Australia's National
Science Agency

Your Diet and Your DNA

Laboratory Simulation Teacher Guide

Years 10-12

Contents

1 Introduction

The Your Diet and Your DNA simulation is the result of a collaboration between CSIRO Education & Outreach (CEdO), CSIRO Health and Biosecurity, and Danish virtual simulation company LABSTER™.

This simulation has been developed for use in Australian schools as part of a suite of cutting edge, future focussed education resources by CEdO. The simulation is hosted on the LABSTER™ platform, accessible for education purposes nationally and internationally.

1.1 Simulation theme

Understanding of the 'health span' of the population and in turn, risk of disease, is a major research area currently in the health sciences internationally and within CSIRO (Blackburn 1991; Blackburn & Epel 2017; Bull, C pers. comm. 2017; Lopéz-Otín, C. et al. 2013).

The chosen theme for the simulation centres on how diet choices can impact the short to long-term health of individuals, explored through different aspects of DNA health. This was made possible by access to CSIRO research staff, Dr Caroline Bull and Dr Michael Conlon, who undertake cutting edge research within the CSIRO Health and Biosecurity business unit in this field.

1.2 Collaborators

1.2.1 LABSTER™

LABSTER™ is a Danish technology company specialising in the creation of interactive laboratory simulations. The simulations are developed using a mathematical algorithm with the aim to support open ended investigations around a given narrative, while combining gamified elements, within a 3D virtual reality environment (www.labster.com).

It was founded by Mads Bonde in 2013, in response to his observation during teaching in traditional laboratories of the often-inefficient delivery of content and access to equipment (Gaglani, S. 2013).

1.2.2 CSIRO Health and Biosecurity

CSIRO's Health and Biosecurity business unit consists of multidisciplinary research teams, tackling major national and international health and biosecurity challenges. Their goal is to provide leadership and deliver measurable improvement in Australia's one-Health system: enhancing health, social, environmental and economic wellbeing in the face of increased healthcare pressures and global biosecurity threats (www.csiro.au/en/Research/BF).

Dr Caroline Bull's research focusses on DNA health, looking at the role of the protective caps of DNA, telomeres, in maintaining DNA health through an individuals' lifespan and their associated risk of disease (Bull et al. 2009).

Dr Michael Conlon's research focusses on the gut, looking at the link between diet choices and the level of chemical modifications of DNA (DNA adducts) within the bowel, and the associated risk for disease, such as bowel cancer (Conlon & Bird, 2015).

1.2.3 CSIRO Education and Outreach

CSIRO Education and Outreach has nearly 40 years' experience delivering innovative learning opportunities to schools, teachers and the wider community. All education programs are backed by real science, delivered by education professionals and linked to the Australian Curriculum. Education and Outreach have coordinated the development of the Your Diet and Your DNA simulation in collaboration with LABSTER™ for school teachers and students (www.csiro.au/Education).

2 Background

2.1 Simulation overview

In the simulation, students consider the role of diet choice in relation to an individual's overall health. Users are introduced to two high school students, Lily and Mia, and compare the accumulated DNA damage from the generally healthy and unhealthy diets of these students. This is explored through the two experiments, that of Telomere length assessment (via blood testing), and DNA adduct testing of bowel tissue (via large intestine cell sample testing). The final activity for users is to design a healthy lunch option for one of the students, Mia, using the accumulated knowledge gained through the simulation. The simulation concludes with the two students meeting again and chatting about how they feel since doing their diet focussed science project.

2.2 Key understandings

- That diet choice over your lifespan affects different cells and tissues in different ways
- How certain cellular and molecular changes can lead to disease
- How different components of food can stop or slow these changes and thus protect against disease
- That the food we consume is comprised of macro-nutrients and micro-nutrients which play an important role in health
- That a healthy diet includes a wide variety of nutrients from different sources
- The different cellular and molecular impact of healthy and unhealthy diet choices
- Understanding the impact of diet on genomic stability and long-term health

3 Resources

3.1 How to use this simulation

This simulation has been designed as a discrete in-class or flipped classroom homework task. With the aim to enrich students understanding of diet choices and related impacts on long-term health and wellbeing, with a focus on the role of DNA health.

The simulation is curriculum linked with Year 10 science and senior Biological sciences (Australian Curriculum) and other subjects from different state-based curricula. It should take approximately 45 minutes, dominated by laboratory work where the students undertake two different experiments. Interspersed through the simulation are short videos with the simulation characters, a digestion animation, and quizzes to test comprehension.

Added information on these experiments and the concepts covered is given via the 'Lab Pad', by the virtual lab assistant 'Dr One', or can be found on the 'Theory pages' (Appendix 6.3). Additionally, throughout the simulation, there are short quizzes to test understanding of concepts (Table 2 and Appendix 6.4).

3.1.1 Virtual laboratory features

Table 1: Summary of simulation features and how to navigate in virtual space

TOOL	DESCRIPTION
Audio	The default setting is off, turn on by clicking icon in top left corner
Movement	Click on the screen and hold as you drag to different locations in the simulation
Picking up items	Click on item
Flashing arrows	Show the direction of travel. These arrows cannot be clicked to move.
Flashing objects	Indicates the next step in an experiment or in the simulation
Hologram	Acts as a positioning tool, for example click on hologram to go through laboratory doors, or go to centre of the room
Musical note icon	Turns on/off background soundtrack
BACK button	Takes user back to previous point in simulation
Esc	Use the 'Esc' key to exit the simulation upon completion

3.2 Required materials

- Desktop/Laptop computer
- Windows or Mac OS
- Internet access with latest version of Firefox, Chrome or Safari
- LABSTER™ referral link

For further information: help.labster.com/technical-requirements

3.3 Pre-simulation classroom preparation ideas

To prepare for this simulation, class discussion and concept introduction around food choices and health, diet, DNA structure and function, telomeres, gut function and general health, and the digestive process would be valuable.

Useful Resources

The Hungry Microbiome Video, CSIRO (Figure 1)

www.csiro.au/en/Research/BF/Areas/Nutrition-and-health/Nutrition-and-health-science/Case-studies/Resistant-starch

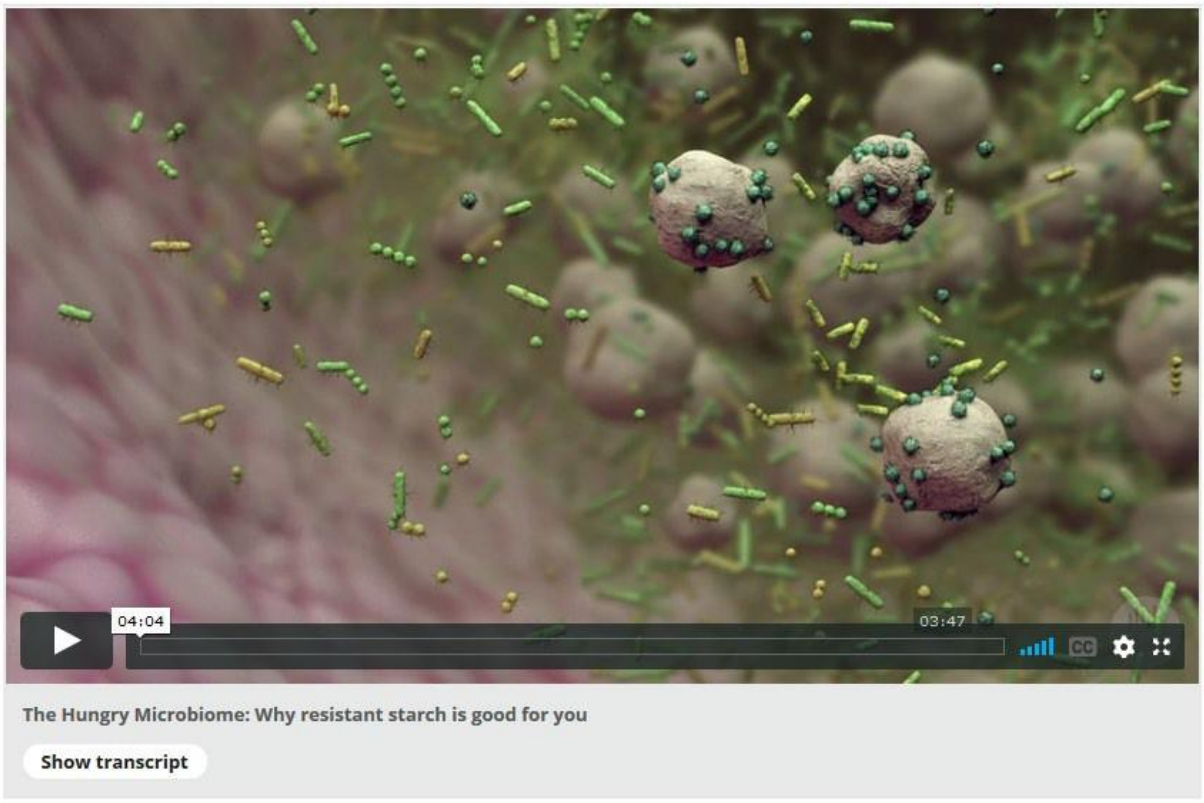

Figure 1: Hungry Microbiome video, Australian E-Health Research Centre, 2015

Digestion – Better Health

www.betterhealth.vic.gov.au/health/conditionsandtreatments/digestive-system

Australian Guide to Healthy Eating

www.betterhealth.vic.gov.au/health/healthyliving/food-variety-and-a-healthy-diet

3.4 General laboratory skills used during the simulation

3.4.1 Laboratory skills

- Use of a micropipette and tip
- Safe disposal of contaminated micropipette tips
- Applying cover slips to microscope slides
- Various steps required for two experiments; Telomere length, DNA adduct testing

3.4.2 HSE skills

- Correct personal protective equipment (PPE); gloves, lab coat, safety glasses
- Correct use of bins, i.e. biohazard

3.5 Post-simulation classroom ideas

The learnings from the simulation could be used as part of a CREST project, integrated with other project based learning, or used to stimulate further discussions with a STEM professional in the classroom. Project topics could cover the role of DNA health and risk of disease in humans; how diet choices can be used to prevent disease; or DNA replication processes and ageing.

With discretion, students could track and monitor their own dietary intake for one week and suggest dietary modifications based on what they have learnt from the simulation. They could additionally monitor their activity/energy/mood during this time and present their new diet and findings to peers/class. See Appendix 6.2 for student recording sheet.

Extension ideas:

Students could reflect on their original nutrition diary and discuss if/how their current diet choices will impact on their future health. What small changes could they make to their current lifestyle that could help reduce DNA damage and the onset of health-related diseases in the future?

Useful resources:

CSIRO STEM Professionals in Schools network access to scientists in this field:
www.csiro.au/en/Education/Programs/STEM-Professionals-in-Schools

CSIRO Creativity in Research, Science, Engineering, and Technology (CREST) project work:
www.csiro.au/en/Education/Programs/CREST

3.6 Curriculum links

The target audience are students in senior secondary school undertaking Biological Sciences. Suggested Australian Curriculum links for Biology and Year 10 science are listed in Table 1 and these are linked to the different stages of the simulation Table 2 in Section 4. Additional potential curriculum links for various state-based curricula can be found in section 6.1.

Table 2: Summary of potential curriculum links for Year 10 General Science

STRAND	YEAR 10
Science	
Science Understanding	Biological sciences - Transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)* **With classroom discussion*
Science as a Human Endeavour	Values and needs of contemporary society can influence the focus of scientific research (ACSHE230)
Science Inquiry Skills	Analyse patterns and trends in data, including relationships between variables and identifying inconsistencies (ACSIS203) Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204)

Table 3: Summary of potential curriculum links to Year 11 & 12 Senior Science - Biology

STRAND	YEAR 11 & 12
Biology	
Science Inquiry Skills	Conduct investigations, including microscopy techniques, real or virtual dissections and chemical analysis, safely, competently and methodically for the collection of valid and reliable data (ACSBL032) Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSBL033)* **With work in class outside of simulation*
Science Understanding	Proteins, including enzymes, are essential to cell structure and functioning (ACSBL080) Mutations in genes and chromosomes can result from errors in DNA replication or cell division, or from damage by physical or chemical factors in the environment (ACSBL082) Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth (ACSBL083)* **With classroom discussion*

4 Simulation breakdown

In this section, the simulation is broken down into sections, with associated curriculum links in Table 2, and brief description of the main stages, in sections 4.1 – 4.7.

