Topic 1: Principles of nutrition, physiology, and health

1

1.1 Determining Energy and Nutrient Requirements

Science understanding

- Macronutrients (proteins, carbohydrates, and lipids) are consumed daily and contribute to energy intake. Calculate total energy content of foods in kJ and percentage of energy from macronutrients, alcohol, and water, using the following energy values:
  - proteins, 16.7 kJ per gram
  - carbohydrates, 16.7 kJ per gram
  - lipids (fats), 37.7 kJ per gram
  - alcohol, 29.3 kJ per gram
  - water, 0 kJ per gram
- Compare energy intake from a macronutrient as a percentage of the total energy content with the Acceptable Macronutrient Distribution Range (AMDR).
  - 20 – 35% from fats
  - 45 – 65% from carbohydrates
  - 15 – 25% from proteins
- Daily energy needs are affected by a range of dietary, lifestyle and health factors.
- The energy required to maintain essential bodily functions when in a fasting and resting state is known as the basal metabolic rate (BMR).
  - Calculate the BMR for males using BMR (kJ) = Body weight (kg) x 1.0 x 24 hours x 4.2.
  - Calculate the BMR for females using BMR (kJ) = Body weight (kg) x 0.9 x 24 hours x 4.2.
  - Explain factors that can affect an individual's basal metabolic rate (BMR).
- Energy required by the body to digest, absorb and metabolise the nutrients consumed is estimated to be 10% of the daily energy intake, and is known as the thermic effect of food (TEF).
  - Calculate the thermic effect of food using energy intake values.
- The estimated energy expenditure (EEE) is the total amount of energy used in the body every day.
  - Calculate the EEE, using: EEE (kJ) = BMR (kJ) + TEF (kJ) + energy expended through physical activity (kJ).
- A neutral energy balance is achieved when an individual's total energy intake is equal to their estimated energy expenditure.
  - Calculate the energy balance for an individual, using: Energy balance (kJ) = daily energy intake (kJ) – daily estimated energy expenditure (EEE) (kJ).
  - Explain how a sustained change in energy balance could affect an individual's weight.
- Nutrient reference values (NRVs) provide recommendations of nutritional intake based on current nutrition research.
  - Explain how different nutrient reference values support a healthy nutrition intake:
    - Estimated Average Requirement (EAR)
    - Recommended Daily Intake (RDI)
    - Adequate Intake (AI)
    - Tolerable Upper Intake Level (UL)
    - Estimated Energy Requirement (EER)

SACE Subject Outline, 2024.

Energy yielding nutrients

In the human body, three nutrients can be used to provide energy: carbohydrates, proteins, and lipids. The other nutrients: vitamins, minerals and water do not provide energy to the body, and therefore are not **energy-yielding**. The energy released from carbohydrates, proteins and lipids is measured in **kilojoules** (kJ). However, in countries such as the United States, the term calories are still used as the preferred unit of food energy.

Fast fact

1 Calorie is equal to 4.2 kilojoules.

Most foods contain all three energy-yielding nutrients, as well as water, vitamins, and minerals. The energy stored within a food item is only released when its bonds are completely broken down in the body during metabolism. This energy is then used to fuel everyday activities, such as sending electrical impulses through the brain and nerves, moving muscles and synthesising body compounds.

The amount of energy provided depends on the quantity of carbohydrates, proteins, and lipids a food item contains. Each macronutrient yields a different number of kilojoules per gram. Carbohydrates yield approximately **16.7 kJ** per gram; protein yields **16.7 kJ** per gram and triglycerides yield the greatest amount of **37.7 kJ** per gram (as shown in Table 1.1.1). Therefore, a food item with a greater amount of lipids will provide a greater amount of energy; this food item would be energy dense.

Table 1.1.1: Energy provided by energy-yielding macronutrients.

Macronutrient	Energy (kJ/g)	Energy (calories/g)
Carbohydrate	16.7	4
Protein	16.7	4
Lipid	37.7	9

Alcohol contributes 29.3 kilojoules per gram (7 calories per gram). However, it is not considered a nutrient, as, due to its diuretic nature, it depletes the body of its nutrients and interferes with the growth, maintenance, and repair of the body. Water provides no kilojoules, contributing 0 kilojoules per gram and serves other benefits in the body (explained further in Topic 1.5: Water and Other Fluids).

