replace sodium with potassium. Vegetables salted with Lo-Salt are a great way to boost your intake

In summary, maintaining a proper water balance is vital for maintaining proper health and it can be done very simply – drink when you're thirsty, don't over-salt food but at the same time don't avoid sodium completely and keep an eye on your vegetable intake to make sure your potassium levels are where they should be.

4.4. Introduction to fibre

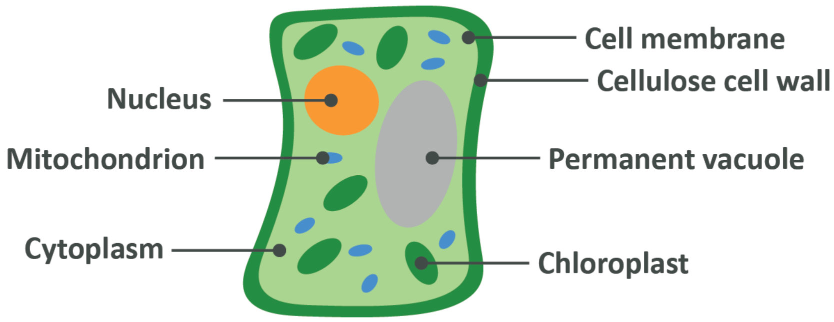
It's time to move the discussion to fibre. Fibre is found in two forms within the diet:

- **Dietary fibre:** This is non-digestible carbohydrates and lignin that are intrinsic in foods we eat

- **Functional fibre:** This refers to isolated, extracted or manufactured fibres that are added to foods (or used in supplements) because they have certain physiological effects on humans.

These fibres may be soluble, insoluble, more or less viscous and more or less fermentable by gut bacteria. The impact that this has (and what it means) will be explained in a moment, but for now just remember that each characteristic of fibre results in a different effect on you and your health.

Fig. 51



Both forms of fibre initially come primarily from plants. Plant cells, unlike human cells, have a cell wall which adds protection, rigidity and shape, and this cell wall is comprised of 95% dietary fibres of numerous different forms that may change with the plant's maturity. Certain specialised plant cells designed to help provide structure also contain lignin deposits. As you can probably deduce from this brief introduction, consuming whole plant foods provides a vast array of different kinds of plant matter – with the specific kind of fibre you get being determined by the part of the plant you eat (be that the stem, leaf or root), and the age of the plant itself (a mature plant will contain more lignin, for example). Because the majority of fibre is found in cell walls, and the thickest cell walls are found on the outer edge of plants, it should be self-evident that whole grains and unpeeled whole fruits and vegetables are the most effective foods to eat if you want to get the most fibre per bite.

It is important to note that we very rarely, if ever, consume single sources of fibre in whole foods. When we eat fruits, vegetables, grains, legumes and nuts we are eating an array of different fibres and therefore benefit from each uniquely. As such, while you are reading the following information, it may be useful to bear in mind that the benefits of all different kinds of fibre will probably apply to any diet comprised of whole foods, that contains a lot of plants, rather than it being the case that eating X food has Y benefit.

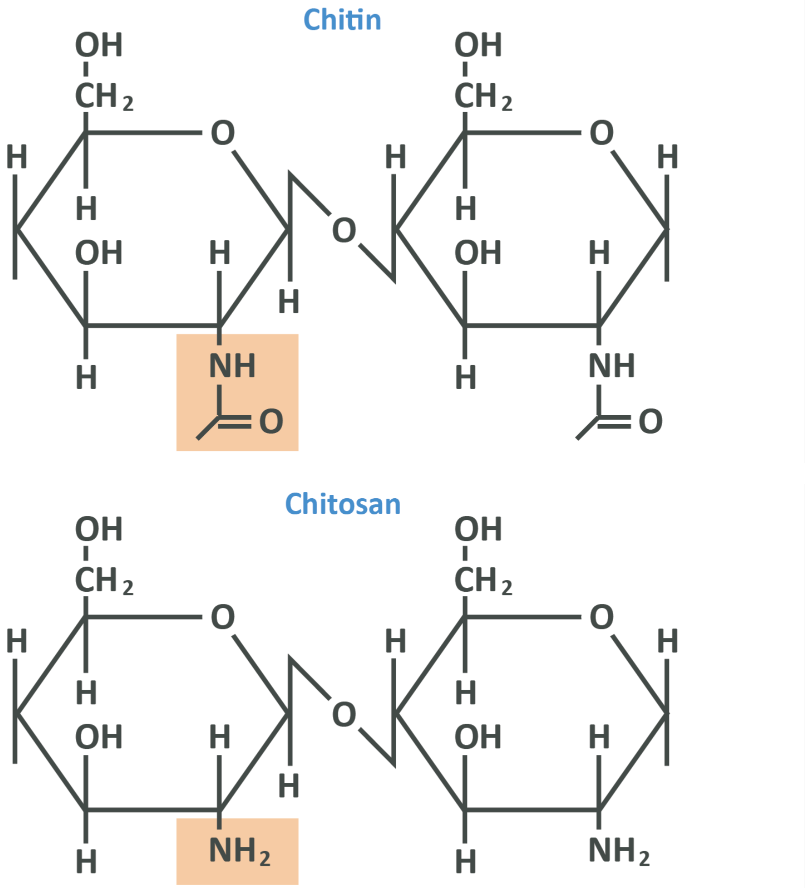
With that being said, it can be useful to reflect on the different fibres contained within the diet, as understanding the parts always increases an appreciation for the whole. Let's now look at the kinds of fibre we eat.