SIMULATION LOCATION	ACTIVITY	AC CODE
General themes in simulation		ACSBL080, ACSBL082, ACSBL083
Opening lab scene	Laboratory tour option, questions relating to simulation Introduction to Dr. One – the virtual lab assistant	*N/A*
Student introduction scene in classroom [video]	Two students, Lily and Mia, having lunch at school Mia shares how she is not feeling well, with symptoms such as tiredness and lethargy They decide to make food choice and impact on wellbeing the topic of their science project	*N/A*
Laboratory entrance	PPE collection: lab coat, safety glasses, gloves Dr One interaction and student question revision Food choice overview, impact on short and long-term health and risk of disease	ACSBL032
Holotable activity	**Quiz: Diet definition – Food and beverages a person consumes** Nutrients in students' lunch choices – bean tuna salad, pizza Nutrient information given for food choices General macro- and micro-nutrient information: Carbohydrate (fibre, sugars, starch), Protein, Fat, Polyphenols, Minerals, and Vitamins **Quiz: Nutrients - Nutrients** **Quiz: Macronutrients – Starch** Nutrient graph comparison between two lunch options Digestion animation [Built in animation] • Learning the pathway of food digestion from the mouth through the digestive system • Overview of the breakdown, absorption, and fermentation processes of macro- and micronutrients during digestion • Cell function in relation to nutrient availability Term distinctions: Starch, Dietary fibre, Resistant starch (dietary fibre) **Quiz: Food containing resistant starch – Legumes**	ACSBL033, ACSBL080, ACSBL082, ACSBL083
Centre of room information bite	Need for appropriate nutrients to reduce likelihood of disease	ACSBL080, ACSBL082, ACSHE230
Workbench 1: Telomere length experiment	DNA health experiment using healthy and unhealthy diet blood samples Telomeres and their role in protecting DNA from damage during replication Hypothesis choice around telomere length, nutrition, and disease risk Test tube activity to run samples in Flow cytometer Explanation of graphs, telomere length results comparison of two samples Consideration of hypothesis choice – correct/incorrect/unsure *Equipment:* Tube rack, white blood cells, red blood cells, Flow Cytometer	ACSBL032, ACSBL033, ACSIS203, ACSIS204, ACSHE230, ACSSU184

SIMULATION LOCATION	ACTIVITY	AC CODE
Workbench 1: DNA adduct experiment	DNA health experiment using healthy and unhealthy diet samples from colon **Quiz: What are DNA adducts? – A chemical modification of DNA** DNA adduct explanation and link to disease risk Fridge sample collection Slide preparation with correct disposal of equipment **Quiz: Level of DNA adducts in samples – Fewer in healthy diet sample** Comparison of both telomere and DNA adduct results Conclusion: Lily has longer telomeres and fewer DNA adducts – showing a generally healthy diet *Equipment:* Test tube rack, paraffin cassettes, micro-pipette, forceps, biohazard bins, microscope slides, microscope	ACSBL032, ACSBL033, ACSBL082, ACSBL083, ACSIS203, ACSIS204, ACSHE230, ACSSU184
Workbench 2: Mia lunch choice	Discussion around social influence on food choice – morning tea example Criteria for what makes up a healthy diet Users choose from a range of options to plan a healthy example lunch for Mia, using knowledge gained during simulation Use computer to determine if choice is calorie appropriate and is nutritionally balanced Users given feedback on choices, given overall rating if healthy or unhealthy, and suggestions to modify if needed **Quiz: What are essential amino acids? – Amino acids that the body cannot synthesize** **Quiz: An organic, essential nutrient required in tiny amounts to perform specific functions – Vitamin** **Quiz: Which of these is not classified as dietary fibre? - Starch**	ACSBL032, ACSBL082, ACSBL083
Exit lab	Glove disposal and lab exit	*N/A*
Closing scene with two students	Students discuss how Mia is fairing since modifying her diet choices She notices an improvement in concentration, less tiredness and lethargy, more upbeat in mood	*N/A*
Final exit	Congratulations on finishing the lab, 100% completion recorded Theory pages show references Exit the lab by using the 'Esc' key	*N/A*

4.1 Simulation opening

The two student characters, Lily and Mia, are introduced over their school lunchtime. During their opening discussion, they come to discuss their meal choices, that of a bean tuna salad and pizza respectively (Figure 2). These two meal choices are then used throughout the simulation as examples to examine healthy and unhealthy diet choices. They discuss how Mia, with the pizza and soft drink, isn't feeling at her best, is tired and not performing well at school. Mia then observes that Lily seems to be the opposite, feeling energetic, happy, and performing well at school. Considering this, they decide to use food choice and its link to overall health and wellbeing, as their topic for their upcoming science project.

Figure 2: Mia and Lily chatting over their lunch

4.2 Laboratory entrance

Before entering the laboratory, users need to pick up the appropriate personal protective equipment (PPE) for their laboratory work, including a lab coat, safety goggles, and gloves.

To navigate around the entrance area, users can click and drag anywhere on the screen. During this scene, Dr One, the virtual laboratory assistant, is introduced and reiterates the question being posed for the science project.

4.3 The holotable

The holotable is the first activity users will undertake in the laboratory. They are presented with two buttons on the table: Pizza and Salad, representing the meal choices of the two characters. By clicking on each of these buttons, 3D pie charts appear on the holotable which show the different nutrient compositions and percentages of these for each meal (Figure 3).

To work through this section, users need to click on each part of the two graphs to progress and at each stage will be given more information about the given nutrient, which includes a short description and a 3D depiction of the associated molecule (Figure 4). The nutrients covered in this activity include: Carbohydrate (fibre, sugars, and starch), Protein, Fat, Polyphenols, Minerals, and Vitamins.

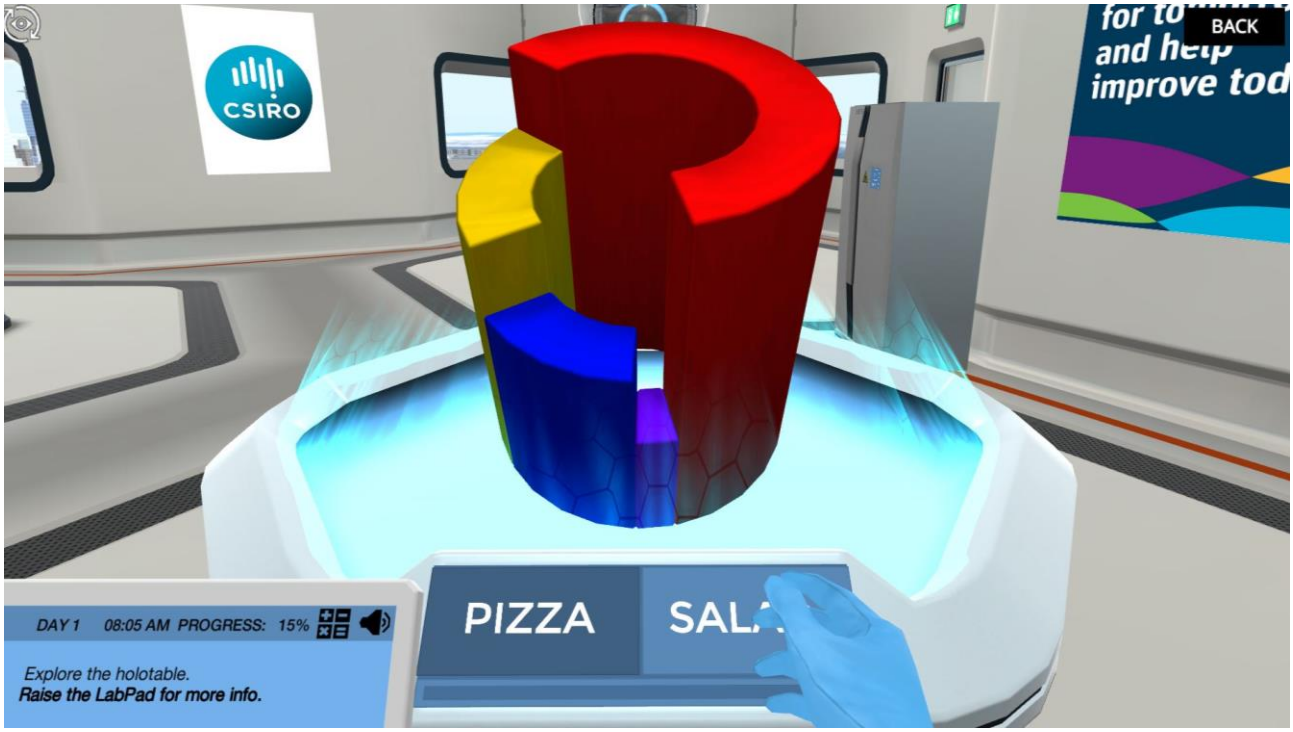

Figure 3: The holotable with example meal nutrient graph

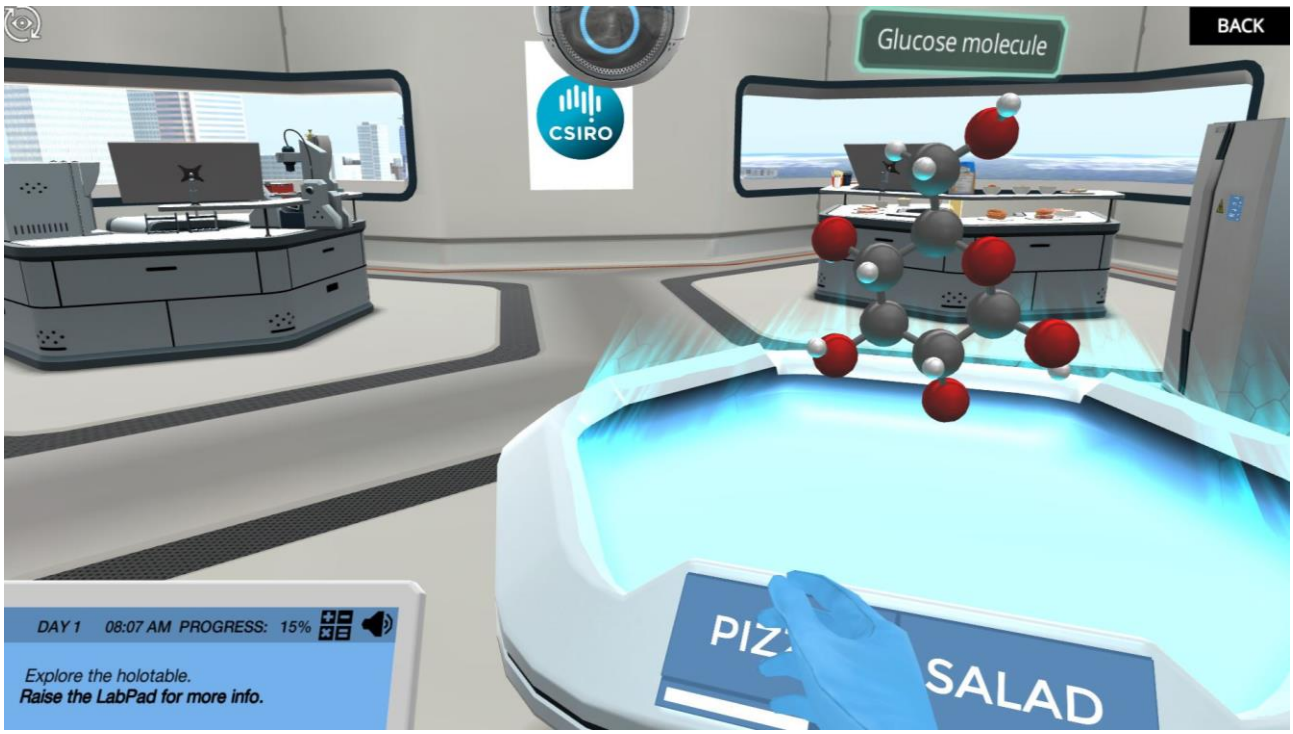

Figure 4: An example 3D molecule on the holotable

Once users have gone through both meal options, there is a short quiz to answer. Following this, users pick up a virtual reality headset and watch a digestion animation. This animation has a further quiz related to the information it delivers, which users complete before moving on to the main simulation experiments.