Helpful online resources

Kilojoules on the menu | an introduction to kilojoules

https://youtu.be/SsDPRP0XIqA?si=1uNSqn6nXBZyPIbs

Calculating the composition of macronutrients in food

To calculate the energy composition from a food product, the quantity (grams) of carbohydrate, protein and lipid is multiplied by the energy provided by one gram of each of these macronutrients. These amounts are then added together. The total energy provided by a serving and 100g/ml is a legal requirement and must be displayed on all nutritional information panels (as highlighted on Figure 1.1.1).

The **energy distribution (%)** of each energy-yielding nutrient can be calculated using the following formula:

$$\text{Energy distribution} = \frac{\text{amount of energy provided per macronutrient}}{\text{total energy provided}} \times 100$$

NUTRITION INFORMATION

Servings per package: 3
Serving size: 150g

	Quantity per serving	Quantity per 100 g
Energy	608 kJ	405 kJ
Protein	4.2 g	2.8 g
Fat, total	7.4 g	4.9 g
— saturated	4.5 g	3.0 g
Carbohydrate, total	18.6 g	12.4 g
— sugars	18.6 g	12.4 g
Sodium	90 mg	60 mg

Ingredients: Whole milk, concentrated skim milk, sugar, banana (8%), strawberry (6%), grape (4%), peach (2%), pineapple (2%), gelatine, culture, thickener (1442)

All quantities above are averages

Figure 1.1.1: The energy content per serving and per 100 g (or mL) is a legal requirement of all nutritional information panels on food products.

1

Example

A cup of fried rice contains 30g of carbohydrates, 5g of protein and 11g of lipids.

(a) Calculate the total energy provided by a cup of fried rice. Show all your calculations and round your final answer to the nearest whole number.

30 g carbohydrate × 16.7 kJ/g = 501 kJ

5 g protein × 16.7 kJ/g = 83.5kJ

11 g lipid × 37.7kJ/g = 414.7 kJ

Total = 999.2 kJ = 999kJ

(b) Calculate the energy distribution of each macronutrient in the fried rice example above. Show all calculations and round your answers to the nearest whole number.

Carbohydrate energy distribution = $\frac{501}{999.2} \times 100 = 50.1\% \approx 50\%$

Protein energy distribution = $\frac{83.5}{999.2} \times 100 = 8.4\% \approx 8\%$

Lipid energy distribution = $\frac{414.7}{999.2} \times 100 = 41.5\% \approx 42\%$

Reminder

To confirm your calculations are correct, add up all your percentages. The total should equal 100.

Australian Acceptable Macronutrient Distribution Range (AMDR)

These percentages can then be compared to the acceptable macronutrient distribution ranges (AMDR) (Figure 1.1.2). These are recommendations for optimising the balance of macronutrient intake to reduce the risk of developing diet-related disorders, while also allowing for an adequate intake of nutrients. These ranges are set for healthy individuals who are maintaining their body weight and are not appropriate for weight loss or management of a specific health concern.

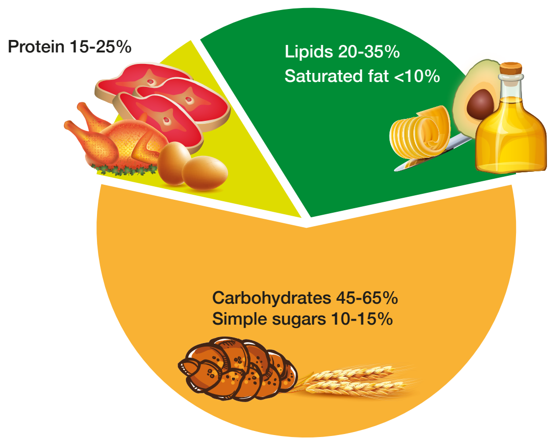

Figure 1.1.2: The acceptable macronutrient distribution ranges of each of the energy-yielding nutrients for individuals.

Example

(c) Compare the energy distribution of each of the macronutrients in the fried rice example with those from the acceptable macronutrient distribution ranges and make suitable recommendations when necessary to ensure they meet these ranges.

Knowing that the fried rice provides 50% of its kilojoules as carbohydrates tells an individual that this is a suitable carbohydrate selection as it is within the recommended range of 45–65%. On the other hand, only 8% of the kilojoules are provided by protein, which tells an individual they need to make higher protein selections at other times of the day to meet the recommended range of 15–25%. The fried rice provides 42% of its kilojoules as lipids, which suggests that an individual should make lower lipid selections at other times of the day to keep with the recommended range of 20–35%.

