The science behind sports nutrition is very much explained by sports physiology which describes the complex chemical and mechanical body functions during exercise. Therefore scientific knowledge/evidence around sports nutrition is changing little compared to the input coming from “trends” in sports nutrition driven by the “weight loss” industry. I won’t dare to put out another opinion on sports nutrition instead I want to provide some basic facts that are only explained on physiological mechanisms within our body. Many of these mechanisms and reactions were presented in my previous articles (read “Aerobic and anaerobic energy supply” or “General trainings effects”) and I recommend to read them again to answer potential questions that come up when reading this article.

Generally I want to suggest a well-balanced and healthy diet that is adjusted towards your high energy requirements in times of intense training. This article is to provide you with some key principles to support your body to work towards your highest potential based on metabolic requirements. The facts presented here only apply for high intensity exercise (TTs, marathon racing) as energy metabolism is very different for low intensity exercise (touring).

A healthy and “well-balanced” diet

A healthy diet includes all essential macro (carbohydrates, fat and protein) and micro (vitamins, minerals and trace elements) nutrients to restore and renew our body tissues and to function. However no single food contains all nutrients. Some foods are packed with fats, others are rich in protein or carbs. When I talk about a “well-balanced” diet I mean “eat everything very little and nothing too much” (Paracelsus: “Res omnes venena sunt dosis sola facit venenum”). All foods contain goodies and baddies, to get all the goodies we will also get all the baddies. Key to a balanced diet is to eat it all in healthy amounts, change your foods often and consume nothing too much.

Macronutrients

1. **Proteins:** Proteins in our diet provide essential building blocks, the amino acids, to build and renew our body tissues and to provide many other carriers and metabolically and osmotically active compounds. Half of the protein content of a human body is found in skeletal muscle mass. An 80 kg person should be eating at least 65 g of protein a day when not in training to provide enough amino acids to renew and restore the daily body turnover but this needs to be increased significantly (100-140g/day) when training heavily and muscle building is the goal. There is a whole industry around sports protein supplements but proteins of high quality are present in natural foods such as eggs, milk products, meat and fish. There is no benefit in taking supplements over normal food proteins unless you end up having to eat 5 steaks a day to achieve your protein intake.

2. **Fat:** Fat is often considered as the baddie, but this is not the case. Fats are essential! Here the type of fat is important and you definitely want to have a basic understanding of saturated and non-saturated fats to get your fat intake right. Particularly plant fats (Linolenic and Linoleic acids) are absolutely necessary as structural lipids and cannot be generated by the body. Many vitamins (ADEK) are fat-soluble and can only be absorbed together with fat. Therefore oils and fish are an important part of your diet.

   Proteins and also fats can be metabolised into carbohydrates but this is a highly energy dependent (least efficient) process and releases acidic ketone bodies as by-products into the system (see "keto diet").
3. **Carbohydrates:** Carbohydrates are the main energy source for high intensity sports (etc in racing). They come in various complexity and are more or less easy to digest which means are more or less quickly available as a source of energy.

   Glucose, a simple carbohydrate, is the end product of all carbohydrate digestion, the only energy source for cells during high intensity sports and the only fuel source for the brain. All other simple sugars are converted to glucose in the liver which then is used for ATP production and glycogen storage. The amount consumed daily is completely dependent on the physical activity but is normally around 50% of your diet. To make this energy source useful for you particularly during training and for performance in competition you want to understand the basic chemistry below.

Simple and complex carbs

Depending on its chemical composition, carbohydrates can be "fast-releasing" which means easily digestible and readily absorbable. "Slow-releasing" carbohydrates are only slowly digestible and provide smaller amounts of energy over a long time. This equates to the blood sugar levels.

Fast-releasing carbohydrates are "simple" carbs such as **mono**saccharides (Fig. 1, glucose, fructose, and galactose-**one** carbon ring structure) and **di**saccharides (Fig. 2, lactose, maltose, and sucrose- **two** carbon ring structures hooked together). Monosaccharides, because of their simple structure, are highly absorbable and ready to enter the blood stream "now". Disaccharides, consisting of 2 monosaccharides, are also easily broken down into their 2 monosaccharides therefore can be readily absorbed.