4.4 Telomere experiment

Dr Caroline Bull discusses why she undertakes the telomere experiment

Telomeres form the ends of all of our chromosomes (Figure 5). They are a sequence of 6 bases (a hexamer) repeated over and over. Due to the way the polymerase works, every time our cells divide, and the DNA is copied, a small amount of telomere is lost from the ends. As a result, telomeres shorten over time. Critically short telomere lengths (TL) leads to the DNA being unstable and more prone to damage, resulting in accelerated ageing and diseases such as cancers. We use the TL assay to study someone's genome health. It is also used to test if a particular intervention, such as a diet or lifestyle change, has impacted on a person's genome health and future disease risk.

In the assay users determine TL in lymphocytes (white blood cells) from a fresh blood sample. A synthetic probe is used that is 18 bases long and mimics the complementary strand of telomeric DNA (i.e. the hexamer repeated 3 times). After isolating DNA from the cells, the DNA strands are separated by heating, allowing the synthetic probe to bind specifically to telomere sequences. The probe contains a fluorescent dye. The flow cytometer is then used to quantify the amount of fluorescence in the sample (Figure 6). Using the TL of a reference cell line, this allows us to calculate the amount of telomere present (i.e. the telomere length) in the cells.

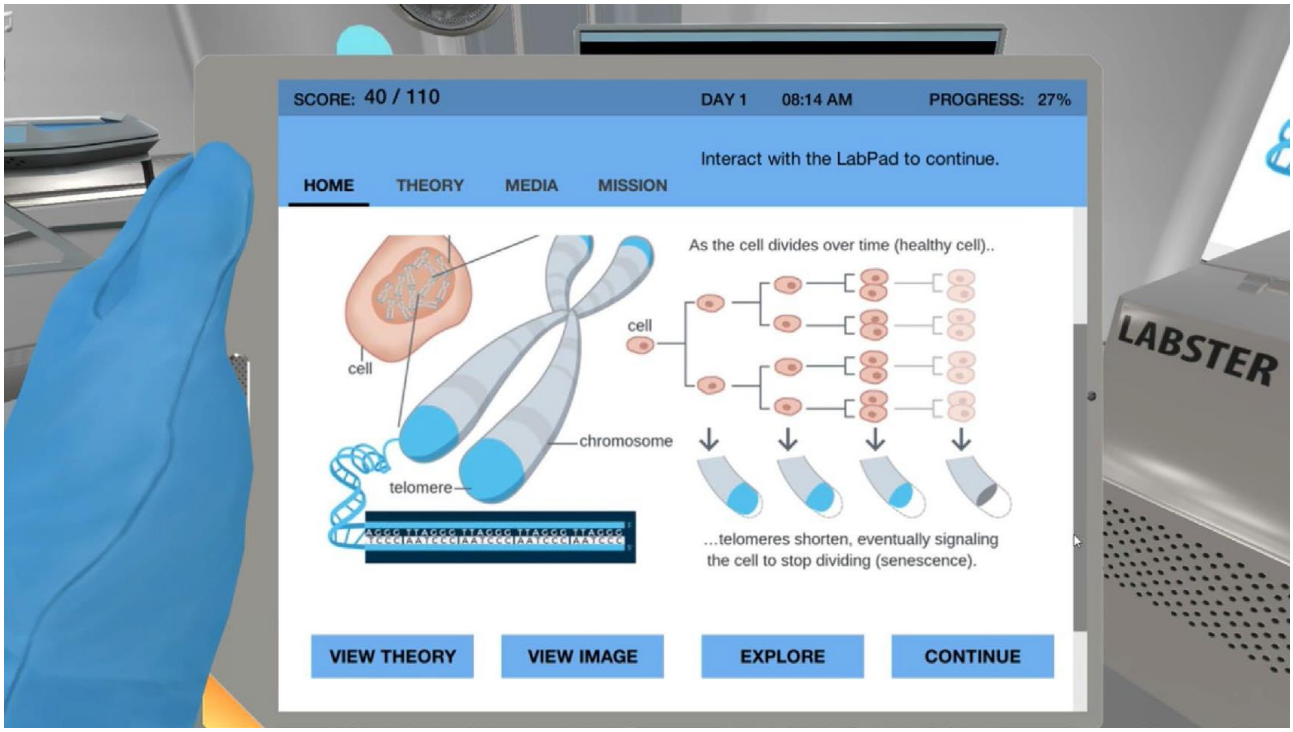

Figure 5: Labpad explanation of telomeres and changes in telomere length during DNA replication

Figure 6: Flow cytometer equipment and results screen used during the blood sample testing for the telomere length experiment

4.5 DNA adduct experiment

Dr Michael Conlon discusses the DNA adduct experiment

In the simulation we have conducted an experiment looking at the influence of diet on formation of a particular type of modification to DNA that may lead to a greater risk of colorectal cancer. It is now becoming clearer that the tissues of the large bowel are reliant on certain products that result from the microbial fermentation of fibre in the large bowel for much of their energy and also for their long-term integrity. These products are the short chain fatty acids, mainly acetate, butyrate and propionate. Butyrate appears to be important for helping maintain healthy colorectal tissues by stimulating apoptosis (cell death) of cells which have high damage, particularly DNA damage.

An unhealthy western-style diet high in protein and fat but low in fermentable dietary fibre leads to the presence of more toxic components reaching, or being formed in, the large bowel where they can damage the tissues and DNA. Consumption of such a western-style diet has been shown to increase the formation of DNA adducts such as O6-methyl-2-deoxyguanosine (O6MeG) which are implicated in increasing the chances of cells becoming cancerous over the long-term.

In this simulation we have asked the user to examine colonic tissue sections from individuals consuming a generally healthy diet and an unhealthy diet (Figure 7). The tissue sections have been stained to detect the O6MeG DNA adduct. It should be apparent that there is greater staining (more adducts) with the unhealthy diet.

Figure 7: Workstation setup for the DNA adduct experiment, including micro-pipette, forceps, microscope, microscope slides and waste bins

4.6 Lunch choice activity

After users have completed the two main experiments, they are given the chance to put the knowledge they have gained around macro- and micro-nutrients and food choices into action, by planning a healthy lunch suggestion for Mia.

They are given an array of food and drink options and need to come up with a calorie and nutritionally balanced meal option. Once they have finished, they press the 'Calculate' button on the computer to see if they have included enough of the appropriate nutrients to constitute a healthy option (Figure 8).

Students can attempt this activity several times and will receive feedback as they go. If struggling with getting the balance right, they can find more information in the Theory pages on the Lab Pad (Appendix 6.3).

Figure 8: Students choose food and beverage options that they consider to be a healthy lunch example for Mia

4.7 Simulation closing

After completion of this activity, users need to place their gloves in the waste bin at work bench 1 and then exit the laboratory. The laboratory finishes with a final video where the two student characters discuss the results of their research. The simulation then acknowledges user completion of the lab.

To find out more about the references for the laboratory, click on the Theory Pages section of the Lab Pad.

To exit the laboratory, press the 'Esc' button on your keyboard.

5 Resources

ACT Board of Senior Secondary Studies (BSSS): www.bsss.act.edu.au/

Australian E-Health Research Centre, 2015. 'The Hungry microbiome – Why resistant starch is good for you'. aehrc.com/research/case-studies/the-hungry-microbiome/

Australian Curriculum: www.australiancurriculum.edu.au

Blackburn, E.H., 1991. 'Structure and function of telomeres'. Nature 350, 569 – 573

Blackburn, E., & Epel, E., 2017. 'The Telomere Effect: A Revolutionary Approach to Living Younger, Healthier, Longer', Grand Central Publishing, 416 p.

CSIRO Education and Outreach: www.csiro.au/en/Education

CSIRO Health and Biosecurity: www.csiro.au/en/Research/BF

LABSTER™ website: www.labster.com/about/

Lopéz-Otín, C., Blasco, M.A., Partridge, L., Serrano, M., and Kroemer, G. 2013. 'The hallmarks of aging'. Cell 153, 1194 – 1211

NSW Education Standards Authority (NESA): www.educationstandards.nsw.edu.au

Office of Tasmanian Assessment, Standards and Certification (TASC): www.tasc.tas.gov.au

School Curriculum and Standards Authority (SCSA): www.scsa.wa.edu.au

South Australian Certificate of Education (SACE): www.sace.sa.edu.au

Queensland Curriculum and Assessment Authority (QCAA): www.qcaa.qld.edu.au

Victorian Curriculum and Assessment Authority (VCAA): www.vcaa.vic.edu.au

Appendix A State-Specific Syllabus References

A.1 ACT (BSSS)

COMPONENT	YEAR 11 & 12
Food Science and Management (T)	
Food and Nutrition	Identify specific macro and micronutrients in food and apply this knowledge to the principles of healthy eating Analyse information relating the role and importance of nutrition to health Demonstrate knowledge of the relationship between food and nutrient intake and diet related diseases due to affluence and deficiency
Nutrition and Health	Define and critically evaluate topical food issues and controversies
Food Chemistry	Compare and contrast the physical and chemical properties of nutrients in foods Examine the chemical makeup of specific macro and micro nutrients in food, and how they interact in the human body Investigate the physical and chemical properties of food constituents
Food For Life (A/M)	
Nutrition for Life	Acquire a sound knowledge of food selection models, in particular the Australian Guide to Healthy Eating Describe nutrients required for good health Identify and describe the attributes of a balanced diet and its role in maintaining health throughout the lifecycle Recognise, research and describe nutritional issues in our society today Critique nutritional information provided by a variety of media

A.2 New South Wales (NESA)

COMPONENT	STAGE 6
Biology	
Course Outcomes	Develop and evaluate questions and hypotheses for scientific investigation (BIO11/12-1) Conduct investigations to collect valid and reliable primary and secondary data and information (BIO11/12-3) Analyse and evaluate primary and secondary data and information (BIO11/12-5) Solve scientific problems using primary and secondary data, critical thinking skills and scientific processes (BIO11/12-6)
Module 2 Organisation of Living Things	**Nutrient and Gas Requirements** Trace the digestion of foods in a mammalian digestive system, including: • Physical digestion • Chemical digestion • Absorption of nutrients, minerals and water **Transport** Compare the structures and function of transport systems in animals and plants, including but not limited to: • Vascular systems in plants and animals Open and closed transport systems in animals
Module 8 Non-infectious Disease and Disorders	**Causes and Effects** Investigate the causes and effects of non-infectious diseases in humans, including but not limited to: • Nutritional diseases • Cancer **Epidemiology** Analyse patterns of non-infectious diseases in populations, including their incidence and prevalence, including but not limited to: • Nutritional diseases Investigate the treatment/management, and possible future directions for further research, of a non-infectious disease using an example from one of the non-infectious diseases categories listed above

COMPONENT	STAGE 6
Food Technology	
Course Outcomes	Explain the role of food nutrients in human nutrition (P2.1) Assess the nutrient value of meals/diets for particular individuals and groups (P3.1) Select foods, plans and prepares meals/diets to achieve optimum nutrition for individuals and groups (P4.3) Evaluate the relationship between food, its production, consumption, promotion and health (H2.1) Investigate operations of one organisation within the Australian food industry (H3.1)
8.1 Food Availability and Selection	**Factors affecting food selection** physiological factors, including: nutritional requirements, eg age, gender, size, activity level
8.3 Nutrition	**Food nutrients** Food nutrients: carbohydrates, proteins, lipids, vitamins, minerals and water Structure of carbohydrates, proteins and lipids Sources of carbohydrates, proteins, lipids, vitamins, minerals and water Functions of carbohydrates, proteins, lipids, vitamins, minerals and water in the body Digestion, absorption and metabolism of food Identify food nutrients Identify types of carbohydrates, proteins and lipids Identify the nutrient composition of various foods Explain the functions of food nutrients in human nutrition Describe the process of digestion, absorption and metabolism of food **Diets for optimum nutrition** Current food selection guides and nutritional information that assist in planning and evaluating meals/diets Select foods to provide a balanced intake of nutrients for particular individuals and groups to meet a variety of nutritional needs
9.1 The Australian Food Industry	**Aspects of the Australian food industry** Operation of organisations within the Australian food industry with particular attention to: • research and development
9.4 Contemporary Nutrition Issues	**Diet and health in Australia** Physical effects and economic costs of malnutrition (under and over nutrition) and diet related disorders The role of 'active non-nutrients' in the diet, e.g. phytochemicals, probiotics and fibre The role of supplements in the diet Influences on nutritional status Health and the role of diet in the development of conditions, including obesity, diabetes, cardiovascular disease, food sensitivity/intolerance/allergies Lifestyle and the effect of cultural and social practices on nutritional status