Factors that Determine Energy Balance

We continuously expend energy and consume food periodically to refuel. Ideally, an individual's energy intake (energy in) should be equal to their energy expenditure (energy out), to achieve an **energy balance** and maintenance of their weight (as shown in figure 1.1.3). When the balance shifts, weight can fluctuate.

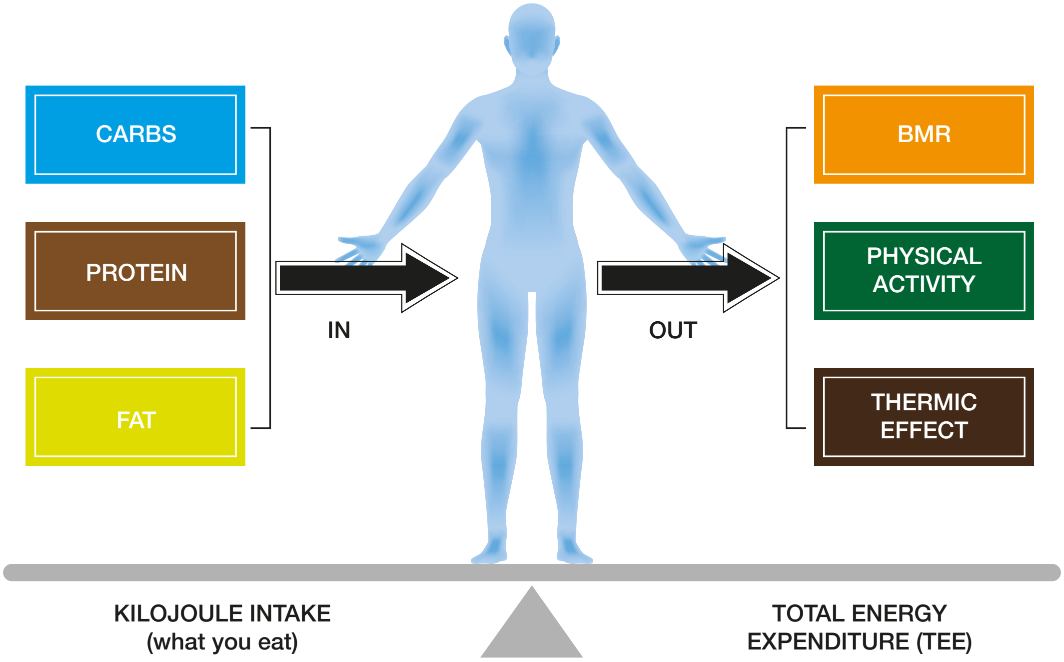

Figure 1.1.3: The energy balance, where the energy in is equal to the energy out.

A **positive energy balance** occurs when energy intake is greater than energy expenditure. That is, a person has consumed more kilojoules than the body needs. This leads to excess energy being stored as body fat, resulting in weight gain. Weight loss results from a **negative energy balance** when energy intake is less than energy used (as shown in Figure 1.1.4).

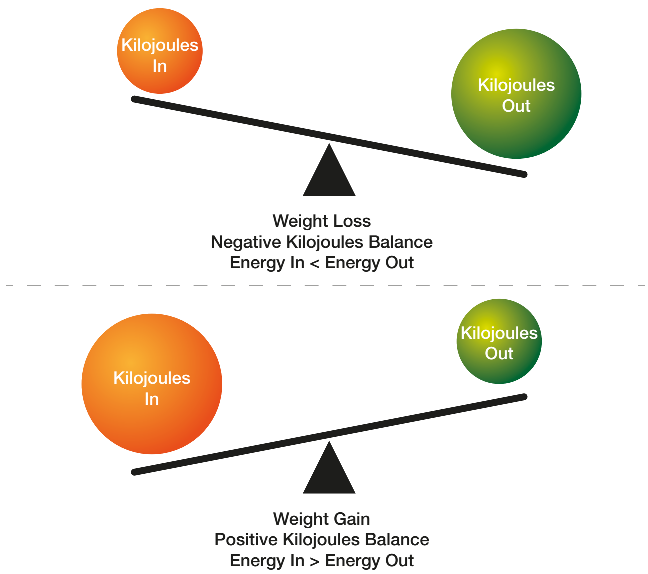

Figure 1.1.4: Positive and negative Energy Balance

Energy Intake (Energy In)

The consumption of food and beverages contributes to an individual's **energy intake**, which is dependent on the composition of food (number of kilojoules) and the amount that is eaten. The amount of food consumed must meet the nutritional needs without taking in too much or too little energy; however, a person's appetite prompts how much and how often to eat.