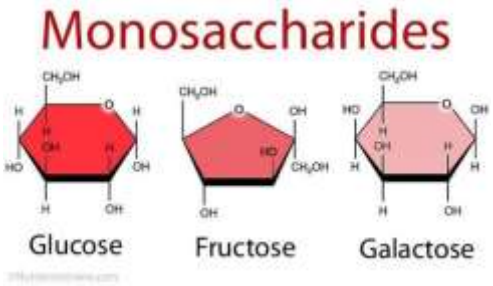

Figure 1.

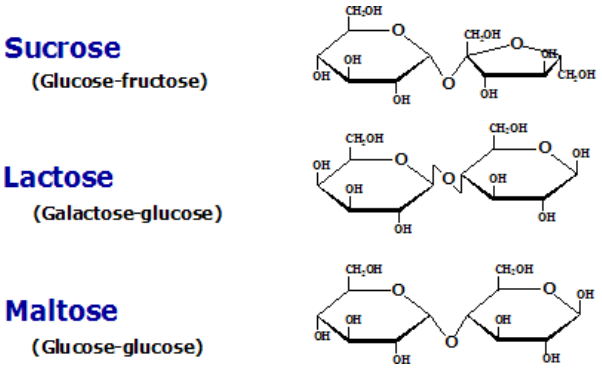

Figure 2. Disachharides https://microbenotes.com/carbohydrates/

More complex carbs are the **oligo**saccharides which have **three to ten** monosaccharide molecules hooked in a chain. These are often found in sports drinks and are a chain of glucose molecules.

Slow-releasing carbohydrates are **poly**saccharides (**many** saccharides) which are long complex chains of simple carbs which have to be broken down first by enzymes. Digestion and absorption occurs slowly but over several hours. These are the starches (Fig. 3 and 4).

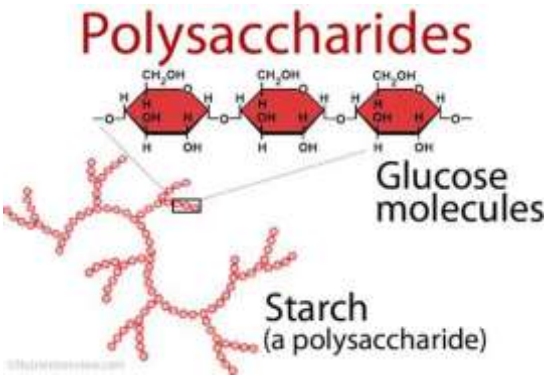

Figure 3. https://microbenotes.com/carbohydrates/

Starch is a very common form of carbohydrate in grains, legumes, and root vegetables, such as potatoes. Amylose, a plant starch, is a linear chain containing hundreds of glucose units. Amylopectin, another plant starch, is a branched chain containing thousands of glucose units.

From: A Closer Look at Carbohydrates. (2020, August 14). https://med.libretexts.org/@go/page/23304

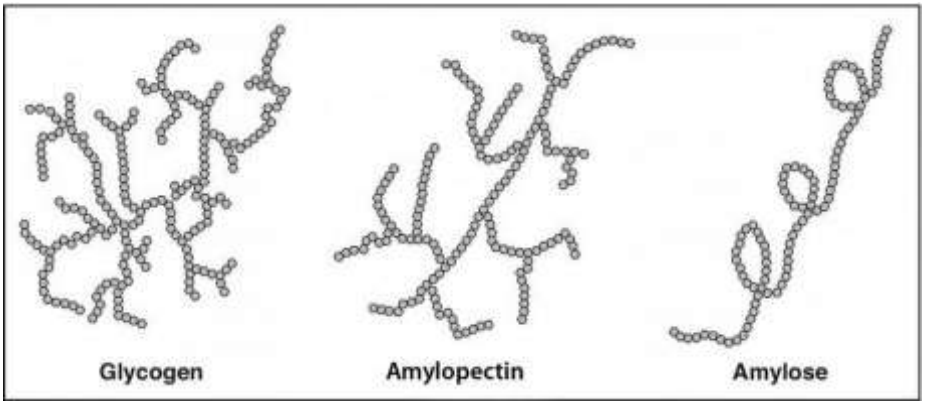

Figure 4. Structures of the Plant Starches and Glycogen

Fibres are another form of polysaccharides that are highly branched and cross-linked. Some dietary fibres are pectin, gums, cellulose, and lignin. The human gut microbiota is unable to make dietary fibres useable as an energy source. Dietary fibres are very beneficial to our gut health but maybe not ideal to carry around during a race.