A.3 Queensland

COMPONENT	YEAR 11 & 12
Home Economics	
Nutrition and food	Knowledge of nutrition and the use of food selection models or tools are necessary for the critiquing, designing and planning of dietary patterns Nutrition and food choices impact on wellbeing and sustainable food futures

A.4 South Australia (SACE)

COMPONENT	STAGE 2
Nutrition	
Core Topic 1: The Fundamentals of Human Nutrition	**1. Humans need essential nutrients for good health** 1.1 Why do humans need to include essential nutrients in their diet? • How do macronutrients and micronutrients function? 1.2 Why is it essential to know about and understand the nutritional composition of a variety of sources of food? • How can foods be combined to improve their nutritional status? **2. The digestion and metabolism of food influence the absorption and use of nutrients** 2.1 How are foods digested and nutrients absorbed in the human body? • What are some of the factors that interfere with the absorption of nutrients?
Core Topic 2: Diet, Lifestyle and Health	**1. Australians may be affected by diet-related disorders** 1.2 How can the symptoms of diet-related disorders be prevented, controlled or reversed? • What are some of the risk factors associated with diet-related disorders? • How can diet and lifestyle strategies help individuals and communities prevent, control, or reverse the symptoms of diet-related disorders
Core Topic 3: Food Selection and Dietary Evaluation	**1. Many factors influence food choices and nutritional status** 1.4 How can good nutrition be maintained by the selection and preparation of food? **2. Behaviour modification can improve nutritional outcomes** 2.1 How can individuals modify their behaviour to improve their nutritional health and well-being?

A.5 Tasmania (TASC)

COMPONENT	YEAR 11 & 12
Food and Nutrition	
Learning Outcomes	Apply an understanding of nutrition, food and health to analyse and modify diets, menus and recipes Use knowledge of food to analyse the nutritional and aesthetic qualities of food and food products Analyse information and data regarding food related issues Locate and critically analyse food and nutrition related information Design and evaluate nutrition promotion strategies
Unit 1 Nutrition	**Energy** Overview of requirements and recommended proportions ad % of total energy from macronutrients including BMR and activity **Macronutrients** Proteins (complete and incomplete) Lipids/fats (saturated, monounsaturated & polyunsaturated) and trans Essential fatty acids Omega 3 and 6 Carbohydrates (mono/disaccharides and polysaccharides including fibre) **Micronutrients** Vitamins – classification and awareness of generalised roles and interrelationships Minerals – overview and sources Focus on Iron, Calcium, Sodium, Potassium and Iodine (sources, functions and imbalances)
Unit 2 Dietary and Data Analysis	**Food and Nutrition research** Investigate different research methodologies Ethical implications of and for research Analysis of research **Apply nutrient reference values and food selection tools to analyse and modify diets, menus and recipes** Nutrient reference values

COMPONENT	YEAR 11 & 12
Food, Cooking and Nutrition	
Learning Outcomes	Appraise the nutritional, physical, sensory and functional properties of key foods Describe how environmental, cultural, economic and nutritional factors can relate to food choice
Unit 2 Nutrients, Energy and Health	Basic functions of Protein, Carbohydrates and Fibre, Fats, Vitamins, Minerals and Water Assess the nutritional quality of foods and meal Modify recipes, menus and diets to reflect current nutrition principles

A.6 Victoria (VCAA)

COMPONENT	YEAR 11 & 12
Food Studies	
Unit 2 Food makers	**Food in the home** Influences on effective planning, management and decision making in the provision and preparation of food in the home, including resources such as time and money, and values such as health and environmental sustainability
Unit 3 Food in daily life	**The science of food** The microbiology of the intestinal tract and the sequential processes of the digestion of carbohydrates, protein and fats, including enzymatic hydrolysis, absorption and utilisation of these macronutrients in the body The rationale and evidence-based principles of the Australian Dietary Guidelines and the Australian Guide to Healthy Eating, with particular focus on the ways in which food selection can assist in the prevention of obesity and related lifestyle diseases Explain the physiology of eating and digesting, and the absorption and utilisation of macronutrients Apply the principles of the Australian Dietary Guidelines and Australian Guide to Healthy Eating to the planning of daily food intake and demonstrate a range of practical food skills to create healthy meals Evaluate the nutritional quality of foods and meals **Food choice, health and wellbeing** Explain and analyse links between food, behaviours and effects on health
Unit 4 Food issues, challenges and futures	**Navigating food information** The principles of research used in the development of Australian Dietary Guidelines, including the recognition of credible sources, evidence-based information and accurate analysis of data, and how these principles can be applied in response to contemporary food fads, trends and diets Categories of compulsory and optional information contained on food labels, the purpose behind them, and the advantages of accurate label information for food consumers Practical ways to apply evidence-based recommendations relating to food and health, including the Australian Dietary Guidelines and the Australian Guide to Healthy Eating, to everyday food behaviours and habits, with particular attention to maintaining a healthy weight. Identify a variety of contexts in which food knowledge and skills takes place Identify the components of a food label and summaries the purpose of each Demonstrate understanding of the Australian Guide to Healthy Eating by applying it to practical food selection, planning and preparation and cooking activities.

COMPONENT	YEAR 11 & 12
Health & Human Development	
Unit 1 Understanding health and wellbeing	**Health and nutrition** The use of food selection models and other tools to promote healthy eating among youth, such as the Australian Guide to Healthy eating, the Healthy Eating Pyramid and the Health Star Rating System The consequences of nutritional imbalance in youths' diet on short- and long-term health and wellbeing Describe the possible consequences of nutritional imbalance in youths' diet on short- and long-term health and wellbeing
Unit 2 Managing health and development	**The science of food** Determinants that act as risk and/or protective factors in relation to one health issue such as cardiovascular disease, cancer, type 2 diabetes, obesity or mental illness
Unit 3 Australia's health in a globalised world	**Understanding health and wellbeing** The contribution to Australia's health status and burden of disease of smoking, alcohol, high body mass index, and dietary risks (under-consumption of vegetables, fruit and dairy foods; high intake of fat, salt and sugar; low intake of fibre and iron) Describe interrelationships between dimensions of health and wellbeing **Promoting health and wellbeing** Initiatives to promote healthy eating in Australia, including Australian Dietary Guidelines and the work of Nutrition Australia, and the challenges in bringing about dietary change

A.7 Western Australia (SCSA)

COMPONENT	YEAR 11 & 12
Food Science and Technology	
Unit 1 Food science	**Nutrition** Food sources and role of macronutrients and water in the body • Protein – complete and incomplete • Carbohydrates – starches, sugars and fibre or cellulose • Lipids – saturated fats and oils, and unsaturated fats and oils Food sources and role of micronutrients in the body • Fat-soluble vitamins – A and D • Water-soluble vitamins – B1 (thiamine), B2 (riboflavin), B3 (niacin) and C • Minerals – calcium, iron and sodium Effects of under-consumption of nutrients on health Effects of over-consumption of nutrients on health
Unit 2 The undercover story	**Nutrition** Dietary planning
Unit 3 Food diversity and equity	**Nutrition** Food sources and impact of macronutrient and water intake on health • Protein – complete and incomplete • Carbohydrates – starches, sugars and fibre or cellulose • Lipids – saturated fats and oils, and unsaturated fats and oils Food sources and impact of micronutrient intake on health • Fat-soluble vitamins, A, D, E and K • Water-soluble vitamins – B2 (riboflavin), B9 (folate), B12 (cobalamin) and C • Minerals – calcium, iron, sodium and potassium The effect of the consumption of functional foods on health • Digestive system
Unit 4 The future of food	**Nutrition** Digestion of macronutrients • Digestive tract • Associated organs of digestion • Mechanical digestion • Chemical digestion

Appendix B Student Task

Monitor your food and drink consumption for seven days and record how these nutritional choices affect your mood and energy levels.

Student nutrition diary (including how many glasses of water or other drinks are consumed)

Draw an emoji that best represents your mood and energy level after each meal. Include any physical activities in the comments section (e.g. went for a run, went swimming, played tennis). Adding in an approximate time when you consume each meal is also important.

DAY #	BREAKFAST	MORNING TEA	LUNCH	AFTERNOON TEA	DINNER	COMMENTS
1						
2						
3						
4						
5						
6						
7						

Review the data you entered in the previous table and create an example meal plan that would benefit a person's mood and energy levels, adding in at least 30 minutes of moderate exercise each day. Include how much water this person should consume in relation to their food intake and exercise. Suggest appropriate meal times to help the person maintain consistent energy levels.

Example meal plan

DAY #	BREAKFAST	MORNING TEA	LUNCH	AFTERNOON TEA	DINNER	COMMENTS
1						
2						
3						
4						
5						
6						
7						

Appendix C Theory Pages

Welcome to Your Diet and Your DNA Simulation

This simulation follows the food choices of two students and how they are impacting their performance and well-being. Through laboratory work you will explore digestion and nutrition, and test for DNA damage. You will also review the nutritional content of different foods and drinks. This information will then be used to identify healthy and unhealthy diets and to see how nutrition can impact performance and DNA health during your lifespan. Will you be able to help Mia get her energy back?

To find out more information about the topics in the simulation, check out the theory screens on the Lab Pad.

Good luck and have fun!

- Diet
- Calories
- Nutrition
  - Carbohydrates
  - Proteins
  - Fats
  - Minerals
  - Vitamins
- DNA Damage or Genomic instability
  - Telomeres
  - DNA adducts

Acknowledgment

The content of these theory pages has been developed based on the resources provided by:

- OpenStax College, Biology OpenStax CNX. 30 May 2015.
- Bull, C., O'Callaghan, N., Mayrhofer, G., and Fenech, M. 2009. Telomere length in lymphocytes of older South Australian men may be inversely associated with plasma homocysteine. Rejuvenation Research 12(5):341-349
- Conlon, M., & Bird, A. 2014. The Impact of Diet and Lifestyle on Gut Microbiota and Human Health. Nutrients, 7(1), 17-44. doi:10.3390/nu7010017
- Le Leu, R., Scherer, B., Mano, M., Winter, J., Lannagan, T., Head, R., Lockett, T. and Clarke, J. 2016. Dietary butyrylated high-amylose starch reduces azoxymethane-induced colonic O6-methylguanine adducts in rats as measured by immunohistochemistry and high-pressure liquid chromatography. Nutrition research 36(9):982-988.

Diet

The term diet describes the food and drink consumed by a person.

A healthy diet does not depend on the selection of a single type of food. Instead, it depends on the selection of many different foods over time. A healthy diet encourages you to enjoy a wide variety of nutritious food.

Consistently having a poor diet can impact our health on a DNA level and can lead to DNA damage, and thus to an increased risk of disease.

Healthy diet

- High in fibre
- Low in saturated fat
- High fruit or vegetables intake (High polyphenols)
- High level of micronutrients
- Calorie intake appropriate for BMI, age, gender and activity levels
- Sufficient omega-3 fatty acids
- Moderate protein

Unhealthy diet

- Low in fibre
- High in saturated fat
- Low fruit or vegetables intake (Low polyphenols)
- Low level of micronutrients
- Calorie-dense
- Low omega-3 fatty acids
- High protein

Click here to view the Australian dietary guideline poster.

An example of healthy diet:

- Lean chicken
- Salad
- Broccoli
- Olive oil
- Milk

References:

- Commonwealth of Australia. Australian dietary guidelines. 2013. www.eatforhealth.gov.au
- WHO. Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation. WHO technical report series, 2002.

