Nutrition for Sport

a metabolic perspective

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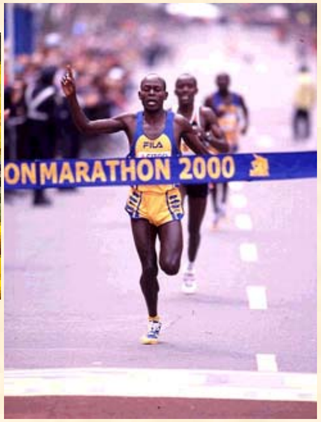
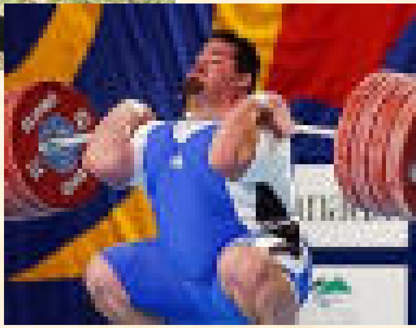
Nutrition for Sport



- **How do they do that?......moving the mass**
  - Requirements

- **What do they need to do it?.....**
  - Metabolism, limitations of this



- **How do we meet this need?....feeding them!**
  - Nutrient provision

Eating correctly

Nutrients to meet requirements

- Nutrients from the diet
- The requirement dictates what should be in the diet
- The type of metabolism used to do exercise dictates the requirement

sports person's requirement

sports person's requirement

The minimum….
Basal Metabolic Rate

sports person's requirement

The minimum….
Basal Metabolic Rate

sports person's requirement

The minimum....
Basal Metabolic Rate

Extra....
varying levels

sports person's requirement

The minimum....
Basal Metabolic Rate

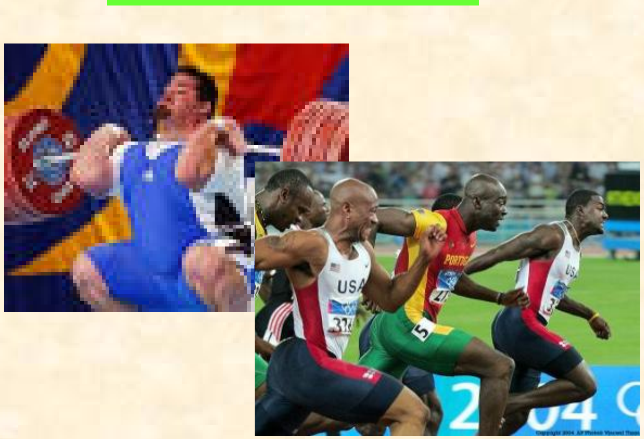
Extra....
varying levels

Are the requirements the same?

POWER: a determinant of requirement

Power = ENERGY per unit time

High power ⟷ Lower power



Power equivalents……
of a 1,500m (mile) runner?

Desk top PC 120W

Electric cooker 2500W

Fridge freezer 600W

Kettle 1800W

Dishwasher 1200W

Electric hob 7000W

Power equivalents……
of a 1,500m (mile) runner?

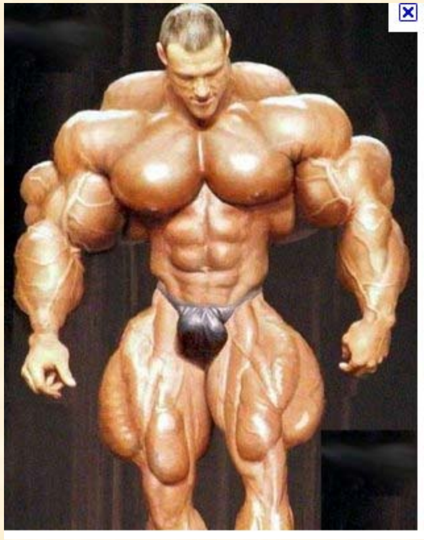
Kettle 1800W

Power output vs exercise time

Other requirements……

- Growth

  Muscles getting larger!



Other requirements……

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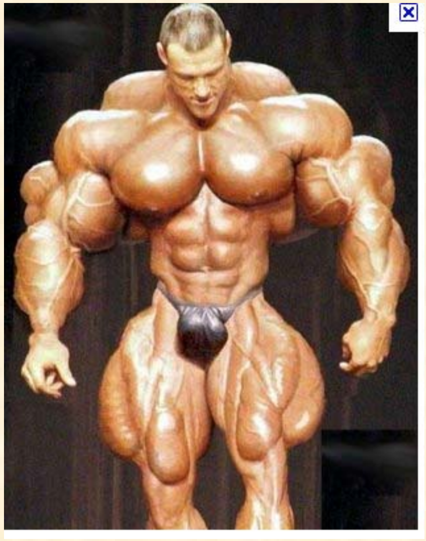
  Muscles getting larger!



- Damage repair
  Applies to all athletes
  big and small!