Why do I need to know all this chemistry?

It is important to know what fast-releasing and slow-releasing carbohydrates are.

Do you want energy fast (now) but for a short time or within the next hour but then for a long time. One of the most important first aid supply in sports medicine is a simple sugar solution taken orally to get the blood sugar back up very quickly but it won't last long. Starches, common in noodles, potatoes and rice, provide a slow release of carbs that can bring you through a couple of hours but will not spike your blood sugar. Fibres (in salads and other vegetables) are useless as an energy source but will fill your guts unnecessarily which can make you feel uncomfortable and even "gassy" during training or competition.

How do I know what food contains what carbohydrate?

You probably heard about the glycaemic index (GI). High GI foods release sugar (glucose) quickly, resulting in a rapid rise in blood sugar levels; a sugar level spike. In contrast, low GI foods release sugar gradually over a number of hours, resulting in less insulin being produced.

GI	GI rating	Blood glucose level	A few examples
High	Over 70	Increases rapidly	• White rice • White bread • Baked potato • Water melon
Medium	56 to 69	Increases moderately	• Brown rice • Oatmeal • Macaroni cheese • Sugar
Low	Less than 55	Increases slowly	• Chickpeas • Bean sprouts • Spaghetti • Carrots

Figure 5. https://www.agewatch.net/diet/glycemic-index-and-glycemic-lo/

Aren't high GI- Foods bad for me?

There are no bad carbs, only carbs eaten at the wrong time in wrong amounts! I suggest to leave high GI foods for the times pre and post racing and not during your day at the office.

Glycogen, your biggest asset!

Humans store glucose energy from starches in the form of glycogen. Glycogen has many branches but it breaks down quickly when energy is needed by cells in the body. It is predominantly found in liver and muscle

tissue. As you can see in the table below (Fig. 6) blood sugar (10g) is a minor source of energy during a race compared to the glycogen that can be stored in muscle (245g) and liver tissue (90g), depending on body weight. This puts our emphasis on enhancing glycogen storage capacity for race performance.

	Percentage of Tissue Weight	*Tissue Weight*	*Body Content (g)*
Liver glycogen	5.0	1.8 kg	90
Muscle glycogen	0.7	35 kg	245
Extracellular glucose	0.1	10 L	10

Murray RK, Bender DA, Botham KM, Kennelly PJ, Rodwell VW, Weil PA. *Harper's Illustrated Biochemistry*, 29th ed. New York, NY: McGraw-Hill; 2012.

Figure 6

Glycogen storage is influenced by carbohydrate consumption. The differences between a 40% carbohydrate diet (40% of total energy consumed) and a 70 % carbohydrate diet on glycogen storage is significant when training intensively. As the diagram (Fig. 15.8) shows, repeated training on a low carbohydrate diet can actually deplete muscle glycogen storage quickly and severely affect performance. In this study a 70% carbohydrate diet was necessary to bring back muscle glycogen to normal levels within 24 hours for that specific trainings intensity. Therefore carbohydrate consumption has to be adjusted towards your trainings intensity. Keep in mind that the restoration of glycogen levels will take 24 hours or even longer when muscle damage has occurred, so the storage level reflects your diet in the last 24 hours and not just your last meal.