Food sources for essential nutrients

A healthy diet depends on the selection of different foods. Listed below are the best food sources for nutrients that our body needs.

Nutrient Sources

NUTRIENT	SOURCES
Complex carbohydrates and fibres	Wholemeal bread, wholegrain cereals, baked beans, pasta, potatoes, peas, other starchy vegetables
Protein	Lean meat, chicken, fish, cheese, milk, eggs, bread, nuts, legumes
Fat	Oils, butter, meat, cheese, nuts
Vitamins	Vegetables and fruits. See vitamins list for more details.
Minerals	Fish and vegetables. See minerals list for more details
Polyphenols	Cloves, cocoa powder, berries, plums, apples, beans, nuts, vegetables, soy, black tea, green tea, and red wine.

References:

- Healthy Eating Club, Best food sources of essential nutrients. 2004. http://apjcn.nhri.org.tw

Vitamins

Vitamins are organic compounds found in foods and are required for many biochemical reactions in the body.

They are involved in a number of processes, including mineral and bone metabolism and cell and tissue growth. They also act as co-factors for energy metabolism. The B group of vitamins are of particular importance, and play many essential roles in cellular metabolism and health.

You get most of your vitamins through your diet, although some can be formed from precursors absorbed during digestion. For example, the body synthesizes vitamin A from the β-carotene in orange vegetables like carrots and sweet potatoes.

Figure 1. A healthy diet should include a variety of foods to ensure that the requirements of essential nutrients are met.

List of vitamins

Water-soluble essential vitamins

VITAMIN	SOURCE
Vitamin B1 (Thiamine)	Milk, meat, dried beans, whole grains
Vitamin B2 (Riboflavin)	Meat, eggs, enriched grains, vegetables
Vitamin B3 (Niacin)	Meat, eggs, grains, nuts, potatoes
Vitamin B5 (Pantothenic acid)	Meat, whole grains, milk, fruits, vegetables
Vitamin B6 (Pyridoxine)	Meat, dairy products, whole grains, orange juice
Vitamin B7 (Biotin)	Meat, eggs, legumes and other vegetables
Vitamin B9 (Folic acid)	Leafy green vegetables, whole wheat, fruits, nuts, legumes
Vitamin B12 (Cobalamin)	Meat, eggs, animal products
Vitamin C (Ascorbic acid)	Citrus fruits, broccoli, tomatoes, red bell peppers

Fat-soluble essential vitamins

VITAMIN	SOURCE
Vitamin A (Retinol)	Dark green leafy vegetables, yellow-orange vegetables and fruits, milk, butter
Vitamin D	Cod liver oil, milk, egg yolk
Vitamin E (Tocopherol)	Wheat germ oil, unrefined vegetable oils, nuts, seeds, grains
Vitamin K (Phylloquinone)	Leafy green vegetables, tea

References:

- Commonwealth of Australia. Australian dietary guidelines. 2013. www.eatforhealth.gov.au
- OpenStax College, Biology OpenStax CNX. 30 May 2015.

Minerals

Minerals are essential inorganic nutrients that must be obtained from food. Among their many functions, minerals help in the structure and regulation of our bodies and are considered co-factors for enzymes to assist with biochemical reactions.

Major minerals are essential mineral nutrients found in the human body in amounts larger than 5g. Trace minerals are needed in smaller amounts (<2 g). Listed below are the major minerals.

MINERALS	SOURCE
Calcium	Milk, yogurt, fish, green leafy vegetables, legumes
Chlorine	Table salt
Magnesium	Wheat germ oil, unrefined vegetable oils, nuts, seeds, grains
Phosphorus	Milk, hard cheese, whole grains, meats
Potassium	Legumes, potato skin, tomatoes, bananas
Sodium	Table salt

References:

- Commonwealth of Australia. Australian dietary guidelines. 2013. www.eatforhealth.gov.au
- OpenStax College, Biology OpenStax CNX. 30 May 2015

Australian dietary poster

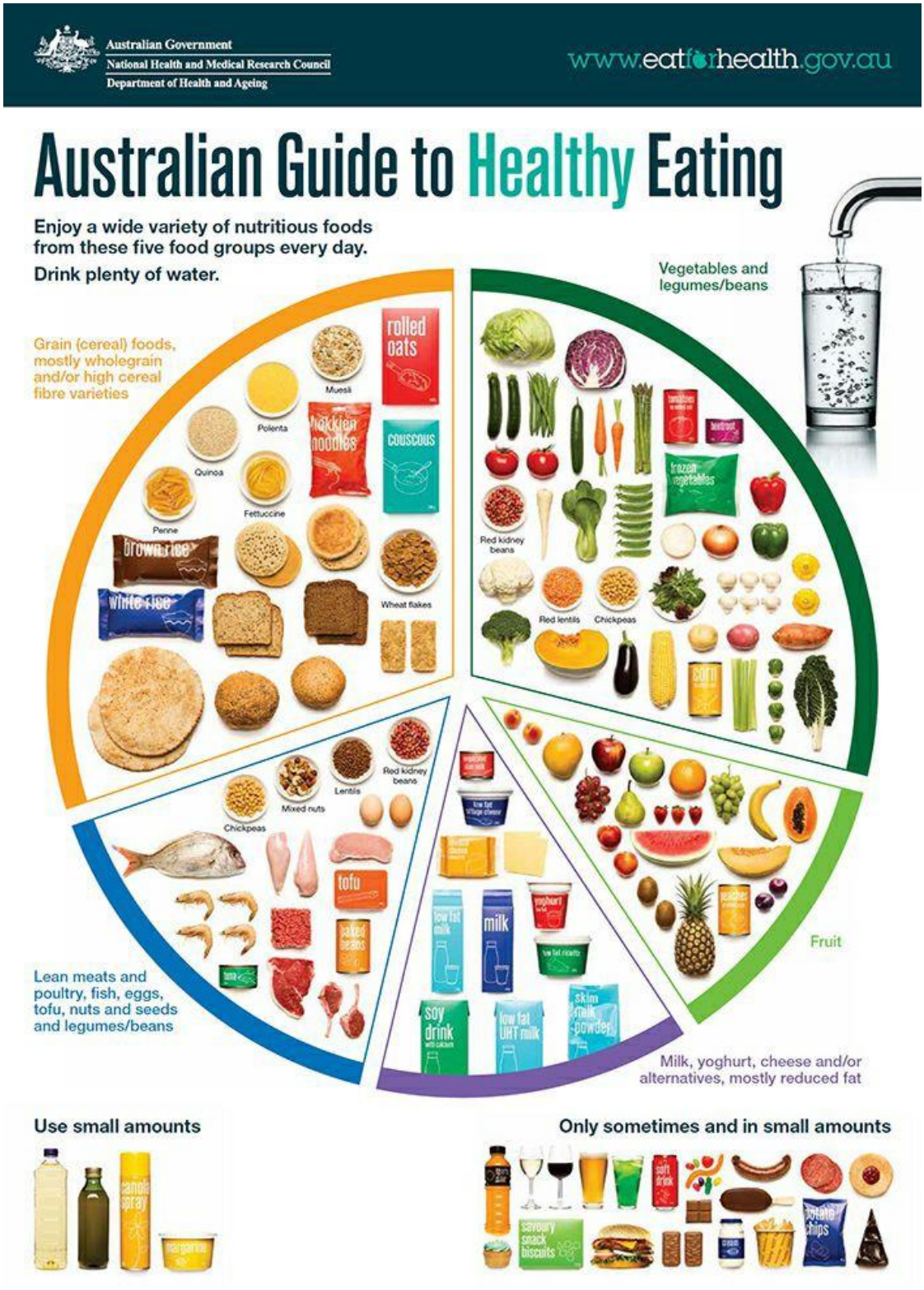

Figure 2. Guide to healthy eating Click here to read more about diet.

References:

- Commonwealth of Australia. Australian dietary guidelines. 2013. www.eatforhealth.gov.au

Nutritional calories

The nutritional calorie (C) is the amount of heat it takes to raise 1 kg (1000 g) of water by 1 °C. You may be more familiar with kilojoules as a measure of energy from food.

4.184 kilojoules = 1 Calorie (C)

*note the capitalization of Calorie (C).

On average, a person needs 1500 to 2000 Calorie (6200-8700 kilojoules) per day to sustain (or carry out) daily activities. The total number of nutritional calories needed by one person is dependent on their body mass, age, height, gender, activity level, and the amount of exercise per day.

Average calories per meal:

- For women: 450 - 750 Calories
- For men: 650 - 850 Calories

References:

- OpenStax College, Biology OpenStax CNX. 30 May 2015
- Rolfes,S. Understanding normal and clinical nutrition 8th ed. Wadsworth, Cengage Learning,

Nutrition

Nutrition is the science of food, the nutrients and other substances it contains, and its actions within the body (including ingestion, digestion, absorption, transport, metabolism, and excretion).

Humans primarily eat food to nourish their bodies. This food contains nutrients for the maintenance of life and the growth and repair of tissue such as skeletal muscle.

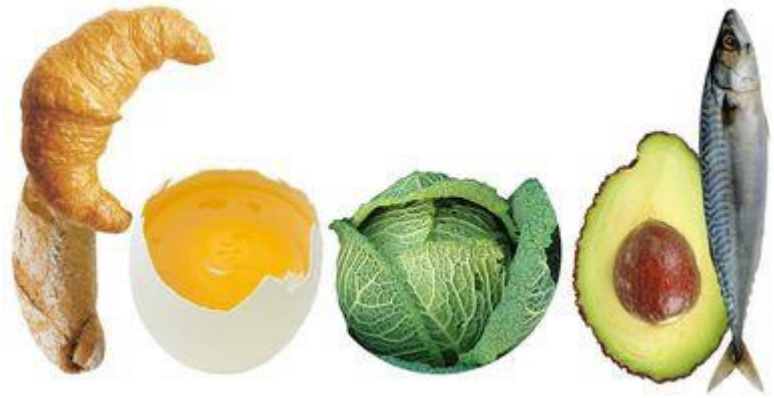

Figure 3. Different foods contains different levels of nutrients.

Macronutrients are nutrients that the body needs in relatively large amounts (many grams daily). Nutrients that we consider macronutrients are carbohydrate, protein, and fat.

Micronutrients are nutrients that the body needs in relatively small amount (milligrams or micrograms daily). Nutrients that we consider micronutrients are vitamins and minerals.

Micronutrients are used to build and repair tissues and to regulate body processes, while macronutrients are converted to and used for energy.

Essential nutrients are nutrients that a person must obtain from food because the body cannot make them by itself in sufficient quantities.

References:

- Rolfes,S. Understanding normal and clinical nutrition 8th ed. Wadsworth, Cengage Learning,

Carbohydrates

Carbohydrates are molecules built from sugars. They can exist as simple, single sugar molecules (monosaccharides), or chains of two or more sugar molecules (disaccharides and polysaccharides). Carbohydrates are an important source of energy and structural material for organisms.

Carbohydrates can be represented by the stoichiometric formula Cm(H2O)n (where m could be different from n). In sugars such as glucose and fructose and their derivatives, n = m and the ratio of carbon to hydrogen to oxygen is 1:2:1. This formula also explains the origin of the term "carbohydrate"; which means hydrated or watered carbon. The components are carbon ("carbo") and water ("hydrate").

Carbohydrates are an essential part of a diet because they provide energy to the body. Most people are familiar with carbohydrates, especially when it comes to what we eat. For example, to lose weight, some individuals adhere to "low-carb" diets. Athletes, in contrast, often "carb-load" before important competitions to ensure that they have enough energy to compete at a high level. Grains, fruits, and vegetables are all natural sources of carbohydrates that can be used for energy. These foods consist of both soluble and insoluble carbohydrates; the insoluble part is known as fibre, which is mostly cellulose.

References:

- McMahon, L. Plants and society 5th Edition. Chapter 10: Human Nutrition. McGraw-Hill, 2008.

Monosaccharides

Monosaccharides (mono = “one”, sacchar = “sweet”) are simple sugars. In monosaccharides, the number of carbon atoms usually ranges from three to seven. Most monosaccharide names end with the suffix "-ose". If the sugar has an aldehyde group (the functional group with the structure R-CHO), it is known as an aldose, and if it has a ketone group (the functional group with the structure RC(=O)R'), it is known as a ketose. Depending on the number of carbons in the sugar, they also may be known as trioses (three carbons), pentoses (five carbons) and/or hexoses (six carbons).