4.4.1. Psyllium

Psyllium is perhaps the most commonly supplemented fibre, and is one of the most widely used functional fibre. It is extracted from the husks of psyllium seeds, and is extremely good at absorbing water, meaning that it's often used to provide viscosity in solutions, but is also used in products such as Metamucil owing to its laxative-like properties.

4.4.2. Chitin and chitosan

Fig. 52



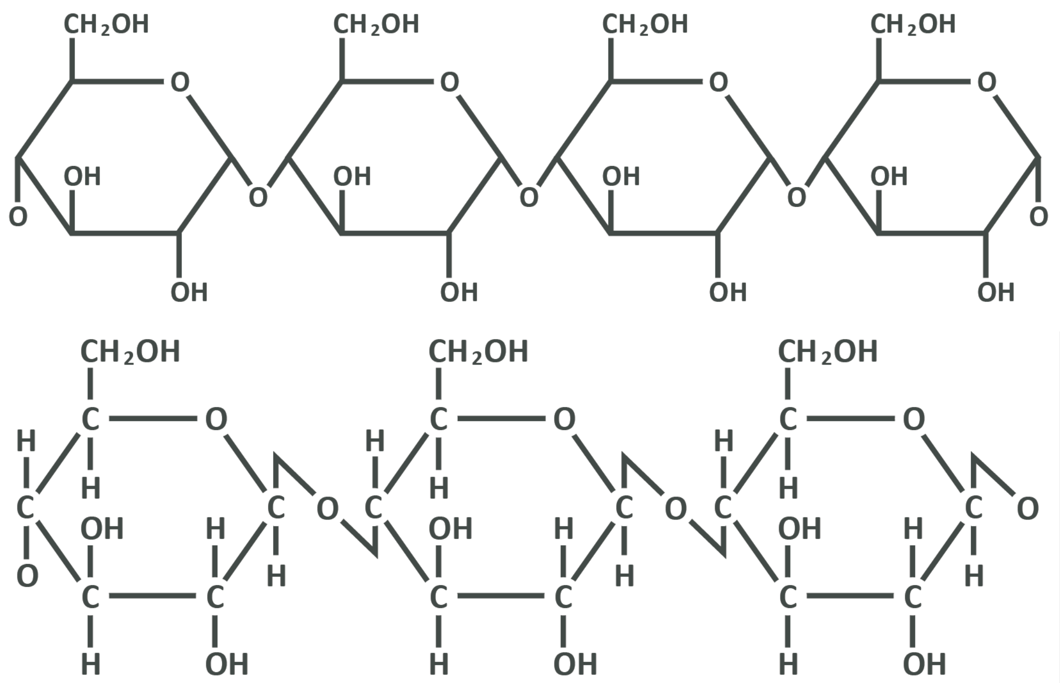
Chitin (kite-in) has a similar structure to cellulose, but has an amino group as one of its side chains. It's found in the cell wall of some plants but, interestingly, is also the prime component of the exoskeleton of some insects and crustaceans. Chitosan has a very similar structure, but is missing an acyl group as above. Both are water insoluble and viscous. Interestingly, chitosan carries a positive electrical charge that allows it to bind to dietary lipids in gastric juices.

This leads chitosan to be referred to as a 'fat binder', often found in supplements. Presently no evidence exists to indicate that these lead to long-term fat loss, however, as the small amount of difference made, is quickly made up for elsewhere in the diet.

4.4.3. Cellulose

This is a dietary fibre but is sometimes added to foods to increase fibre content. It's comprised of long chains of glucose monomers linked together with 1,4 bonds just like the starch amylose, but critically the bond appears on the opposite side of the glucose. Below is an image of amylose and beneath that is cellulose. Notice the subtle difference between the two.

Fig. 53



This slight difference renders the enzyme amylase and brush boarder enzymes incapable of breaking down cellulose chains to allow them to be absorbed into the intestinal wall – a perfect example of why fibre is not digestible by humans. These large chains line up next to each other and join together to create a robust 3D shape perfect for the construction of rigid plant cell walls.

These properties also render cellulose insoluble in water in its natural form, and somewhat difficult (though not impossible) to ferment in your gut. It's found in large amounts in bran, nuts, legumes, peas, root vegetables, cruciferous vegetables and in the skins of fruits like apples. It can also be added to foods to add texture or thickness and is therefore found in cake mixes, sauces and many other packaged goods.

4.4.4. Hemicellulose

Hemicellulose is a highly-branched polysaccharide comprised of xylose, mannose, galactose, arabinose and glucoronic acid in different combinations, used as cellulose to construct plant cell walls. The exact structure of the primary backbone and the branches varies between plants and between areas within the same plant, and this of course alters its behaviour. Hemicellullose that contains acids on its side chain will be somewhat hydrophyllic due to this acidic area, whereas a hemicellulose without acids will be hydrophobic. Additionally, the fermentability of hemicellulose will vary depending on its constituent monomers (a monomer is a molecule that can be bonded to other identical molecules to form a polymer). Hemicellulose is the other primary fibre found in bran, whole grains, nuts and legumes, while being found in lesser amounts in fruits and vegetables. It is not found to any great degree in packaged foods as a functional fibre.