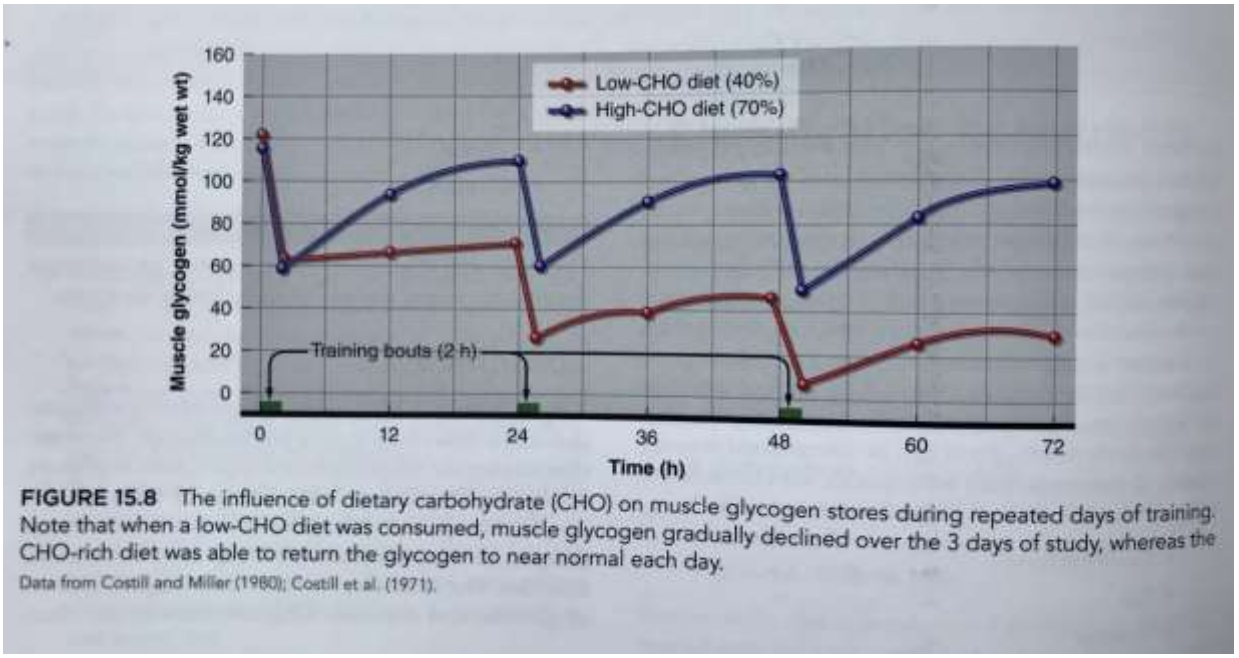

FIGURE 15.8 The influence of dietary carbohydrate (CHO) on muscle glycogen stores during repeated days of training. Note that when a low-CHO diet was consumed, muscle glycogen gradually declined over the 3 days of study, whereas the CHO-rich diet was able to return the glycogen to near normal each day.

Data from Costill and Miller (1980); Costill et al. (1971).