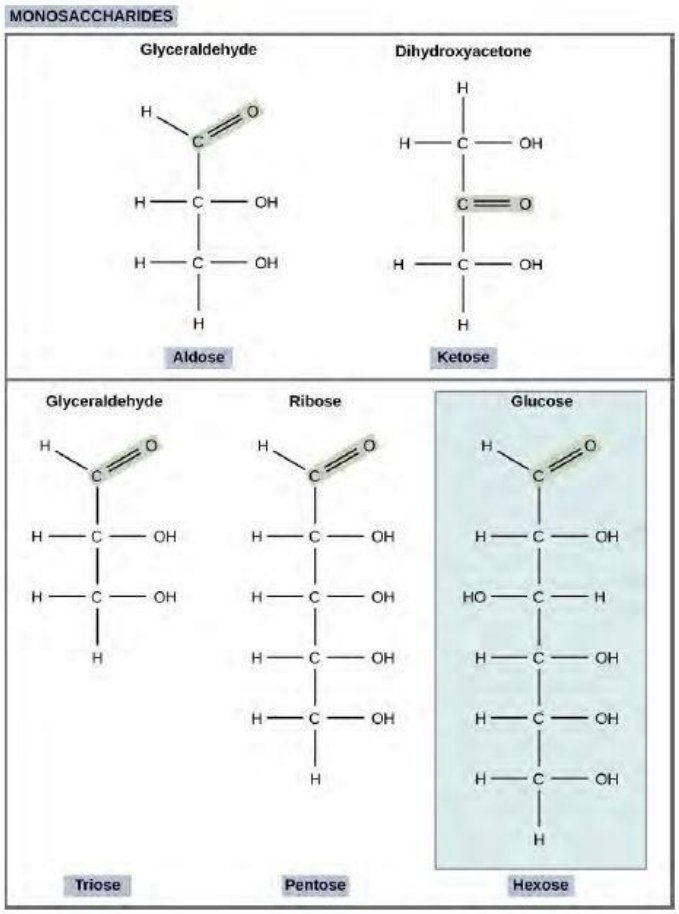

Figure 4: Monosaccharides are classified based on the position of their carbonyl group and the number of carbons in the backbone. Aldoses have a carbonyl group at the end of the carbon chain, and ketoses have a carbonyl group in the middle of the carbon chain. Trioses, pentoses, and hexoses have three, five, and six carbon backbones, respectively.

The most common monosaccharide is glucose, the building block of many important carbohydrates. Galactose (part of lactose or milk sugar) and fructose (found in sucrose in fruit) are other common monosaccharides. Although glucose, galactose and fructose all have the same chemical formula ($C_6H_{12}O_6$), they differ structurally and chemically (and are known as isomers) because of the different arrangement of functional groups around the asymmetric carbon; all of these monosaccharides have more than one asymmetric carbon.

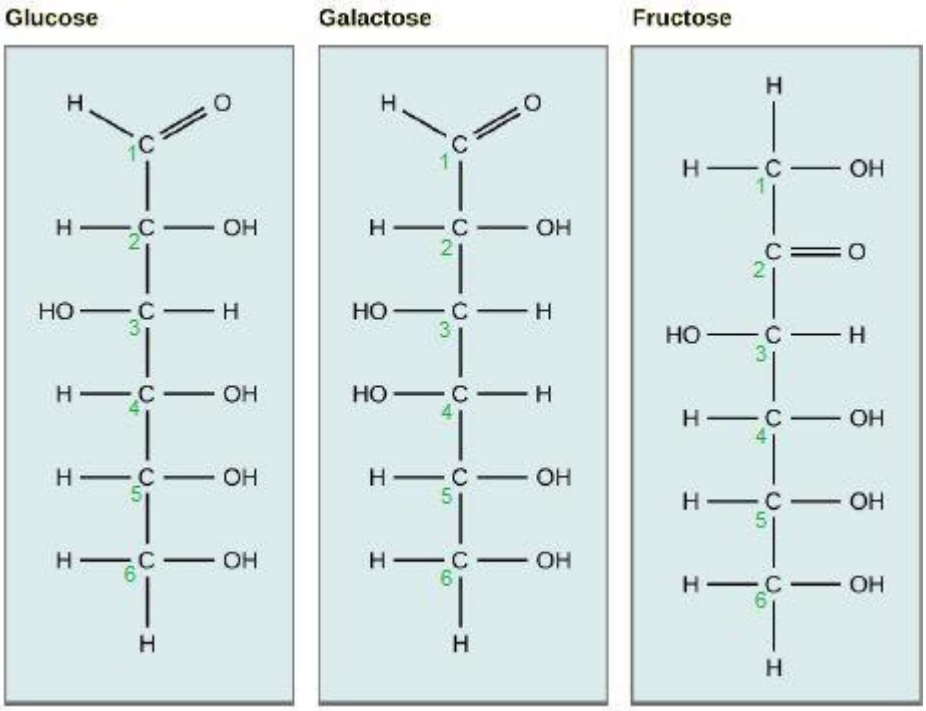

Figure 5: Glucose, galactose and fructose are isomeric monosaccharides (hexoses), meaning they have the same chemical formula but have slightly different structures. Glucose and galactose are aldoses, and fructose is a ketose. By convention, the carbon atoms in a monosaccharide are numbered from the terminal carbon closest to the carbonyl group.

Monosaccharides can exist as a linear chain or as ring-shaped molecules.

Disaccharides

Disaccharides (di- = “two”) consist of two sugar molecules. They form when two monosaccharides undergo a dehydration reaction, forming a glycosidic bond. These bonds can be of the alpha or the beta type.

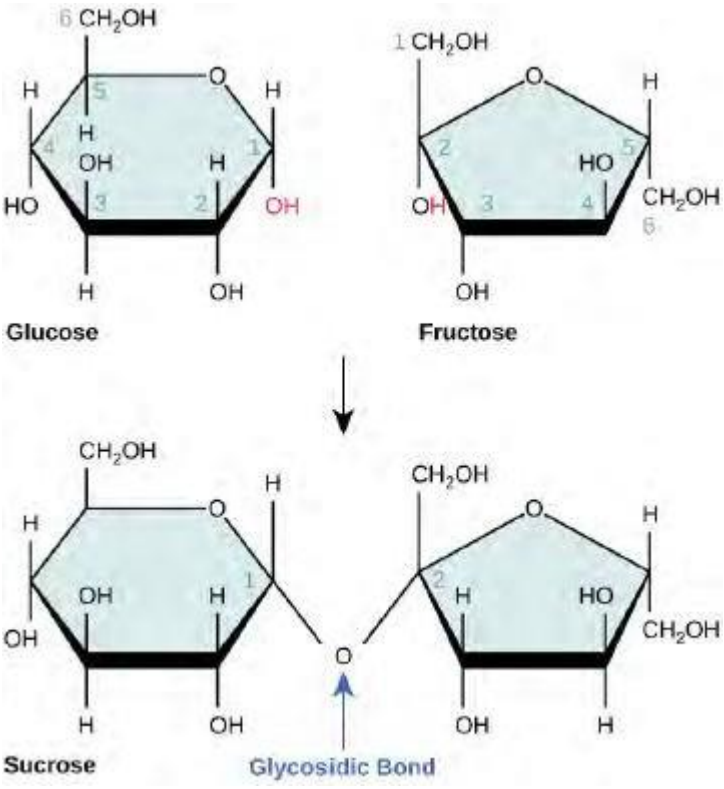

Figure 6: Sucrose is formed when a monomer of glucose and a monomer of fructose are joined in a dehydration reaction to form a glycosidic bond between carbon 1 in glucose and carbon 2 in fructose. In the process, a water molecule is lost.

Common disaccharides include lactose, maltose, and sucrose.

Polysaccharides

Polysaccharides are a long chain of monosaccharides linked by glycosidic bonds (poly- = “many”). The chain may be branched or unbranched, and it may contain different types of monosaccharides. The molecular weight may be 100,000 daltons or more, depending on the number of monomers joined.

Starch, glycogen, cellulose, fiber, and chitin are primary examples of polysaccharides.

Glucose

Glucose is a type of sugar with the chemical formula C6H12O6. In humans, glucose is an important source of energy. During cellular respiration, energy is released from glucose, and that energy is used to help make ATP. Plants synthesize glucose using carbon dioxide and water, and glucose, in turn, is used for the energy requirements of the plant. Excess glucose is often stored as starch which is catabolized by humans and other animals that feed on plants

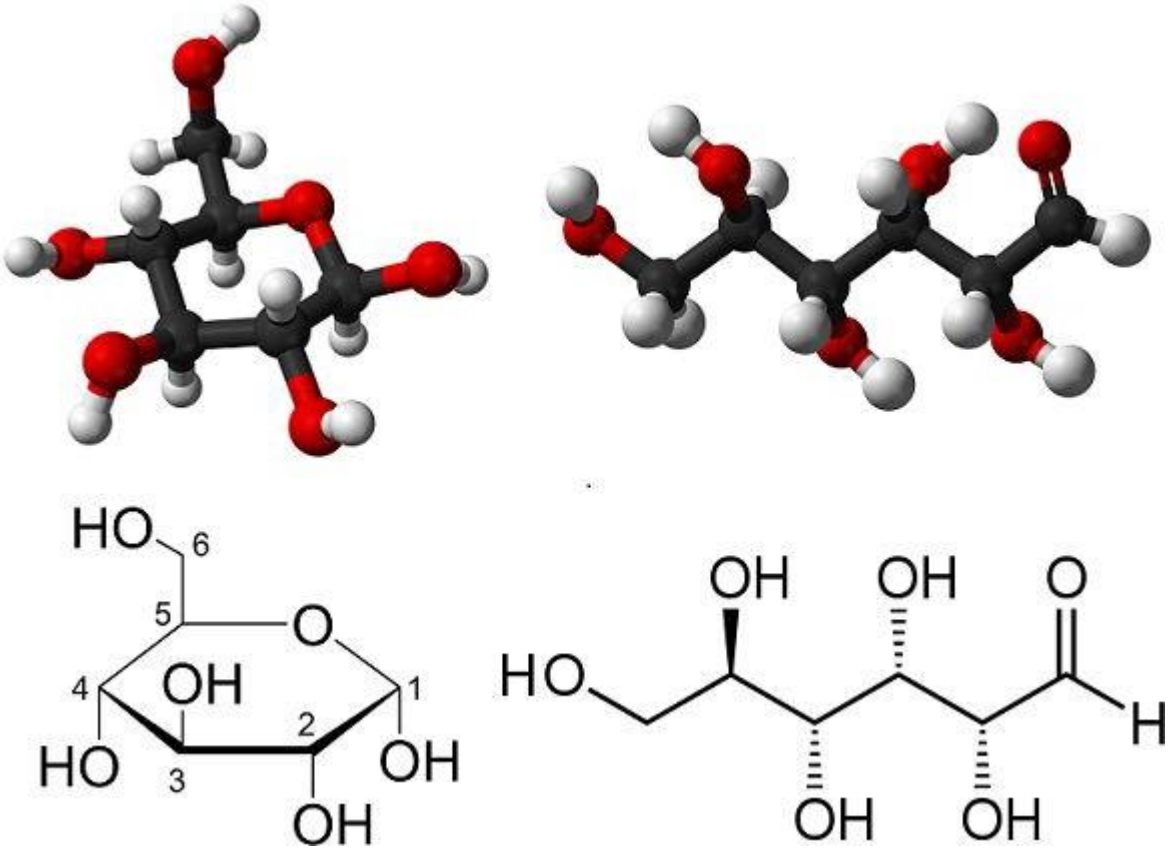

Figure 7: Depending on the solution, glucose molecules form different isomers.

Fructose

Fructose, or fruit sugar, is a simple monosaccharide found in many plants. It is often bonded to glucose to form the disaccharide sucrose. Fructose is found in honey, tree and vine fruits, flowers, berries and most root vegetables. It is absorbed directly into the bloodstream during digestion.