Nutrients available to meet the requirement

Macro Nutrients (large quantities)

_______________________________________?

Micro Nutrients (small quantities)

_______________________________________?

Nutrients available to meet the requirement

Macro Nutrients (large quantities)

Protein, Carbohydrate (**CHO**), Fat

Micro Nutrients (small quantities)

vitamins, minerals

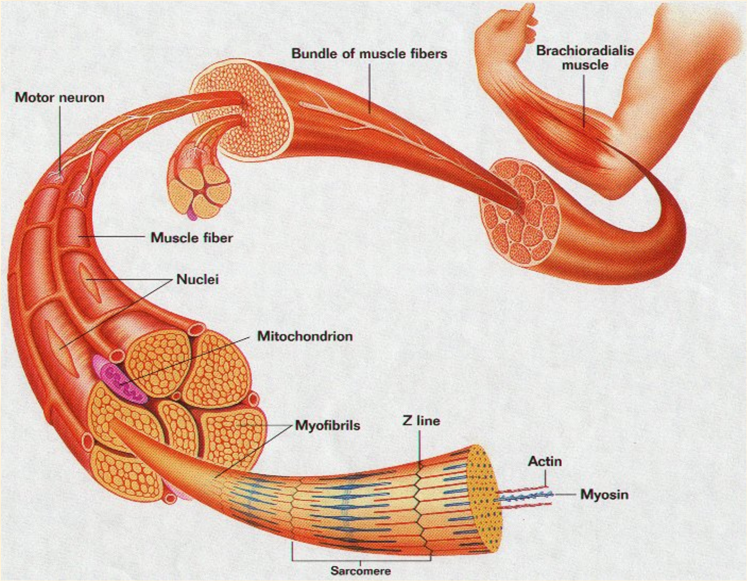
Sport-persons requirements

Require - Energy (muscle contraction)

Nutrients to provide this are........

Macro: ______________

Micro: _______________



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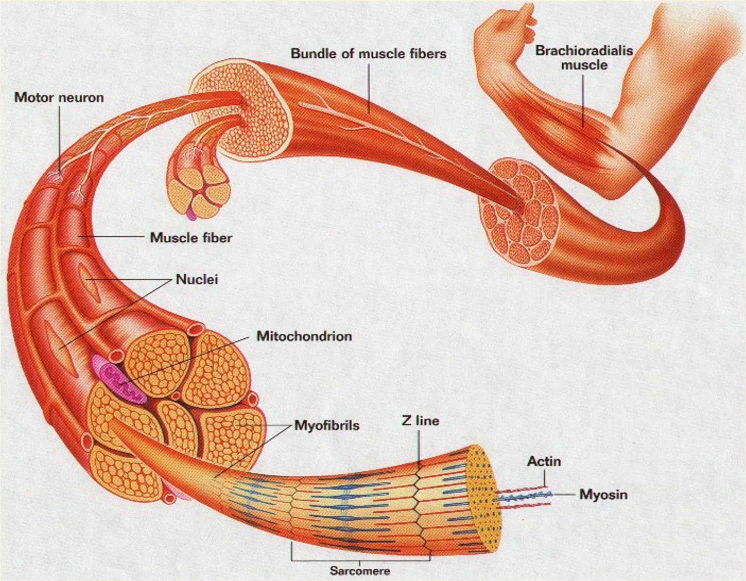
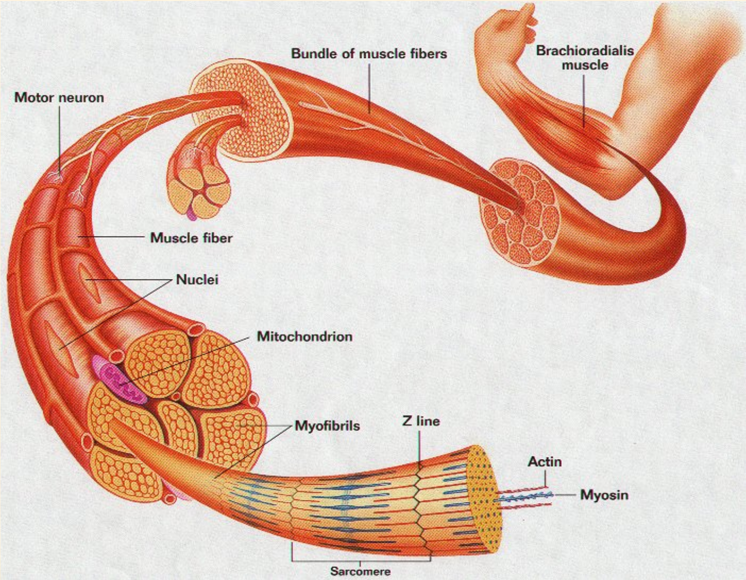
Macro: **CHO**, fat