1

Energy Expenditure (Energy Out)

People expend energy when they are physically active, but they also expend energy when they are resting quietly. An individual's **energy expenditure** is determined by three main categories (as outlined below and shown in figure 1.1.5):

- Energy expended for basal metabolism (BMR)
- Energy expended for physical activities
- Energy expended for food digestion (thermic effect of food)

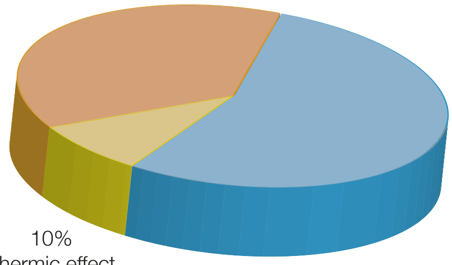

Figure 1.1.5: Components of energy expenditure

Basal Metabolic Rate (BMR)

Basal metabolic rate (BMR) can be defined as the rate at which the body expends energy for basal metabolic activities, which support all basic processes of life. Basal metabolic activities maintain the body temperature, keep the lungs inhaling and exhaling air, allows the bone marrow to continue producing red blood cells, keeps the heat beating 100,000 times a day and keeps the kidneys filtering the blood and removing wastes. Approximately two thirds of the energy an average person expends in a day supports these basal metabolic processes. However, the rate at which an individual expends this energy for these activities varies from person to person and may vary for the same individual with a change in circumstances of physical conditions (as shown in table 1.1.2)

Table 1.1.2: Factors that influence an individual's BMR (the rate at which they expend energy)

Factor	Influence on BMR
Body Composition	A larger amount of lean body tissue increases BMR. This is because muscle tissue is a faster metabolising tissue (burns more kilojoules) than sluggish adipose tissue.
Growth	During childhood, adolescence and pregnancy energy demands are greater due to the growth experienced, increasing their BMR.
Age	Lean body mass diminishes after the age of 30, and the time available to complete physical activity declines, which can contribute to a decline in BMR.
Gender	Males generally have a higher BMR as their body is composed of greater lean body tissue than females. Males also expend more calories per kilogram per hour than females, where males burn 1.0 calorie and females burn 0.9.
Amount of Physical Activity	Regular physical activity increases lean body tissue, increasing BMR as muscle tissue burns more kilojoules than adipose tissue even at rest.
Fever, Infection, and Illness	The body expends more energy when recovering to develop an immune response and maintain normal body temperature. This increases BMR.
Environmental Temperature	High and low environmental temperatures increase BMR, as the body must work harder to maintain normal body temperature of 37°C.
Fasting, Starving, Malnutrition and Crash Dieting	Consuming fewer kilojoules than the body expends reduces BMR. This is because the body's basal metabolism slows down to conserve energy. BMR can drop up to 15%, and even further if lean body tissue is lost also.
Drugs	Drugs can increase or decrease an individual's BMR. For example, nicotine in smoking and caffeine can increase BMR; whilst some antidepressants and steroids can decrease BMR.
Genetics, Hormonal balance	Genetics and hormone levels can increase or decrease BMR, due to their influence on the rate at which the body expends energy.

There are several ways to calculate the BMR of an individual, however a simple method commonly used is to multiply the weight (kg) of an individual by 1.0 calorie per kilogram per hour for adult males and 0.9 calories per kilogram per hour for adult females. This is then multiplied by 24 to determine the kilojoules used for basal metabolic processes in a day, and finally multiplied by 4.2 to convert this value into kilojoules, which is the preferred energy unit used in Australia (as shown by the equations and example).

BMR of a Male (kJ/day) = Bodyweight (kg) × 1 (calories) × 24 (hours) × 4.2 (kilojoules)

BMR of a Female (kJ/day) = Bodyweight (kg) × 0.9 (calories) × 24 (hours) × 4.2 (kilojoules)

Example

Calculate the BMR for a 31-year-old female who weighs 73kg and is 165cm tall. Show all your calculations and round your final answer to the nearest whole number.