4.4.5. Polydextrose and polyols

Polydextrose, as you can imagine, is a long chain of dextrose monomers. Polyols, on the other hand, are comprised of sorbitol or other similar carbohydrates. These are manufactured at high heat in a vacuum, and added to foods as a bulking agent or sugar substitute, often referred to as 'sugar alcohols'. They are slightly sweet in taste but are not absorbed by the intestines and so have no direct caloric value. They are highly fermentable, however, which means that they do impact your energy intake (generally these are considered to provide roughly 2kcal per gram). Excessive consumption of sugar alcohols has been known to cause acute laxative effects.

4.4.6. Resistant starches

Resistant starches are, as is somewhat self-evident, starches that resist digestion. There are 4 different forms of resistant starch:

- **RS1:** This is found in cellulose walls of certain plants, and is therefore inaccessible to amylase enzymes. Un-milled flax seed is a classic example of this
- **RS2:** This is a more granular form of starch. Recall that amylose is comprised of long, linear chains of glucose; these chains can become tightly packed owing to their uniform shape, meaning that the central starches are inaccessible to enzymes. Un-ripened bananas and sweetcorn are both examples of this form
- **RS3:** Retrograde starch is made when starchy foods like potatoes and rice are cooked and then cooled, altering the structural makeup of the carbohydrates within them
- **RS4:** This is similar to RS3, but is made via chemical modifications of starches

Both RS3 and 4 are considered functional fibres whereas RS1 and 2 are dietary fibres. It has been hypothesised that resistant starch can aid in weight loss owing to its impact on calorie intake, but the average intake of resistant starch is estimated to be around 6-8 grams per day, and consuming more than this is relatively difficult, if not highly impractical. Due to this relatively low intake and the small impact it has on total calorie balance, no evidence of weight loss has been seen in clinical resistant starch trials. Some small amount of evidence does suggest that an increased intake of resistant starch may increase lean body mass and reduce fat mass while eating at caloric balance, and potentially increase muscle accruement during a hypercaloric condition. This preliminary data is not yet conclusive, however.

Additionally, resistant starch has been shown in animals to alter the makeup of gut bacterial populations, which has been shown in both humans and animals to be a potential factor in weight management and a host of other health markers. Again this data is relatively new, but remains interesting.

4.4.7. Beta glucans

Beta glucans are large polymers, comprised exclusively of glucopyranose units. Beta glucans are extremely fermentable, and water soluble, and are found in oats, barley and some mushrooms. They are often added to foods as a functional fibre as they have been shown to decrease serum cholesterol in some trials.

4.4.8. Fructans (inulin, oligofructose and fructooligosaccharides)

Fructans are chains comprised primarily of fructose units, that appear in varying lengths. Inulin is comprised of up to 60 fructose units that culminate in a glucose monomer. Though human digestive enzymes are not able to break these down, bacteria such as bifidobacteria are, thanks to their ability to secrete beta-fructosidase enzymes. Oligofructose and fructooligosaccharides can be considered to be 'chunks' of larger inulin chains, comprising 2-8 or 2-4 fructose units respectively (each may or may not also contain a glucose). The interaction between fructans and bifidobacteria will be discussed later in this module.

Fructans are found in alliums (onions, garlic, leeks), Jerusalem artichokes, bananas, wheat, barley and rye. Occasionally fructans are added to products such as low-fat ice cream or low-fat cakes to provide a similar mouthfeel to the full-fat version.

4.4.9. Gums

There are a number of different gums relevant to human nutrition, each comprised of many different sugars. These are highly branched hydrocolloids, meaning that they form a gel upon contact with water and are therefore, highly viscous and soluble but are also extremely well fermented. These are secreted by plants as a response to injury to promote healing and to protect the vulnerable plant from further damage, but they also have interesting impacts on human nutrition. Gums commonly consumed include guar gum, Xanthan gum and gum Arabic but there are a great deal more.

These are found naturally in oats, barley and legumes while being added to many different packaged goods as thickeners or water binding agents (for example to provide a pleasant mouthfeel in gluten-free baking). Artificially added gums may be extracted from plants, but they can also be secreted by micro-organisms.

4.4.10. Pectin

Pectin is a dietary and functional fibre comprised of an unbranched chain of galacturonic acid units, occasionally punctuated by another sugar. This acidic structure makes it highly hydrophyllic and soluble in water. Additionally, it is extremely well fermented by gut bacteria. Due to its stability in low (acidic) pH environments, it is found in acidic foods like citrus fruits but also in legumes, nuts and some vegetables. Because of its gel-forming capabilities pectin is often added to both confectionary and enteral formulas given to tube fed hospital patients as a source of fibre.