Micro: vitamins, minerals



Sport-persons requirements



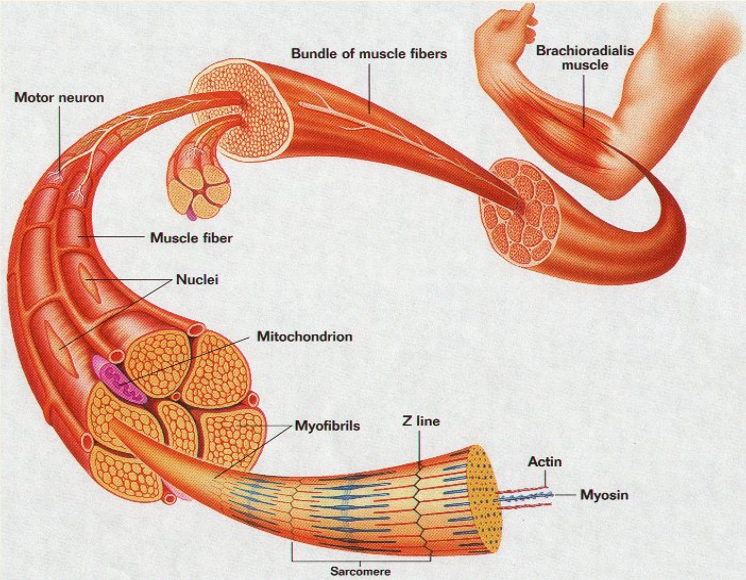
Require - Repair/growth

Nutrients to provide this are

Macro: ________________

Micro: __________________

Sport-persons requirements



Require - Repair/growth

Nutrients to provide this are

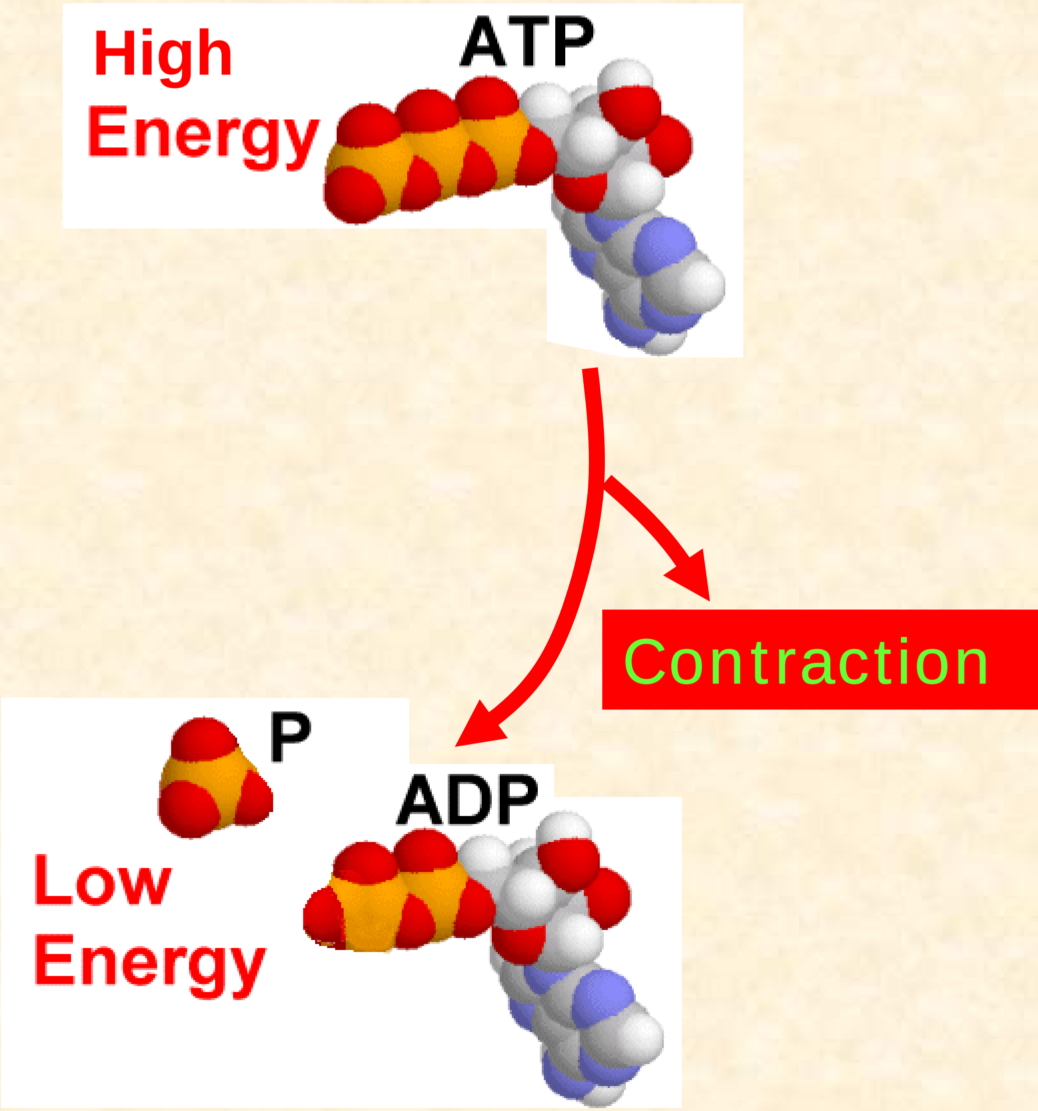
Macro: **protein**……….CHO, fat

Micro: vitamins, minerals

Energy for contraction

Metabolism

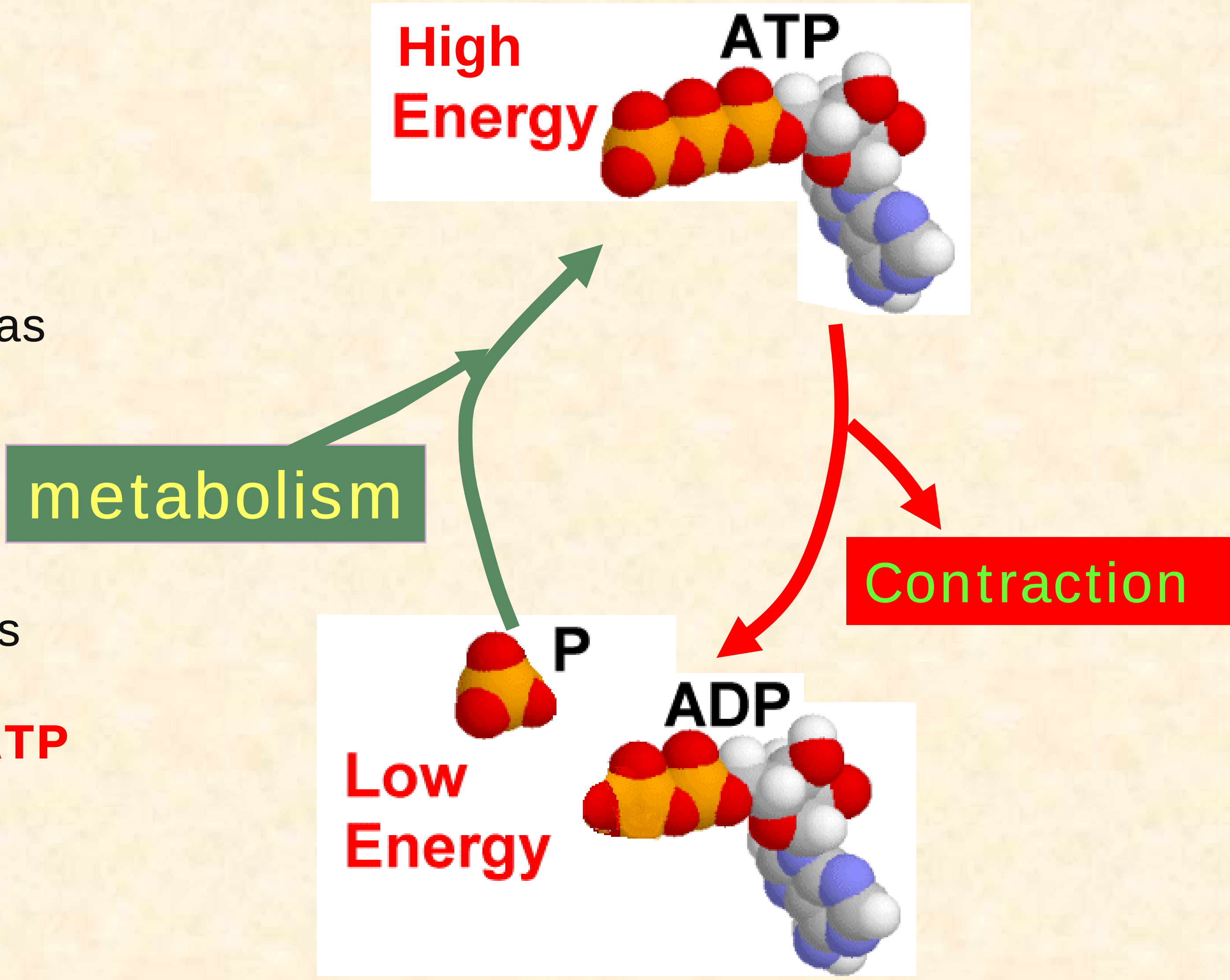
- **ATP** is used as the energy source..immediate



Energy for contraction

Metabolism

- **ATP** is used as the energy source
- nutrients metabolism is used to regenerate **ATP**



Energy in Food

- Which has the most energy per unit mass?
- Protein
- Fat
- CHO

Energy in Food

- Which has the most energy per unit mass?

- Protein

- Fat **37.1 kJ/g**

- CHO

Energy in Food

- Which has the most energy per unit mass?

• Protein	15.9 kJ/g
• Fat	**37.1 kJ/g**
• CHO	15.4 kJ/g

Energy in Food

- Which has the most energy per unit mass?

- Protein 15.9 kJ/g NOT used
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Energy in Food