BMR = 73 × 0.9 × 24 × 4.2

BMR = 6622.56 » 6623 kJ/day

Physical Activity

Another component of an individual's energy expenditure is **physical activity**. This component is the most changeable, however, its influence on both weight gain and weight loss can be significant. During physical activity, the muscles require greater energy to move, and the heart and lungs need additional energy to deliver nutrients and oxygen and dispose of wastes. The amount of energy needed for any activity depends on muscle mass, body weight and activity. The larger the muscle mass and the heavier the body part being moved, the more energy that is expended. The activity's duration, frequency and intensity also influence energy expenditure. The longer, more frequent, and more intense the activity, the more kilojoules expended (as shown in table 1.1.3).

Table 1.1.3: Energy expended on various physical activities.

Activity	kJ/kg/min
Aerobics (vigorous)	0.571
Basketball (vigorous and full court)	0.895
Bicycling (21km/h)	0.416
Rowing (vigorous)	0.895
Running (12km/h)	0.869
Walking (6km/h)	0.345
Soccer (vigorous)	0.895
Swimming (20m/min)	0.322
Table Tennis (skilled)	0.416
Tennis (beginner)	0.294
Gardening	0.416
Vacuuming and other household tasks	0.277
Studying	0.100

Thermic Effect of Food

The **thermic effect of food** refers to the energy required, and the heat produced following the consumption of food. The additional energy required, and the heat produced is due to the increase in the contractions of the gastrointestinal tract, the manufacture and secretion of digestive juices and enzymes by different cells in the body and the active transport processes which absorb some nutrients. Therefore, the thermic effect of food can be defined as the energy required to eat and digest food, absorb nutrients, and move food through the gastrointestinal tract.

The thermic effect of food is proportional to the food energy consumed and is estimated at 10 percent of the energy intake. The proportions vary for different foods, as the thermic effect is greater for high protein foods than for high fat and carbohydrate foods. For example, lipids and carbohydrates, which are relatively easy to digest, raise energy needs by around 0-5% and 5-10% respectively, while proteins, which are more difficult to break down in digestion, require 20-30% of the energy consumed. The thermic effect can also be influenced by the meal size and frequency, as it is greater for a larger meal eaten at once rather than spread out over a couple of hours. However, with such a large variance in foods and their thermic effects, a figure of 10% of kilojoules consumed can be used to calculate energy needs required for the digestion of food (as shown in the example).

Example

Calculate the thermic effect of energy intake when a female's daily energy consumption is 8500kJ. Show all your calculations using: 0.10 × ____ kJ consumed/day.

0.10 × 8500kJ consumed/day = 850kJ

Calculating Total Daily Energy Expenditure

The total energy expenditure (TEE) for a day can be simply calculated by adding an individual's BMR, the energy expended on physical activity that day and their thermic effect of food (as shown by the formula and example).

Total Energy Expenditure = BMR + Energy Expended on Physical Activity + Thermic Effect of Food

Example

Calculate the total energy expenditure for a female who has a BMR of 6623kJ/day, expends 1806kJ on physical activity (cycling and walking) and a thermic effect of 850kJ. Show all your calculations and round your final answer to the nearest whole number.

Total Energy Expenditure = 6623 + 1806 + 850

Total Energy Expenditure = 9279 kJ/day is expended

Calculating Energy Balance

An individual's energy balance can be calculated by subtracting their total energy expenditure for a day from their energy intake from the foods and beverages consumed in that same day (as shown in the equation and example below).

Energy Balance = Energy Intake – Total Energy Expenditure

Energy balance is defined as the state achieved when energy intake is equal to energy expenditure. When the body is in energy balance, body mass is maintained. Differences in energy balance can cause changes in the body's mass. A positive energy balance will result when the energy balance is a positive value, due to the energy intake exceeding the total energy expenditure. This will result in weight gain if this pattern continues over a longer period. Whereas, a negative energy balance will result when the energy balance is a negative value, due to the total energy expenditure exceeding the energy intake. This will result in weight loss if this pattern continues over a longer period. The rate at which weight is gained or lost is determined by the magnitude of the difference between an individual's energy intake and their total energy expenditure. The different types of energy balance can be summarised as:

Energy Balance (maintenance of weight): Energy Intake = Energy Expenditure

Positive Energy Balance (weight gain): Energy Intake > Energy Expenditure

Negative Energy Balance (weight loss): Energy Intake < Energy Expenditure

Example

Calculate the energy balance of a female who consumes 8500kJ a day and has a total daily energy expenditure of 9279kJ. Show all your calculations and explain the impact this balance will have on her weight if this pattern continues.