4.4.11. Lignin

Lignin is a plant cell component used for developing a defined structure. It's comprised of phenols, which are small units that bond together extremely strongly. Because of this, lignin is non-fermentable and does not absorb or dissolve in water. Some phenols can ferment in the gut to become active compounds similar to hormones and there is some preliminary research to suggest ligning does this, resulting in a very weak phytoestrogen but this is generally considered not to happen meaningfully. Lignin is found most commonly in fruits with edible seeds such as many berries, in the bran layer of cereals and in root vegetables like carrots.

As you can see there are a wide range of different fibres, found in foods, added to foods and used as supplements. Each one may be more or less soluble, more or less viscous and more or less fermentable and these properties carry over to differing health effects. As you read the next section which describes these effects, we ask you to remember what was said in the opening section – we rarely, if ever consume one fibre in isolation and consuming a diet rich in all forms of fibre should convey the vast majority of these benefits.

4.5. What are the benefits of fibre?

As you have seen, many fibre types have different properties. They may be more or less viscous, more or less fermentable, more or less adsorptive and more or less soluble. Rather than list the benefits of each fibre it is more practical to list the benefits of each fibre 'class'.

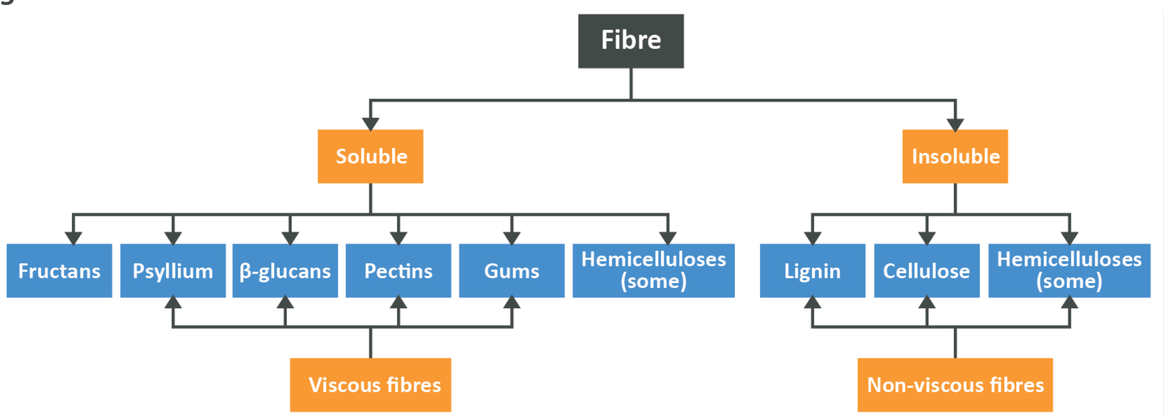
4.5.1. Solubility

Solubility is perhaps the most broadly-recognised property of fibres. Soluble fibres are those that will become a solution in hot water, whereas insoluble fibres will not. Very generally speaking, soluble fibres will delay gastric emptying time and delay transit time through the gut, whereas insoluble fibres can increase faecal bulk thus increasing transit time. The benefits provided by all of this will be discussed later.

4.5.2. Viscosity

Viscosity denotes the hydration potential of a fibre. Viscosity is not tied to solubility, meaning an insoluble fibre can still 'soak up' water without becoming a solute. The graphic below indicates the relationship between the 2.

Fig. 54



Viscous fibres have a number of benefits, namely:

- **They delay gastric emptying.** By hydrating and forming thick gels, viscous fibres slow the release of chyme to the duodenum. This slowed gastric emptying results in a greater duration of postprandial satiation and can therefore help with hunger during periods of caloric restriction
- **Reduced digestive enzyme function.** This happens in two ways. Firstly, the viscosity of the chyme simply restricts the ability of enzymes to come into contact with foods, thus impairing nutrient digestion. Furthermore, some fibres such as gums are able to directly impair hydrolysis of proteins and lipids. This should be carefully considered by those with very high protein and fibre intakes
- **Decreased nutrient diffusion rate.** Thanks both to delayed gastric emptying, and then slow movement of nutrients through chyme that has been emptied into the duodenum, glucose enters the bloodstream far more slowly than it otherwise would. This has the ability to reduce the glycaemic response and reduce insulin secretion so should be carefully considered by diabetics who may benefit from these effects. Supplemental fibre (specifically guar gum and pectin) appear most effective

4.6. Adsorption ability

Adsorption denotes the ability of something (here a fibre) to bind to something else. Some fibres can adhere to nutrients and, by doing so, alter their digestive fate. Highly adsorptive fibres can:

- Diminish lipid absorption as already mentioned in the case of chitosan
- Increase bile acid secretion. As you already learned, bile acids are added to the stomach to help fatty acid digestion, and then reabsorbed through the intestine, via the liver, and used again. These bile acids are synthesised from cholesterol meaning that this process has been shown to reduce serum cholesterol levels, specifically LDL cholesterol, thus potentially decreasing cardiovascular health risks
- Decrease the absorption of some vitamins and minerals

4.7. Fermentability

As fibre is indigestible, it enters the colon unaltered for the most part. When they reach here, some are able to be fermented by colonic microflora, with soluble fibres typically being affected more so than insoluble ones. This happens when intestinal bacteria use enzymes that they synthesise to digest the fibre (and any other nutrients that enter the colon) in a very similar set of reactions to anaerobic respiration detailed in module 2 (in fact one of the main metabolites that these bacteria produce via this process is lactate, just like human cells). The most fermentable fibres, are:

- Fructans
- Galactooligosaccharides

- Pectin
- Gums
- Psyllium
- Beta glucans
- Polydextrose
- Resistant starch 3 (RS3)

This fermentation provides the bacteria mostly with nitrogen, which is an essential part of life, but side-products are also created including short-chain fatty acids (SCFA's). Both of these result in benefits to the host organism.