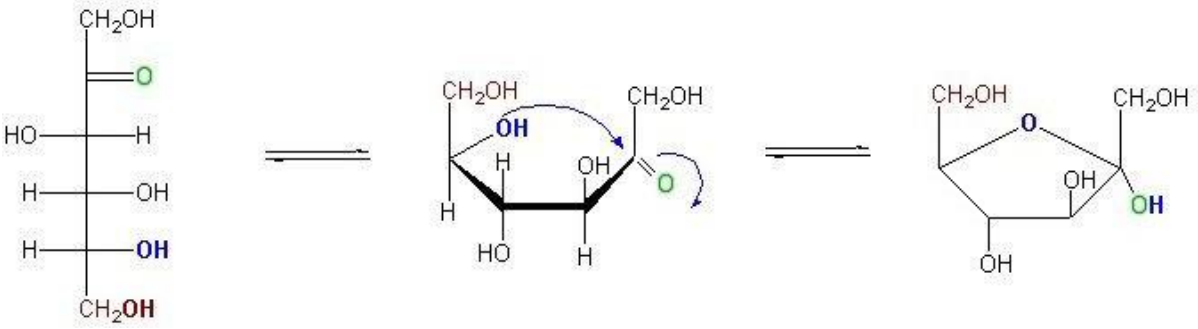

Figure 8: The most common isoform of fructose is a five-membered ring.

Dietary fibre

Dietary fibre refers to mainly indigestible carbohydrates found in plant-based foods. Most dietary fibre is in the form of polysaccharides.

Dietary fibre is divided into two groups:

- Soluble fibre, for example, inulin, pectin, or xylose.
- Insoluble fibre, for example, cellulose, chitin, resistant starch.

Starch, also a polysaccharide, differs from dietary fibre in that the bonds between its monosaccharides cannot be broken down by the digestive enzymes in the body. A few starches, known as resistant starches, are classified as dietary fibre.

Advantage

Fibre is highly beneficial to the digestive system. It promotes regular bowel movement by adding bulk to food waste, and it slows down the absorption rate of glucose from food.

Fibre helps remove excess cholesterol from the body. It binds to the cholesterol in the small intestine and transports cholesterol out of the body through faeces.

Fibre-rich diets also have a protective role in reducing the occurrence of colon cancer.

In addition, a meal high in fibre, such as one containing whole-grains and vegetables, gives a feeling of fullness for longer.

Cellulose

Cellulose is the most abundant natural biopolymer on Earth because it is the main component in plant cell walls. Cellulose provides plants with structural support, hence wood and paper are mostly composed of cellulose. Cellulose is made up of glucose monomers that are linked by β 1,4 glycosidic bonds.

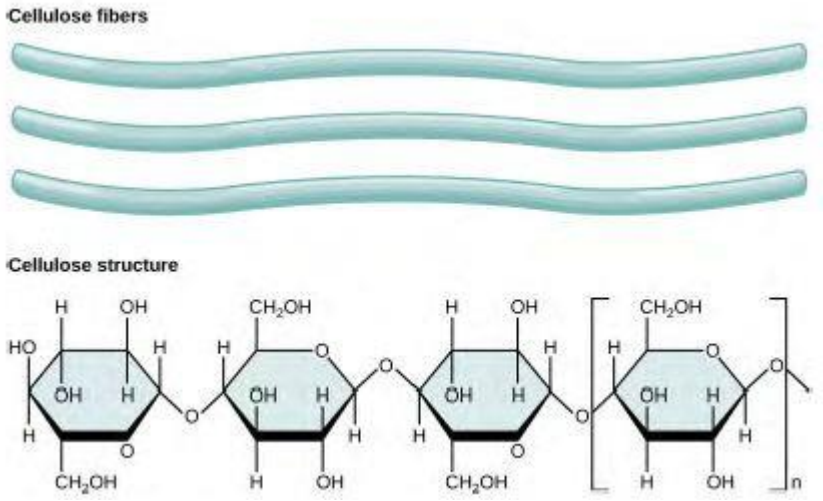

Figure 9: In cellulose, glucose monomers are linked in unbranched chains by β 1,4 glycosidic bonds.

Because of the way the glucose subunits are joined, every glucose monomer is flipped relative to the next one resulting in a linear, fibrous structure. This gives cellulose its rigidity and high tensile strength — which is so important to plant cells.

Human digestive enzymes cannot break down the β 1,4 glycosidic bonds. However, herbivores such as cows, koalas, buffalos, and horses possess specialized gut flora which can digest cellulose and use it as a food source. In these animals, certain species of bacteria and protists reside in the rumen (part of the digestive system of herbivores) and secrete the enzyme cellulase.

Cellulose-digesting bacteria also live in the appendix of grazing animals. The appendix is therefore important in the digestive systems of ruminants.

Termites also contain microorganisms in their body which can break down cellulose.

Amino acids

A polymer of amino acids is called a polypeptide.

All amino acids share common structures (see List of amino acids). Amino acids consist of an amino group and a carboxyl group connected by an alpha carbon. The R group, also known as side chain, differs with each amino acid. The side chain's physical and chemical properties determine the functional role of the amino acid in the polypeptide. Because of the unique

characteristic of the side group, an amino acid can be hydrophobic, hydrophilic, acidic or basic. Amino acids are connected with peptide bonds.

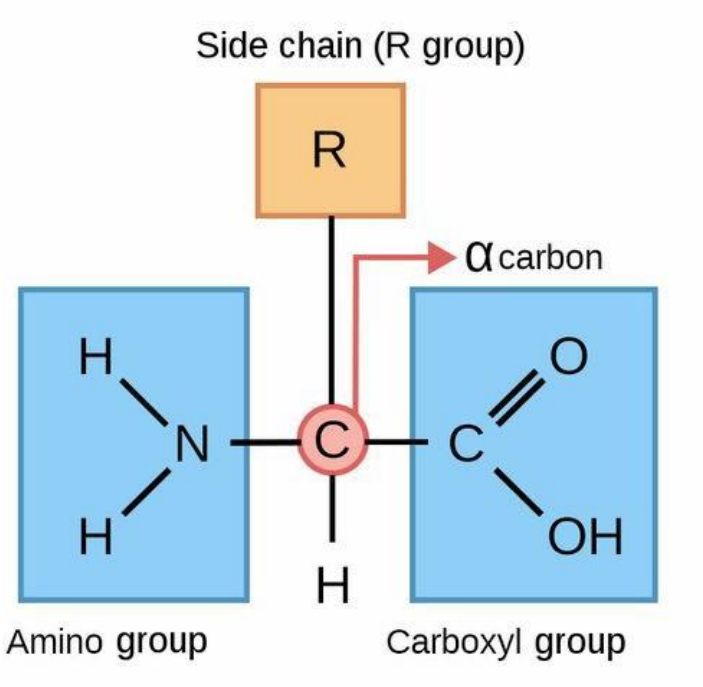

Figure 10: Structure of a representative amino acid. All amino acids contain an amino group and a carboxyl group joined to a central carbon atom. The side group varies between amino acids and it is this which gives rise to their unique chemical and physical properties.

Peptide Bonds

A peptide bond (amide bond) is a covalent chemical bond formed between two amino acid molecules. Amino acids are connected by a dehydration reaction, marked by the removal of water. The resulting covalent bond is called a peptide bond. A polypeptide, regardless of length, has a single amino acid end (N-terminus) and a single carboxyl end (C-terminus).

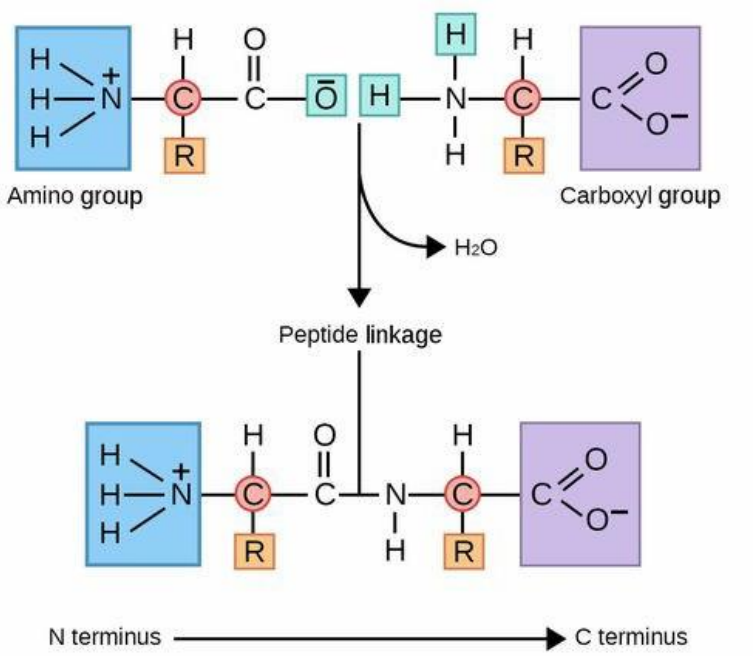

Figure 11: Amino acids are bound by peptide bonds to form polypeptides. The linkage occurs between the amino and carboxyl group releasing H20 in the process.

Protein Structure

Proteins have at least three structures: primary, secondary, and tertiary structure.

The primary structure of a protein is its polypeptide sequence. The secondary structure consists of the coil (alpha-helix) and folds (beta-sheet) that result from hydrogen bonds between repeating constituents of the polypeptide chains. The tertiary structure is the overall shape of the polypeptide resulting from all the interactions between the side chains of various amino acids. A quaternary structure also arises when a protein consists of two or more polypeptide chains (Figure 1).

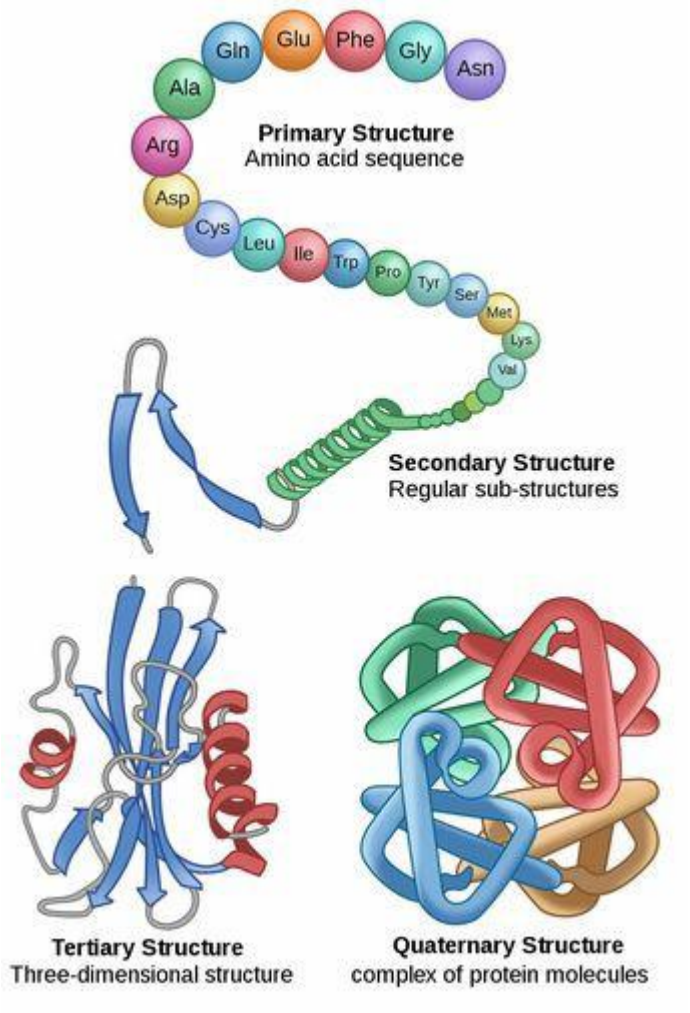

Figure 12. The various structures formed by amino acids and proteins are given specific terms. The primary structure refers to the linear amino acid sequence. The secondary structure refers to the formation of regular substructures such as alpha helices or beta sheets. The tertiary structure describes the 3D structure of the protein, accounting for the way the substructures interact with each other. Finally, if a protein is comprised of multiple polypeptides, their interaction is described in the quaternary structure.

