(6) Metabolically active cells have more mitochondria with longer and more densely packed cristae to house more electron transport chains and ATP synthase enzymes eg. Mammalian liver cell may contain up to 2500 mitochondria (20% of cell volume)

iii) Outer membrane

(1) Phospholipid composition (similar to membranes around other organelles)

(2) Can include channels or carries that allow the passage of molecules eg. pyruvate

(3) Other proteins in the membranes are enzymes

iv) Inner membrane – an energy-transducing membrane

(1) Different lipid composition compared to outer

(2) Impermeable to most small ions – including hydrogen ions (protons)

(3) Folded into many cristae to give a large surface area

(4) Includes electron carriers – protein complexes arranged in electron transport chains

(a) Each electron carrier has an enzyme associated with a cofactor (non-protein groups) which is, in this case, a haem group with an iron atom

(b) The cofactors can accept and donate electrons – the iron atoms become reduced to Fe^{2+} and oxidised to Fe^{3+}

(c) The iron atom is oxidised by donating an electron to the next electron carrier

(d) The enzymes involved are oxidoreductase enzymes – involved in redox reactions

(e) Some of the electron carriers have a coenzyme that pumps (using energy from the passage of electrons) protons from the matrix to the intermembrane space

(5) Embedded ATP synthase enzymes aka. stalked particles

(a) Large and protrude from the inner membrane into the matrix

(b) Allows protons to pass through them via the channel part of the enzyme

(6) FAD (flavine adenine dinucleotide) dehydrogenase enzyme

(a) FAD is bound to a dehydrogenase enzyme embedded in the inner membrane

(b) Hydrogen atoms accepted by FAD do not get pumped into the intermembrane space – they stay back in the mitochondrial matrix

v) Matrix – site of the Link Reaction and Krebs cycle containing…

(1) Enzymes that catalyse stages in the Link Reaction and Krebs cycle

(2) Molecules of coenzyme NAD

(3) Oxaloacetic – 4 carbon compound that accepts acetate from the Link Reaction

(4) Mitochondrial DNA – some codes for mitochondrial enzymes and other proteins

(5) Mitochondrial ribosomes – where proteins are assembled

i) State that the link reaction takes place in the mitochondrial matrix

j) Outline the link reaction, with reference to decarboxylation of pyruvate to acetate and the reduction of NAD

k) Explain that acetate is combined with coenzyme A to be carried to the next stage

(a) Some is converted to pyruvate and enters the Link Reaction

(b) Some is converted to acetate and enters the Krebs Cycle

(4) The number of hydrogen atoms accepted by NAD is more than glucose, so there is a slightly higher energy yield than equivalent masses of carbohydrate

iii) Lipids – mean energy value of $39.4 kJg^{-1}$ (almost double the energy yield) (only aerobic)

(1) Respiratory quotient = 0.7

(2) An important respiratory substrate for many tissues (particularly muscle tissues)

(3) Triglycerides are hydrolysed by the enzyme lipase to glycerol and fatty acids

(4) Glycerol can be converted to glucose and then respired (unlike fatty acids)

(5) Fatty acids are long hydrocarbon chains with a carboxylic acid group

(6) Many carbons and even more hydrogen atoms from the hydrocarbon chains can produce a lot of ATP by chemiosmosis during oxidative phosphorylation

(7) Each fatty acid is combined with Coenzyme A (CoA) – requires energy from the hydrolysis of a molecule of ATP to AMP and two inorganic phosphate groups

(8) The fatty acids CoA complex is transported to the mitochondrial matrix where it is broken down into 2 carbon acetyl groups (that are attached to the CoA)

(9) During this breakdown via the beta oxidation pathway, reduced NAD and reduced FAD are formed

(10) Acetyl groups enter the Krebs Cycle – 3 molecules of reduced NAD, one molecule of reduced FAD and one molecule of ATP are produced from each acetate molecule

(11) The large amount of reduced NAD is reoxidised at the electron transport chain, producing large amounts of ATP by chemiosmosis during oxidative phosphorylation