Firstly, by providing nutrients for gut bacteria, fermentable fibres act as pre-biotics. A pre-biotic is simply something that promotes the growth and diversity of the gut microflora – resulting in a state associated with a number of health benefits including a potential reduction in IBS symptoms, improved immune system function, and a decreased ability for more harmful bacteria such as certain strains of E.Coli to colonise.

Additionally, fermentation leads to SCFA production, primarily acetic, butyric and propionic acids. The fatty acids produced depend entirely upon the bacteria and the fibre in question, and it would be far beyond the scope of this course to lay out the exact details. Suffice to say that these three are produced upon the ingestion of fermentable fibres and they all play important roles in GI health:

- SCFA are rapidly absorbed into the intestinal walls. This process uses transport proteins on the cells which also allow water and sodium absorption. This of course plays in to retaining hydration and forming more solid stool
- These fatty acids alter the differentiation fate of cells in the intestinal walls. Intestinal wall cells 'turn over' rapidly to stay healthy, and to accomplish this there is a layer of undifferentiated cells always ready to replace the cells at the surface. An undifferentiated cell is simply one that has not fully 'formed' into the final cell type that it will adopt for the rest of its life, meaning that it is malleable. SCFA's promote cells to more preferentially differentiate into mucosal cells, meaning that SCFA absorption increases the density of the mucosal layer inside the intestines. This layer is critical for avoiding the absorption of pathogens, so this process has important impacts on disease avoidance
- SCFA's alter the intestinal pH, making it more acidic. This causes bile acids to become more soluble and 'deactivates' certain enzymes present in the intestine. These enzymes are responsible for altering bile acids from their primary to their more harmful secondary form, and so SFCA's can reduce secondary bile acid formation. Secondary bile acids are associated with colonic cancer and so this is a very important process. Additionally, SCFA acid seem to halt tumour cell differentiation and promote apoptosis (programmed cell death) in these cell populations

- SCFA's provide energy. In fact, butyric acid and propionic acid are considered to be primary energy sources for the colonic cells. What isn't used here finds its way via the portal vein to the liver, and is used for glucose synthesis, or transport to peripheral cells for ATP production there. It is estimated that fermentable fibre, though it is not digestible in and of itself, provides 1.5-2.5kcal per gram via this process
- Propionic acid delivered to the liver seems to reduce cholesterol production
- SCFA's interact with the intestinal nervous system and smooth muscle to increase blood flow to this area
- SCFA's promote the production of immune cells, while the decrease in the intestinal pH helps to prevent pathogens from colonising

Fermentable fibres are clearly very helpful, but it is a mistake to think that this means non-fermentable fibres are without merit. Non-fermentable fibres include:

- Cellulose
- Lignin
- Plant waxes
- Resistant starch 1 and 2 (RS1 and RS2)
- Some hemicelluloses

These benefit you in the following ways:

- Non-fermentable fibres can adsorb hydrophobic carcinogens, preventing them from interacting with the intestinal wall. These can then be excreted or rendered inert by bacteria
- Most obviously, non-fermentable fibres increase faecal volume. Faeces is primarily comprised of unfermented fibre, salts, water and bacteria. An increase in gut bacteria thanks to fermentable fibres increases stool mass, but un-fermentable fibres do this in a more direct manner. Increased stool mass leads to easier passage, as peristalsis in the intestines is more effective at moving the stool towards the anus

Clearly fibre has a huge number of benefits, and it can impact our health in far more ways than being a laxative. It can even help us to avoid disease.

4.8. How can fibre help us combat disease?

Diets high in fibre are associated with avoidance or management of a significant number of health problems. On top of this, fibre rich foods in isolation have been associated with certain improvements in markers of health (for example oat bran has long been suggested as a potential ingredient in a diet promoting improved blood lipid markers). A lot of this research is somewhat inconclusive and further research is needed, but the current body of literature suggests that fibre rich diets (or at least, diets high in fibre rich foods) can help with:

- Cardiovascular disease. The ability for various fibres to reduce serum cholesterol and LDL indicates a mechanism that is preventative for cardiovascular health. Diets rich in whole grains are associated with reduced heart health complaints, and there is a moderate inverse relationship between intakes of fruit and vegetables and heart attacks/strokes. It's difficult to conclusively isolate the causal factor here as fibre, but the effects remain clear
- As mentioned, viscous gels can reduce the rate at which glucose appears in the blood, thus mediating spikes in blood glucose and lowering the requirement for insulin release. This may be useful for those who have diabetes. There has also been an inverse relationship between fibre intake and type 2 diabetes documented in eight different European countries
- Moderate to high fibre intakes can help with weight management. Fibre-rich foods are generally low in caloric density and hyper-palatability while being high in satiating volume. Due to this volume, satiety-signalling hormones such as peptide 1 and ghrelin are secreted in response to physical stomach fullness and this, coupled with delayed gastric emptying time, can help maintain a calorie deficit without excessive hunger. There is also a relationship between fibre intakes and waist circumference in observational population studies
- Gastrointestinal disorders including constipation and diverticulosis (a condition caused by damage to the colon walls, due to prolonged constipation) are associated with lower fibre intakes, largely due to the ability of fibre to both soften (by hydrating, thanks to viscous fibres) and bulk out a stool