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- Protein 15.9 kJ/g NOT used **………..required for contraction**
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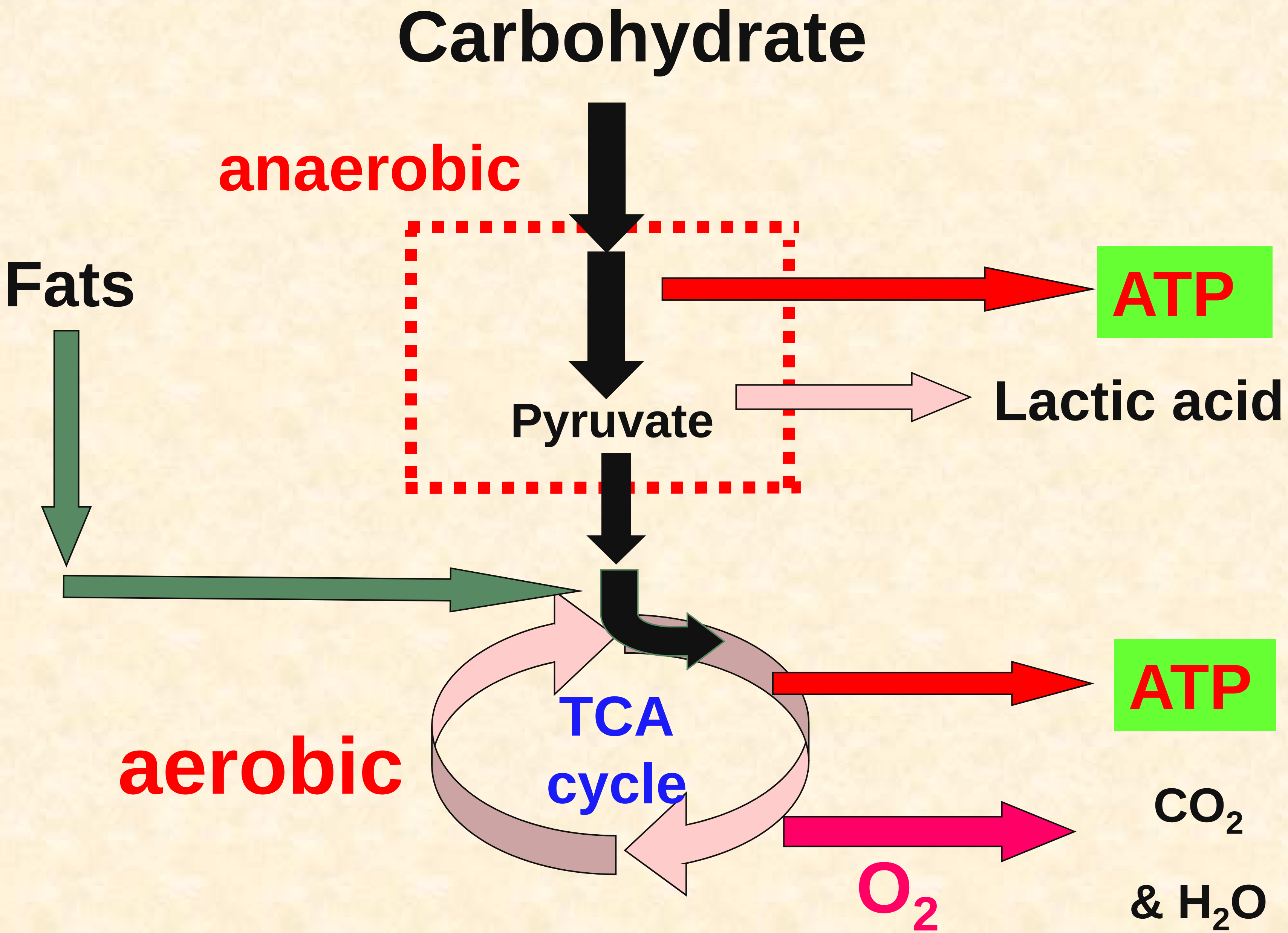
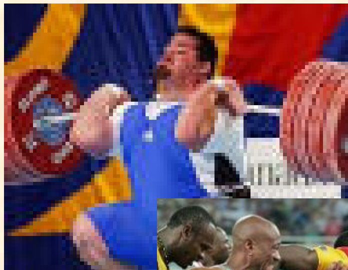
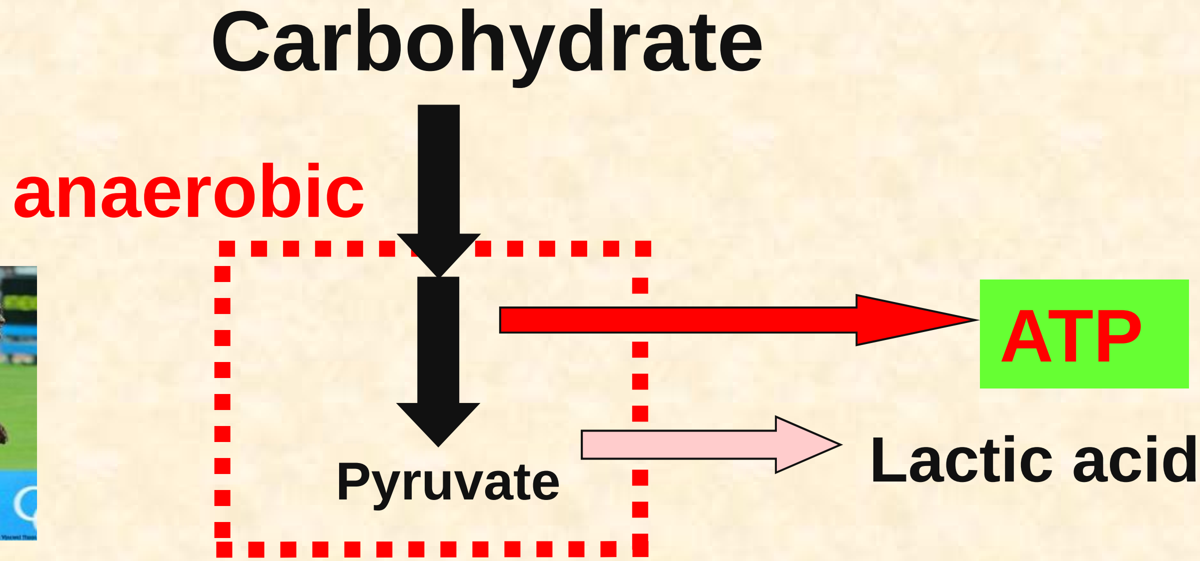
- CHO 15.4 kJ/g