Fats and Oil

Fats belong to a group of a biological compounds called lipids. A fat, also known as a triglyceride, is constructed from two kinds of smaller molecules: glycerol and fatty acids.

Fatty acids are the building blocks of fat. To form a triglyceride molecule, three fatty acid molecules are joined to glycerol by an ester linkage. An ester linkage is a bond formed by a dehydration reaction between a hydroxyl group and a carboxyl group.

Based on the type of the fatty acid, fats can be saturated or unsaturated.

Fat mostly refers to fats that are solid at room temperature. Fats that are liquid at room temperature are called oils.

References:

- OpenStax College, Biology OpenStax CNX. 30 May 2015

Lipid

Lipids refer to a group of water-insoluble compounds found in the tissue of plants and animals. This group of compounds is classified as:

- Fats
- Phospholipids
- Sphingomyelins
- Waxes
- Sterols

The main functions of lipids are energy storage, mobilization, and utilization. Other functions of lipids are synthesis of prostaglandin and cytokine, cell differentiation and growth, cell membrane structure, signal transmission, hormone synthesis, and bile acid synthesis.

Fatty acids

Fatty acids are carbon chains with a methyl group at one end of the molecule and a carboxyl group at the other end. The length of carbon chains is usually 16 or 18 carbon atoms.

The C-H bonds in fatty acids are relatively non-polar. This is the reason fats mix poorly with water.

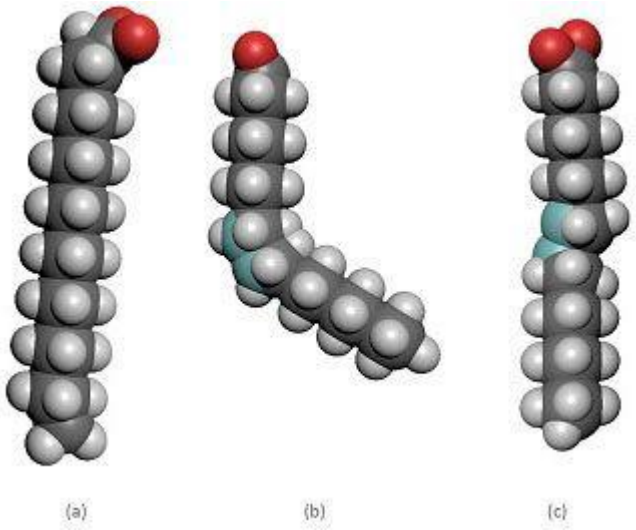

Figure 13. Types of fatty acid. a) Saturated fatty acid, b) Unsaturated fatty acid, c) Trans fatty acid

Saturated fatty acids

Saturated fatty acids are 'filled' (saturated) with hydrogen. This type of fatty acids don't have double bonds in their structure.

Most saturated fatty acids are straight hydrocarbon chains. Saturated fats pack closely forming a solid at room temperature. Sources of saturated fatty acids include fats from meats and dairy products.

Unsaturated fatty acids

Unsaturated fatty acids have a double bond in their structure. The double bond is in cis configuration. Monounsaturated fatty acids have one double, while polyunsaturated fatty acids have two or more double bonds in their structure.

Unsaturated fatty acids cannot pack together closely enough to solidify because of the bends in hydrocarbon chains. Therefore, unsaturated fats are liquid at room temperature. Sources of unsaturated fatty acids include vegetable oils such as olive oil, canola oil and sunflower oil.

Trans fatty acid

Trans fatty acid is the isomer of unsaturated fatty acids. The double bond is in trans configuration. Trans fatty acids result from the process of hydrogenating oils, which converts liquid fat to solid fat.

If you want to avoid eating trans fats, avoid consuming products prepared using hydrogenated vegetable oils like margarine. The most common foods that contain trans fats are commercially prepared baked foods (cookies, pies, donuts, etc.), snack foods, and processed foods, including fast foods.

Essential fatty acids

Essential fatty acids are fatty acids required but not synthesized by the human body.

The human body needs fatty acids, but not all of them can be synthesized by our body - for examples: omega-6 fatty acids and omega-3 fatty acids. Omega-6 and omega-3 fatty acids are essential for health and can only be obtained through the diet.

Foods high in omega-3 and omega-6 fatty acids are vegetables, oils, seeds, nuts, fish, and other seafood.

Figure 14. Seeds and oils are high in omega-3 and omega-6

References:

- Rolfes,S. Understanding normal and clinical nutrition 8th ed. Wadsworth, Cengage Learning, 2009.

Genomic instability

Genomic instability occurs when chromosome integrity and function become compromised. This can take many forms; some examples include double or single strand breaks in chromosomes, mutations within the DNA sequence, fusions between chromosomes, and changes to telomere length.

Genome instability is a critical initiator of many diseases, including cardiovascular and neurodegenerative diseases, and cancers.

Dietary factors are essential in many of the processes that copy, repair and maintain healthy DNA throughout our lives.

References:

- Bull, C., & Fenech, M. (2008). Genome-health nutrigenomics and nutrigenetics: Nutritional requirements or 'nutriomes' for chromosomal stability and telomere length in lymphocytes of older South Australian men may be inversely associated with plasma homocysteine. Rejuvination Research, 12 (5), 341-349

Telomere length

Telomeres form the ends of human chromosomes and protect the chromosome from damage. Think of telomeres like the plastic caps on the end of shoelaces: if the plastic caps break, the shoelace frays. It's the same for our DNA. In human cells, the length of the telomere shortens a small amount each time the cell divides.

After many replications, telomeres become critically short, which can lead to 'genome instability', and potentially cancerous changes in our DNA. A short telomere acts as a signal for the cell to stop dividing, and to enter a protective state called senescence.

Telomeres shorten naturally with normal aging, but they can shorten faster if we have unhealthy lifestyles, including a poor diet. Therefore, telomere length may be used as an indicator of health, and disease risk.

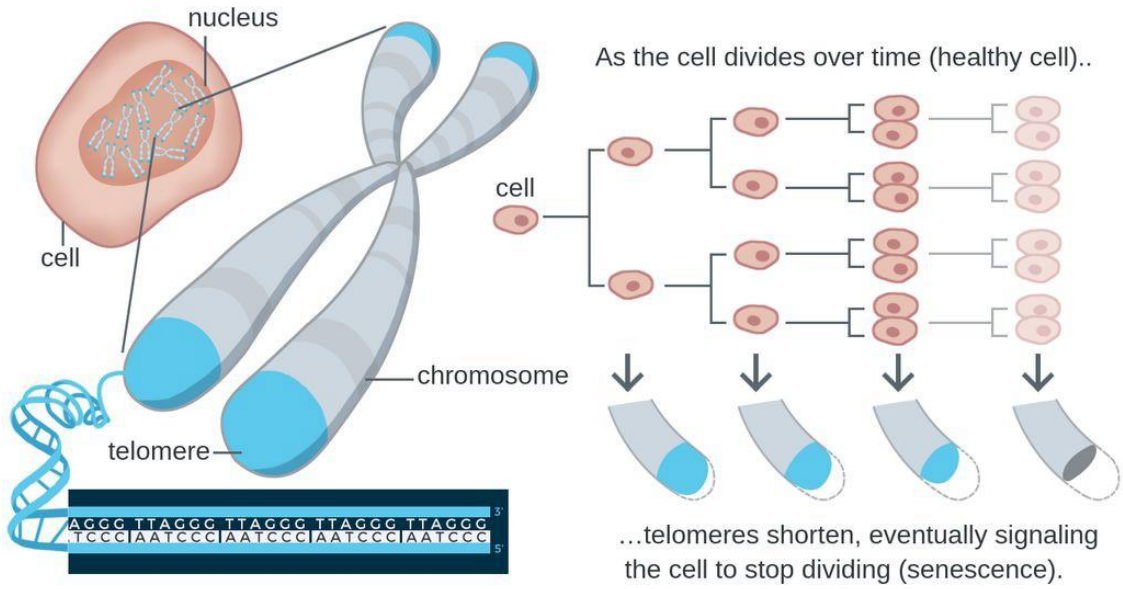

Figure 15. Left to right: Schematic image showing a human cell with DNA within the nucleus; zoomed image showing a chromosome with telomere caps; cell division and associated gradual shortening of the protective telomere cap.

References:

- Bull, C. F., Ocallaghan, N. J., Mayrhofer, G., & Fenech, M. F. (2009). Telomere Length in Lymphocytes of Older South Australian Men May Be Inversely Associated with Plasma Homocysteine. Rejuvenation Research, 12(5), 341-349. doi:10.1089/rej.2009.0868

DNA adducts

DNA adducts are chemical modifications of DNA. A chemical modification on the DNA strand may hinder DNA replication (like when you get something caught in your jacket zipper), resulting in abnormal replication and mutation.

The formation of the adduct in cells does not mean an individual will develop cancer. The DNA is constantly being damaged. The body has systems in place which can repair damaged DNA or induce the death of cells with high levels of DNA damage. Continuous exposure to the environments and substances that lead to the formation of adducts (e.g. through poor diet and lifestyle) can in the long-term lead to a greater chance of proliferation of cells with damage in genes that make it susceptible to becoming cancers. This is a process that can take decades.

DNA adducts can be detected using a method called, immunohistochemistry. In this method, a tissue of interest is embedded into media on microscope slides. Then, an antibody specific for the DNA adduct is applied. Next, a specific stain is added to the slides. In places where the antibody has bound to tissue containing DNA adducts, the stain will show a red colour. Parts of the tissue that have no DNA adducts will be coloured blue by the stain.

Diet modulates levels of DNA adducts in our body.

References:

- Le Leu, R.K., Winter, J.M., Christophersen, C.T., Young , G.P., Humphreys, K.J., Hu, Y., Gratz, S.W., Miller, R.B., Topping, D.L., Bird, A.R., Conlon, M.A. “Butyrylated Starch Intake Can Prevent Red Meat-Induced O6-Methyl-2-Deoxyguanosine Adducts in Human Rectal Tissue: a Randomised Clinical Trial.” British Journal of Nutrition, vol. 114, no. 02, 2015, pp. 220–230., doi:10.1017/s0007114515001750.

Appendix D Simulation Quiz Questions

Your Diet and Your DNA

Question 1: We are going to discuss the composition of Mia and Lily's diet. What does the term diet mean?

✓ The food and beverages a person consumes
– The habit of eating specific food
– The act of eating healthy food
– The act to lose weight

Question 2: What do we collectively call the substances that the body uses for the growth, maintenance, and repair of its tissues?

✓ Nutrients
– Energy
– Ingredient
– Nutrition

Question 3: Which of these is considered a macronutrient?

✓ Starch
– Vitamin C
– Calcium
– Folate

Question 4: Resistant starch refers to the portion of starch that resists digestion as it passes through our digestive system.

Which of these foods contains a high level of resistant starch?

✓ Legumes
– Celery
– Eggs
– Turkey meat

Question 5: What are DNA adducts?

✓ A chemical modification of DNA
– A protein that hinders DNA repair
– A break in the middle of a DNA strand
– An enzyme that cuts DNA to pieces

Question 6: Cells that have DNA adducts are red and those that don't are blue.

Based on the microscopic examination, what can you conclude about the level of DNA adducts in the samples?

✓ There are fewer DNA adducts found in the healthy diet sample
– The unhealthy diet sample exhibits fewer DNA adducts, than the healthy diet sample
– Both samples have similar numbers of DNA adducts
– There are increased DNA adducts found in the healthy diet sample

Question 7: Which of these statements fits the criteria for a healthy diet?

✓ High in fibre
– Low in calcium
– Low in polyphenols
– High in saturated fat

Question 8: What are essential amino acids?

✓ Amino acids that the body cannot synthesize
– Amino acids that can only be found in food derived from animals
– Amino acids that the body needs in a large amount
– All the important amino acids

Question 9: An organic, essential nutrient required in tiny amounts to perform specific functions that promotes growth, reproduction, and the maintenance of health and life is called a ...

✓ Vitamin
– Polyphenol
– Calories
– Carbohydrate

Question 10: Which of these is not classified as dietary fibre?

✓ Starch
– Xylose
– Cellulose
– Resistant starch

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