4.9. How much should I be eating?

According to the Eatwell Guide, In the UK, the RNI for Fibre is 30g for those over the age of 15. As this is a rather blanket number it can also be useful to look to other countries to see a broader perspective. The USA Food and Nutrition board have set the fibre to 14g of total fibre per 1000kcals eaten, which allows us to scale intakes according to total calories (this also roughly fits the UK recommendation bearing in mind the calorie recommendations for the average person). This would calculate to:

- 28g at 2000 calories
- 35g at 2500 calories
- 42g at 3000 calories

Note: No tolerable upper limit is defined, though it is suggested in the same USA report that intakes of over 50g can be considered excessive.

Worthy of note is the fact that increasing fibre dramatically in a short space of time can lead to gas, constipation and bloating. It is wise to increase fibre intake gradually if you are currently not eating enough, increasing by 5-10g or so per day, per week.

Some good sources of fibre include the below:

- Most vegetables, which are around 2.5-5g per 100g
- Fruits vary, with grapefruit having 1.5g fibre per 100g and 9g being found in avocados for the same serving
- Beans and legumes contain around 7-9g per 100g
- Rolled oats have around 10g per 100g
- Wholemeal wheat products generally have 4-7g per serving

Most of these sources will contain a number of different fibres, and by combining them all across the day you are better equipped to ensure you consume all you need, from as many sources as possible.

4.10. Summary

As you can see, fibre comes in a huge range of different forms depending on the plant consumed and the area of the plant in question. Additionally, some fibres are extracted and added to something else, or manufactured in a laboratory for use due to their health-promoting properties. A diet high in fibre is associated with a number of positive health outcomes while a diet low in fibre is associated with the opposite. A diet high in fibre is also associated with lower bodyfat, and may be useful for fat loss efforts. This is impossible to isolate as relating to fibre alone, but the point remains that a diet high in foods containing fibre seem at least mildly health-promoting.

This is one of many instances where it should be considered that foods, rather than nutrients, are what makes up our diets, and so it is fibre rich foods, rather than fibre per se, which should be our focus.

In the following modules, we will be leaving the theoretical stuff behind and exploring the practical application of your new nutritional knowledge. You know the biology. You know the recommendations and it is now time to start the process of changing your life!

4.11. References

Fibre

- Aune, D., Chan, D., Lau, R., Vieira, R., Greenwood, D., Kampman, E. and Norat, T. (2011). Dietary fibre, whole grains, and risk of colorectal cancer: systematic review and dose-response meta-analysis of prospective studies. *BMJ*, 343(nov10 1), pp.d6617-d6617.
- Higgins, J. (2014). Resistant Starch and Energy Balance: Impact on Weight Loss and Maintenance. *Critical Reviews in Food Science and Nutrition*, 54(9), pp.1158-1166.
- Gades, M. and Stern, J. (2005). Chitosan supplementation and fat absorption in men and women. *Journal of the American Dietetic Association*, 105(1), pp.72-77.
- Mhurchu, C., Poppitt, S., McGill, A., Leahy, F., Bennett, D., Lin, R., Ormrod, D., Ward, L., Strik, C. and Rodgers, A. (2004). The effect of the dietary supplement, Chitosan, on body weight: a randomised controlled trial in 250 overweight and obese adults. *International Journal of Obesity*, 28(9), pp.1149-1156.
- Jenkins, D. and Jenkins, A. (1985). Dietary Fiber and the Glycemic Response. *Experimental Biology and Medicine*, 180(3), pp.422-431.
- Whelan, K. (2011). Probiotics and prebiotics in the management of irritable bowel syndrome. *Current Opinion in Clinical Nutrition and Metabolic Care*, 14(6), pp.581-587.
- Gibson, G., McCartney, A. and Rastall, R. (2005). Prebiotics and resistance to gastrointestinal infections. *British Journal of Nutrition*, 93(S1), p.S31.
- Ajouz, H., Mukherji, D. and Shamseddine, A. (2014). Secondary bile acids: an under recognized cause of colon cancer. *World Journal of Surgical Oncology*, 12(1), p.164.
- Vieira, A., Teixeira, M. and Martins, F. (2013). The Role of Probiotics and Prebiotics in Inducing Gut Immunity. *Frontiers in Immunology*, 4.
- Demigné C, Morand C, Levrat MA, Besson C, Moundras C and Rémésy C. (1995). *British Journal of Nutrition*, 74(2):209-19
- Hague, A., Elder, D., Hicks, D. and Paraskeva, C. (1995). Apoptosis in colorectal tumour cells: Induction by the short chain fatty acids butyrate, propionate and acetate and by the bile salt deoxycholate. *International Journal of Cancer*, 60(3), pp.400-406.
- Goverse, G., Molenaar, R., Macia, L., Tan, J., Erkelens, M., Konijn, T., Knippenberg, M., Cook, E., Hanekamp, D., Veldhoen, M., Hartog, A., Roeselers, G., Mackay, C. and Mebius, R. (2017). Diet-Derived Short Chain Fatty Acids Stimulate Intestinal Epithelial Cells To Induce Mucosal Tolerogenic Dendritic Cells. *The Journal of Immunology*, 198(5), pp.2172-2181.
- Scheppach, W. (1994). Effects of short chain fatty acids on gut morphology and function. *Gut*, 35(1 Suppl), pp.S35-S38.