Pathways for energy metabolism



High power exercise - anaerobic

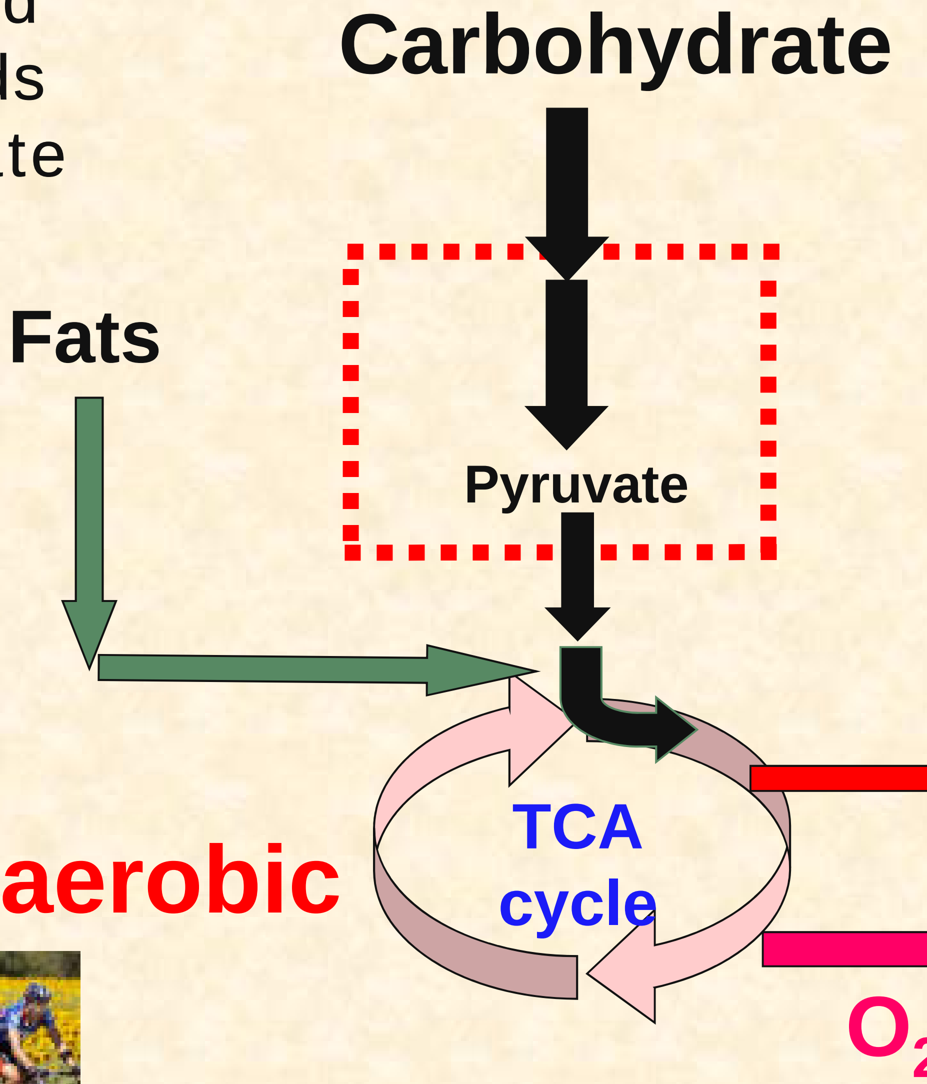




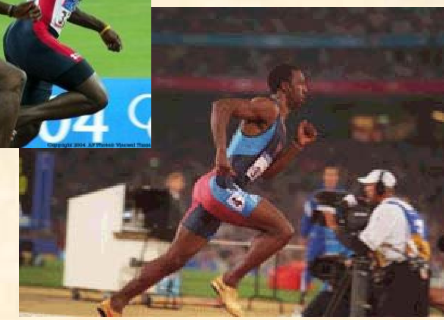
- No oxygen used ...energy demand higher than oxygen supply
- Can only be done for short periods (60sec)
- **lactic acid** build up inhibits exercise
- ONLY carbohydrate can be used

lower power exercise - aerobic

- oxygen used
- Long periods
- Carbohydrate and fat used



Energy from metabolism

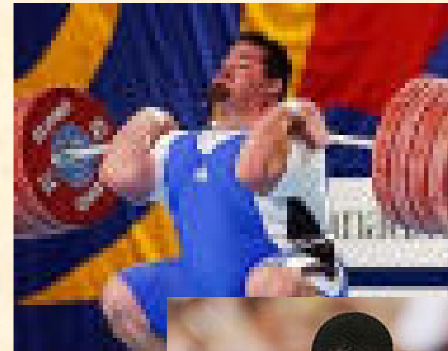


- High power exercise
- Anaerobic
- Only **CHO** used as energy source

- When training have to ensure they have CHO to meet energy needs
- Big muscles to produce energy for high power contraction

- Protein?
  - Bigger muscles need more protein?

Maximium power



- Quick contraction
- deliver **ATP** + regenerate quickly
- large muscle cross sectional area
  - cross sectional area proportional to the power developed
- Bigger muscles that contract quickly
  - Steriods (nandrolone)
  - beta-adrenergic agonists (clenbuterol)

These plus others stimulate growth

BANNED substances...................

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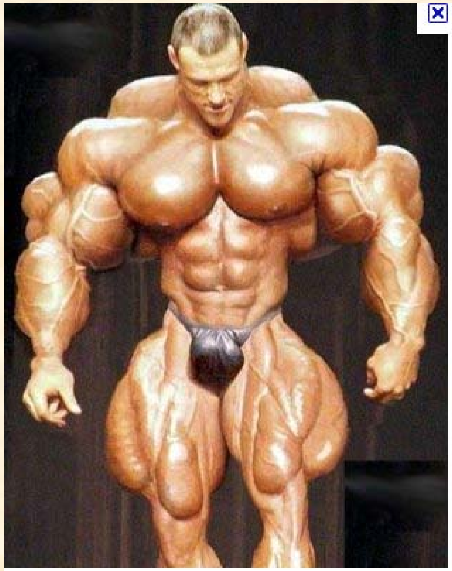


These plus others stimulate growth

BANNED substances………………..

What about dietary protein ?

- "bigger muscles need extra dietary protein"

- Is this true ?
  - sedentary individual basic requirement 0.8g/kg/day
  - **actual** at 10% energy protein (10.5MJ/day) 0.9g/kg/day
  - Recommended strength athletes 1.2-1.8g/kg/day
  - BUT higher energy intakes during training (> 15MJ/day)
  - Therefore intake will be > 1.4g/kg/day

- Training energy requirement must be met
- Carbohydrate intakes high **60-70%** (7-8g/kg/day)
  - Anaerobic metabolism requires glycogen

- Diets tend to be high in protein 15%
  - High quality protein; animal vs plant

If I can go faster, I’ll eat it…………

List of dietary aids !!!!!!!