Energy Balance = 8500 – 9279 Energy Balance = –779kJ

This female's energy expenditure is greater than her energy intake, resulting in a negative energy balance (indicated by the minus sign). If this pattern were to continue, she would experience weight loss.

Nutrient Reference Values

Nutrient reference values (NRVs) are a set of recommendations for nutritional intake based on current available scientific knowledge that best support the health of individuals in Australia and New Zealand. These recommendations apply to healthy people and may not be appropriate for people with diseases that require an increase or decrease in nutrient needs. Each person's body is unique and has its own set of requirements. Men differ from women and needs change as people grow from infancy to old age. Therefore, nutrient recommendations are based on age, gender, and specific life stages. These values provide recommended intakes for energy (kilojoules), protein, carbohydrate, fibre, fats, water, vitamins, and minerals. The NRVs are made up of 5 different values (as discussed in Table 1.1.4):

Table 1.1.4: Description of NRVs used in Australia and New Zealand

NRV	Description
Estimated Average Requirement (EAR)	The average amount of a nutrient estimated to meet the nutrient requirements of half of a group of healthy individuals in a specific life stage and gender group.
Recommended Daily Intake (RDI)	The average daily dietary intake level is sufficient to meet the nutrient requirements of nearly all (approximately 98%) healthy individuals in a specific life stage and gender group. The RDI is set high enough above the EAR to meet the needs of most healthy people. When people's nutrient intakes are consistently below their daily requirements, they can become deficient, causing their nutrient stores to deplete, and leading to poor health and deficiency symptoms. Therefore, the RDI is set so much higher than the EAR, to ensure this value meets the nutrient needs of as many people as possible.
Adequate Intake (AI)	The AI reflects the average amount of a nutrient that a group of healthy individuals consumes. This NRV is used when an RDI or EAR cannot be determined due to insufficient scientific evidence. Therefore, AI relies heavily on scientific judgement.
Tolerable Upper Intake Level (UL)	The UL is the point at which an individual exceeds the recommended intake and where a nutrient is likely to become toxic. It is recommended that an individual not exceed these recommendations often or by much. The RDI should not be thought of as a minimum amount, and a more accurate view is to see an individual's requirements as a range, with a marginal and danger zone both below and above this this range.
Estimated Energy Requirement (EER)	The EER represents the average dietary energy intake (kilojoules consumed per day) that will maintain an energy balance in a person who has a healthy body weight and level of physical activity. These values are determined to sustain a healthy and active life, as too much energy can lead to weight gain and its associated health consequences.

Key terms

- Acceptable macronutrient distribution ranges (AMDR)
- Adequate Intake (AI)
- BMR
- Carbohydrates yield 16.7 kJ/g
- Energy Balance
- Energy distribution
- Energy Expenditure
- Energy Intake
- Energy-yielding nutrient
- Estimated Average Requirement (EAR)
- Estimated Energy Requirement (EER)
- Kilojoule (kJ)
- Lipids yield 37.7 kJ/g
- Negative Energy Balance
- Nutrient Reference Value (NRV)
- Positive Energy Balance
- Proteins yield 16.7 kJ/g
- Recommended Dietary Intake (RDI)
- Thermic Effect of Food
- Tolerable Upper Intake Level (UL)

Review questions: 1.1 Determining Energy and Nutrient Requirements

1

1. Australian researchers found that children and adolescents consume more energy from energy dense foods than any other age group, with the average child receiving three packaged snack foods in their lunchbox each day. Parents should aim to provide only one energy dense snack food in their child's lunch box each day, and ideally it should be less than 600kJ.

   Calculate the total energy provided by one serving of each of the following lunch box snacks and make a recommendation to which snack parents should choose to include in their child's lunch box. Show all your calculations and round your final answers to the nearest whole number.