- Erkkilä, A. and Lichtenstein, A. (2006). Fiber and cardiovascular disease risk: how strong is the evidence?. *The Journal of Cardiovascular Nursing*, 21(1), pp.3-8.
- National Research Council (US) Committee on Diet and Health. Diet and Health: Implications for Reducing Chronic Disease Risk. Washington (DC): National Academies Press (US); 1989. 10, Dietary Fiber [Online] Available at https://www.ncbi.nlm.nih.gov/books/NBK218764/?report=reader [Accessed Ju-ne 29th, 2017]
- Streppel, M. (2005). Dietary Fiber and Blood Pressure. *Archives of Internal Medicine*, 165(2), p.150.
- He, F., Nowson, C. and MacGregor, G. (2006). Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. *The Lancet*, 367(9507), pp.320-326.
- Dauchet, L., Amouyel, P., Hercberg, S. and Dallongeville, J. (2017). *Fruit and Vegetable Consumption and Risk of Coronary Heart Disease: A Meta-Analysis of Cohort Studies*. [online] Jn.nutrition.org. Available at: http://jn.nutrition.org/content/136/10/2588.long [Accessed 5 Jul. 2017].
- McDonald, J., Pirhonen, D. and Rangam, M. (1983). High Fiber Diets: Their Role in Gastrointestinal Disorders. *Canadian Family Physician*, 29, pp.1632–1638.
- Satija, A. and Hu, F. (2012). Cardiovascular Benefits of Dietary Fiber. *Current Atherosclerosis Reports*, 14(6), pp.505-514.
- Berg, A., König, D., Deibert, P., Grathwohl, D., Berg, A., Baumstark, M. and Franz, I. (2003). Effect of an Oat Bran Enriched Diet on the Atherogenic Lipid Profile in Patients with an Increased Coronary Heart Disease Risk. *Annals of Nutrition and Metabolism*, 47(6), pp.306-311.
- Kaline, K., Bornstein, S., Bergmann, A., Hauner, H. and Schwarz, P. (2007). The Importance and Effect of Dietary Fiber in Diabetes Prevention with Particular Consideration of Whole Grain Products. *Hormone and Metabolic Research*, 39(9), pp.687-693.
- Dietary fibre and incidence of type 2 diabetes in eight European countries: the EPIC-InterAct Study and a meta-analysis of prospective studies. (2015). *Diabetologia*, 58(7), pp.1394-1408.
- St-Pierre, D., Rabasa-Lhoret, R., Lavoie, M., Karelis, A., Strychar, I., Doucet, E. and Coderre, L. (2009). Fiber intake predicts ghrelin levels in overweight and obese postmenopausal women. *European Journal of Endocrinology*, 161(1), pp.65-72.
- Romaguera, D., Ängquist, L., Du, H., Jakobsen, M., Forouhi, N., Halkjær, J., Feskens, E., van der A, D., Masala, G., Steffen, A., Palli, D., Wareham, N., Overvad, K., Tjønneland, A., Boeing, H., Riboli, E. and Sørensen, T. (2010). Dietary Determinants of Changes in Waist Circumference Adjusted for Body Mass Index – a Proxy Measure of Visceral Adiposity. *PLoS ONE*, 5(7), p.e11588.

- Du, H., van der A, D., Boshuizen, H., Forouhi, N., Wareham, N., Halkjaer, J., Tjonneland, A., Overvad, K., Jakobsen, M., Boeing, H., Buijsse, B., Masala, G., Palli, D., Sorensen, T., Saris, W. and Feskens, E. (2017). *Dietary fiber and subsequent changes in body weight and waist circumference in European men and women*.
- Van Itallie, T. (1978). Dietary Fiber and Obesity. *American Journal of Clinical Nutrition*, 31(10), pp.S43-52.
- Bodinham, C., Al-Mana, N., Smith, L. and Robertson, M. (2013). Endogenous plasma glucagon-like peptide-1 following acute dietary fibre consumption. *British Journal of Nutrition*, 110(08), pp.1429-1433.
- Bodinham, C., Al-Mana, N., Smith, L. and Robertson, M. (2013). Endogenous plasma glucagon-like peptide-1 following acute dietary fibre consumption. *British Journal of Nutrition*, 110(08), pp.1429-1433.
- www.nutrition.org.uk. (2016). *BNF Nutrition Requirements, Revised*. [online] Available at: https://www.nutrition.org.uk/attachments/article/234/Nutrition%20Requirements_Revised%20Oct%202016.pdf [Accessed 25 June. 2017].
- *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, DC: National Academies Press, 2005), 1, accessed July 5, 2017, http://site.ebrary.com/lib/interpuertorico/doc?id=10091309.