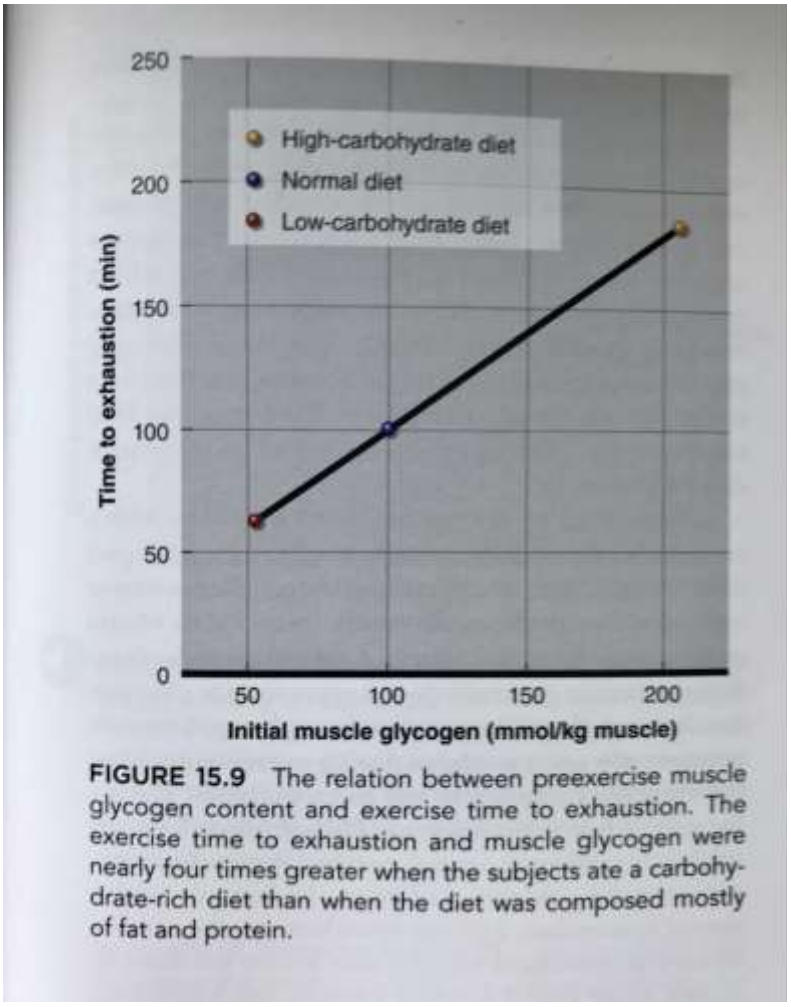

FIGURE 15.9 The relation between preexercise muscle glycogen content and exercise time to exhaustion. The exercise time to exhaustion and muscle glycogen were nearly four times greater when the subjects ate a carbohydrate-rich diet than when the diet was composed mostly of fat and protein.

Figure 7 from Larry Kenney, W., Wilmore, J. H., & Costill, D. L. (2020). Physiology of sport and exercise (7th ed.). Human Kinetics.

When in training, a low carbohydrate diet and consequently low glycogen storage will lead to early muscle exhaustion. Figure 15.9 shows the time to exhaustion of an athlete on a low carbohydrate diet, which was 60 min. When put on a high carbohydrate diet the time to exhaustion could be extended to 180 min. This is the direct result of muscle glycogen storage level. To restore depleted glycogen level it is best to consume carbohydrates within 2 hours after the exercise as the rate of glycogen resynthesis is at its highest then.

How do I apply this to my racing schedule?

You hopefully did not skip the previous chapters above to get here. If you did, you are a most typical student.

- Trainings intensity and volume should be markedly reduced 7 days before a mayor competition (tapering) to prevent additional muscle glycogen depletion and to maximise liver and muscle glycogen reserves.
- Complex carbs in starchy foods (LOW GI foods) will bring you a long way but it is obvious that unless you have eaten it at least an hour and a half before the race you have not eaten anything. Starch takes some time to digest to be useful for you.
- Simple carbs (HIGH GI foods) will spike your blood glucose quickly but also releases a lot of insulin which causes a quick drop in blood sugar levels soon after. Simple carbs are great if you need it "now" but not for very long. After the race your glycogen stores will be depleted and your blood sugar levels might be low. Try some fast release carbs and plenty of water to get you home for a proper meal.

- Glucose is the only food for the brain therefore a low blood sugar level can be recognised by irritability, difficulties performing mental tasks, disorientation and dizziness.
- Gels are highly absorbable carbs and a good way to keep your blood sugar level up during a race but should be consumed rather regular then. Gels 45min to 15 min before the race might be not a good idea as you will likely end up hypo-glycaemic when starting the race.

What about micro nutrients, do I need to supplement when training?

Micro nutrients come with a healthy and well-balanced diet particularly if you put emphasis on variety. In some cases, e.g. in ultramarathons or marathon season, there will be a huge turn-over of some micro nutrients such as calcium and magnesium which should be compensated by an increased intake of food in general but you can only eat so much. In other cases you might be on an exclusive diet (dairy free) and unable to provide your body with the sufficient amounts (of calcium) to support your trainings schedule. I definitely support supplementation then, but supplements can potentially become toxic, interact with or inhibit absorption and metabolism of other minerals or trace elements when taken over a long time and in high amounts. Any supplementation should be used short term only unless supervised by your health professional!