	SNACK A **Small packet (20g) of Original Popcorn**	**SNACK B** **Fruit & Nut Muesli Bar (45g)**	**SNACK C** **Mini Blueberry Muffin (40g)**
Protein	1.8g	4.1g	1.7g
Fat, total	5.1g	6.7g	6.2g
Fat, saturated	1.0g	1.1g	1.0g
Carbohydrate, total	8.4g	25.1	17.0g
Carbohydrate, sugars	0.7g	7.8g	9.4g

(4 marks) (KA4, IAE3)

2. Refer to the ingredients list and nutritional information panel for one serving (100 g) of pasta carbonara.

	100 grams	Ingredients
Energy (kJ)	1246	250 g cooked pasta 20 g butter
Protein (g)	14	cup thickened cream 250 g bacon
Carbohydrates – total (g)	29	eggs
Carbohydrates – sugar (g)	4	2 egg yolks
Fat – total (g)	14	1 cup grated parmesan cheese 1 tablespoon rosemary
Fat – polyunsaturated (g)	2	Pinch of salt Pinch of pepper
Fat – monounsaturated (g)	3	
Fat – saturated (g)	9	
Dietary fibre (g)	1.5	
Sodium (mg)	200	

(a) Calculate the energy distribution of each energy-yielding nutrient and make recommendations in comparison to the acceptable macronutrient distribution ranges (AMDR) for Australians. Show all calculations and round your answers to the nearest whole number.

(6 marks) (KA4, IAE3)

(b) Suggest three specific modifications to the ingredients for the pasta carbonara recipe that would reduce the meal's energy density and increase its nutrient density.

(3 marks) (KA2)

3. Two 17-year-old adolescents – one male (Aaron) and one female (Emma) – are undertaking identical training programs for a national athletics competition.

(a) State which adolescent is likely to have the higher basal metabolic rate (BMR).

(1 mark) (KA2)

(b) Describe how one factor could account for the difference in the BMR of these two adolescents.

(2 marks) (KA2)

(c) Refer to the following table, which provides additional information about Aaron:

weight	77 kg
daily energy intake	12300 kJ
energy expenditure from daily activity	2210 kJ

(i) State the percentage (%) of Aaron's daily energy intake that contributes to the thermic effect of food.

(1 mark) (KA1)

(ii) Calculate Aaron's energy expenditure. ***Show all your working out***.

(4 marks) (KA4)

(iii) Calculate Aaron's energy balance and identify the type of energy balance it is. ***Show all your working out.***

(2 marks) (KA1, KA4)

(iv) Describe the long-term effect on Aaron's weight and health if his energy balance remained the same for a long time.

(2 marks) (KA2)

4. Refer to the following nutritional information panel for a meal made by an elderly female aged 70 years old.

	Per serving
Energy (kJ)	
Protein (g)	15
Carbohydrates – total (g)	58
Carbohydrates – sugar (g)	36
Fat – total (g)	31
Fat – saturated (g)	18
Dietary fibre (g)	3
Sodium (mg)	320

(a) Calculate the total energy content provided by one serving of this meal. Show all calculations and round to the nearest whole number.

(2 marks) (KA2, KA4)

(b) The estimated energy requirement (EER) for an elderly female is 7600 kJ. What percentage of that recommended daily energy requirement is provided by this meal? Show all calculations and round your answer to the nearest whole number.

(2 marks) (KA2, KA4)

(c) Using the NRV calculator on the following website: https://www.nrv.gov.au/nutrients-energy-calc, determine the NRVs of the following nutrients for this elderly woman.

	AI	EAR	RDI	UL
Calcium (mg)				
Iron (mg)				
Vitamin C (mg)				
Dietary Fibre (g)				

(3 marks) (IAE3)

5. Describe one advantage of using the RDI to evaluate an individual's diet and health.

(2 marks) (KA2)

6. A medical study was conducted on the basal metabolic rate (BMR) of 14 participants who went on a weight-loss diet for a short period of time. All participants lost a significant amount of weight while on the diet.

The average BMR of the participants prior to, during and after their weight loss journey is shown in the table below.

	Prior	During	After
Average BMR (kJ/day)	10950	8400	7980

(a) Calculate the change in the average BMR over the time of the participant's weight loss journey in kJ/day.

(1 mark) (KA4)

(b) The study found that, after their weight loss journey had finished, the participants' BMR had changed. Explain how weight loss may have contributed to the decrease in average BMR.

(2 marks) (IAE3)