Hydration

- Maughan, R. and Shirreffs, S. (2008). Development of Individual Hydration Strategies for Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, 18, pp.457-472.
- Wapnir, R. and Lifshitz, F. (1985). Osmolality and Solute Concentration - Their Relationship with Oral Hydration Solution Effectiveness: An Experimental Assessment. *Pediatric Research*, 19(9), pp.898-894.
- Casa, D. (2017). *Proper Hydration for Distance Running Identifying Individual Fluid Needs*. [online] USA Track and Field Advisory. Available at: http://www.athleticscanterbury.org.nz/Portals/6/Coaching%20Resources/Training%20Articles/Proper%20Hydration%20for%20Distance.pdf [Accessed 10 May 2017].
- Krikken, J., Laverman, G. and Navis, G. (2009). Benefits of dietary sodium restriction in the management of chronic kidney disease. *Current Opinion in Nephrology and Hypertension*, 18(6), pp.531-538.
- Drake-Holland, A. and Noble, M. (2016). The Hyponatremia Epidemic: A Frontier Too Far?. *Frontiers in Cardiovascular Medicine*, 3.
- Valentine, V. (2007). The importance of salt in the athlete's diet. *Current Sports Medicine Reports*, 6(4), pp.237-240.

- Heer, M., Baisch, F., Kropp, J., Gerzer, R. and Drummer, C. (2017). *High dietary sodium chloride consumption may not induce body fluid retention in humans*. [online] Ajprenal.physiology.org. Available at: http://ajprenal.physiology.org/content/278/4/F585 [Accessed 6 Jul. 2017].
- Primaryoptions.co.nz. (2017). *POAC Clinical Adult Dehydration Guideline*. [online] Available at: http://www.primaryoptions.co.nz/site_files/359/upload_files/blog/AdultDehydrationGuidelineJuly2015(1).pdf?dl=1 [Accessed 16 June. 2017].
- sportsdieticians.com.au. (2017). *Fact Sheet: Fluid in Sport*. [online] Available at: https://www.sportsdietitians.com.au/wp-content/uploads/2015/04/Fluids-in-sport.pdf [Accessed 6 Jun. 2017].
- Castro, H. and Raij, L. (2013). Potassium in Hypertension and Cardiovascular Disease. *Seminars in Nephrology*, 33(3), pp.277-289.
- Kido, M., Ando, K., Onozato, M., Tojo, A., Yoshikawa, M., Ogita, T. and Fujita, T. (2007). Protective Effect of Dietary Potassium Against Vascular Injury in Salt-Sensitive Hypertension. *Hypertension*, 51(2), pp.225-231.
- Wang, Y., Liu, F., Wang, D., Mu, J., Ren, K., Guo, T., Chu, C., Wang, L., Geng, L. and Yuan, Z. (2014). Effect of Salt Intake and Potassium Supplementation on Serum Renalase Levels in Chinese Adults. *Medicine*, 93(6), p.e44.
- Wang, Y., Chu, C., Ren, J., Mu, J., Wang, D., Liu, F., Ren, K., Guo, T. and Yuan, Z. (2014). Genetic Variants in Renalase and Blood Pressure Responses to Dietary Salt and Potassium Interventions: A Family-Based Association Study. *Kidney and Blood Pressure Research*, 39(5), pp.497-506.
- Ando, K., Matsui, H., Fujita, M. and Fujita, T. (2010). Protective Effect of Dietary Potassium against Cardiovascular Damage in Salt-Sensitive Hypertension: Possible Role of its Antioxidant Action. *Current Vascular Pharmacology*, 8(1), pp.59-63.
- Gropper, S., Smith, J. and Carr, T. (n.d.). *Advanced nutrition and human metabolism*. 6th ed.
- Lindseth, P., Lindseth, G., Petros, T., Jensen, W. and Caspers, J. (2013). Effects of Hydration on Cognitive Function of Pilots. *Military Medicine*, 178(7), pp.792-798.
- Popkin, B., D'Anci, K. and Rosenberg, I. (2010). Water, hydration, and health. *Nutrition Reviews*, 68(8), pp.439-458.
- Dennis, E., Dengo, A., Comber, D., Flack, K., Savla, J., Davy, K. and Davy, B. (2009). Water Consumption Increases Weight Loss During a Hypocaloric Diet Intervention in Middle-aged and Older Adults. *Obesity*, 18(2), pp.300-307.
- Stookey, J. (2016). Negative, Null and Beneficial Effects of Drinking Water on Energy Intake, Energy Expenditure, Fat Oxidation and Weight Change in Randomized Trials: A Qualitative Review. *Nutrients*, 8(1), p.19.

- Public Health England, The Welsh Government, Food Standards Scotland and Food Standards Agency in Northern Ireland (2016). *The Eatwell Guide Booklet*. [ebook] London: Public Health England. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/551502/Eatwell_Guide_booklet.pdf [Accessed 19 Dec. 2017].
- Nutrition Science Team and Public Health England (2016). *Government Dietary Recommendations*. [ebook] London: Public Health England. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/618167/government_dietary_recommendations.pdf [Accessed 19 Dec. 2017].