- Alpha-ketoglutarate
- Amino acids
- Androstenedione
- Antioxidants
- Arnica
- Bee pollen
- Boron
- Buffers
- Caffeine
- Calcium
- Carbohydrate
- Carnitine
- Chinese medicines
- Choline bitartrate/ acetylcholine
- Chondroitin
- Chromium picolinate
- Cissus quadrangularis
- Citrulline
- CLA
- Coenzyme Q10
- Colostrum
- Copper
- Creatine
- Curcumin
- Cytochrome C
- DHEA
- Dihydroxyacetone
- Dimethylglycine
- Echinacea
- Electrolytes
- Ephedra (Ma Huang)
- Fatty acids & MCTs
- Ferulic acid
- Fish oils
- Flavonoids
- Folic acid
- Gamma-butyrolactone (GBL)
- Gamma-oryzanol
- Gamma-aminobutyric acid
- Garlic
- Gingko biloba
- Ginseng
- Glandulars
- Glucosamine
- Glutamine
- Glutathione
- Glycerol
- Green tea
- Guarana
- HMB
- Hydroxycut
- Inosine
- Inositol
- Iron
- KIC (alpha-ketoisocaproate)
- Lecithin
- Leptin
- Linoleic acid
- Magnesium
- Melanine
- Melatonin
- Minerals
- MSG
- MSM
- N-Acetylcysteine
- Nitric oxide stimulators
- Octacosanol
- Omega 3, 6, 9 fatty acids
- Ornithine
- Oxygenated waters
- Phlogenzym
- Phosphate salts
- Phosphatidylserine
- Plant sterols
- Polylactate
- Pre/probiotics
- Prohormones
- Protein
- Pycnogenol
- Pyruvate
- Quercetin
- Rhodiola rosea
- Ribose
- Royal jelly
- Selenium
- Spirulina
- Succinate
- Sugars & sweeteners
- Theobromine
- Theophylline
- Thyroxine
- Vanadium
- Vandyl sulphate
- Vitamins
- Wheat germ oil
- Wobenzym
- Yohimbine
- Yucca
- Zinc
- ZMA

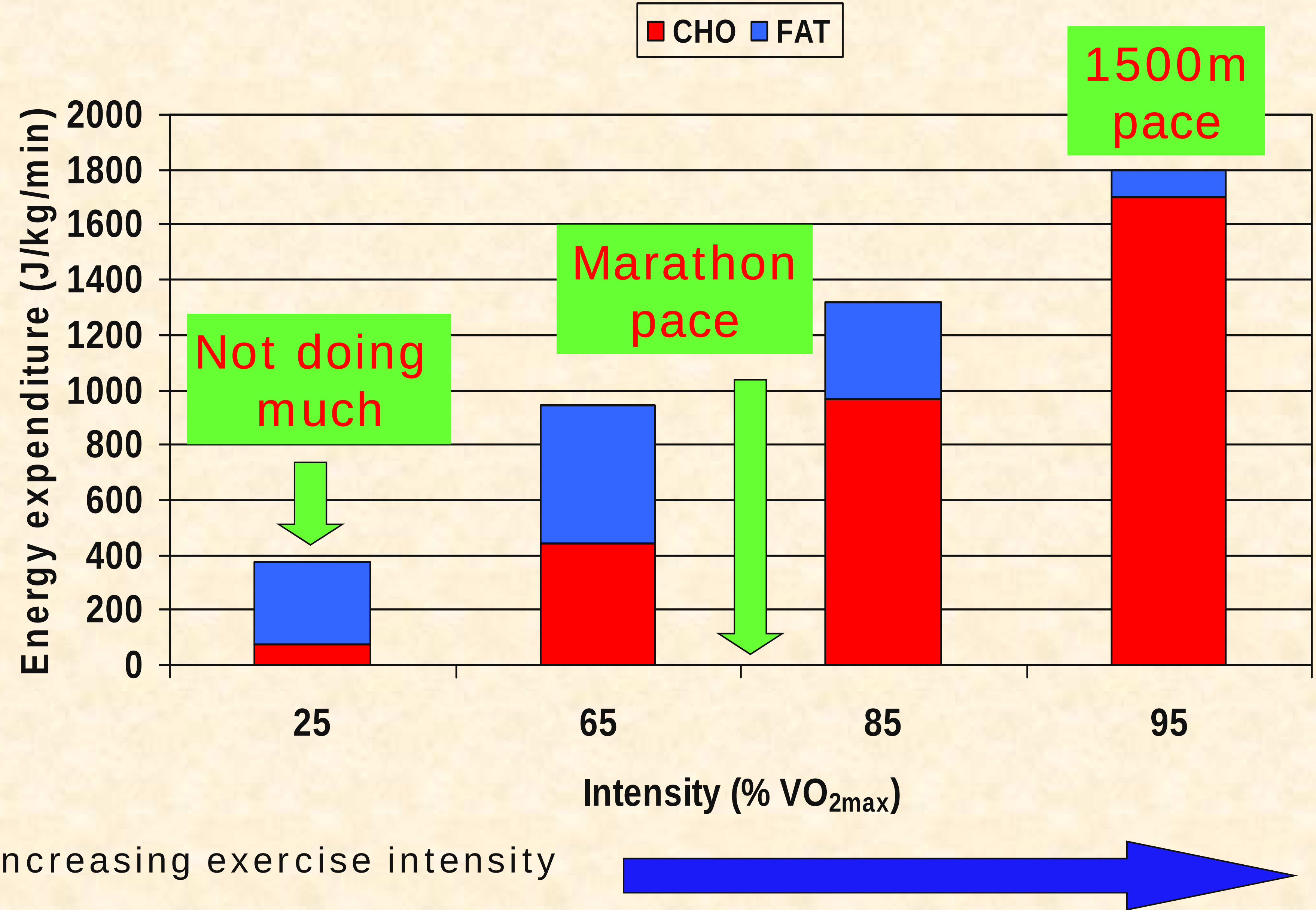
Energy from metabolism

- lower power exercise
- Aerobic metabolism
- CHO and fat can be used as energy source

- BUT CHO is the substrate preferred as the intensity of aerobic exercise increases

- Diets need to high in CHO

As intensity of aerobic exercise increases quantity CHO used increases



CHO is the limiting nutrient !!!!

- Aerobic exercise requires carbohydrate
  - Particularly high intensity
- Body sources

  blood muscle liver

- Which reserve greatest?
  - Blood
  - Muscle
  - Liver

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- Which reserve greatest?
  - Blood 10g
  - **Muscle 300-400g**
  - Liver ~90g

CHO is the limiting nutrient !!!!

- Aerobic exercise requires carbohydrate
  - Particularly high intensity
- Body sources

blood muscle liver

- How long does this last at marathon pace?

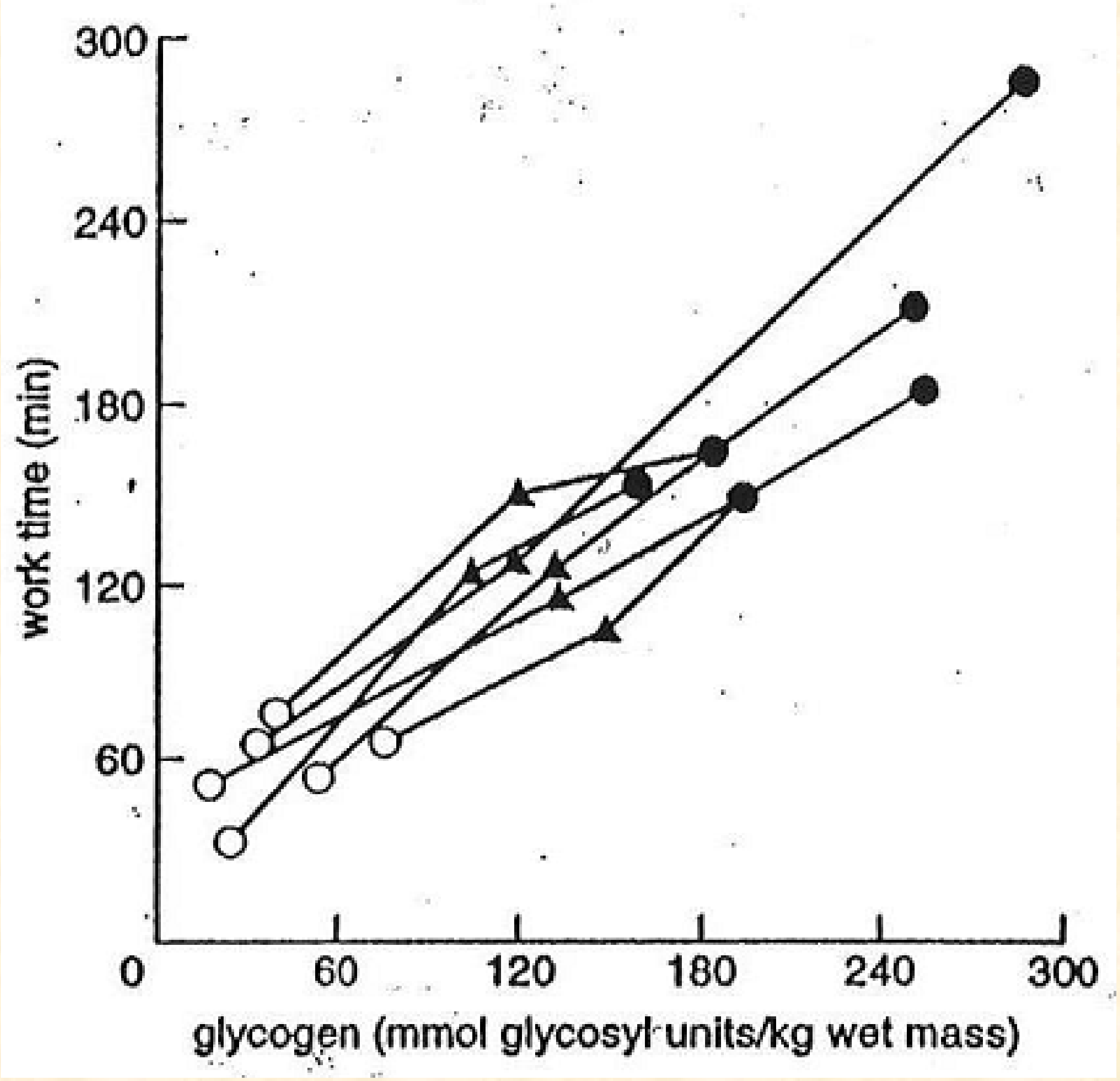
– Blood	10g	2min
– **Muscle**	**300-400g**	**80min**
– Liver	~90g	16min

✓

Nutrient stores of fuel

- Problem: limited CHO reserve
  - Longer events
- CHO (stored as glycogen)
  - 300-400g in skeletal muscle
  - ~90g in liver
- If only CHO used in a marathon used…… there is not enough.
  - 750 g of CHO would be needed
- Training: increased fat utilisation
- Increase CHO reserve is good for aerobic events: exercise longer

High muscle CHO (glycogen) allows longer exercise period



Exercise at marathon pace

Normal diet

Low CHO diet

High CHO diet

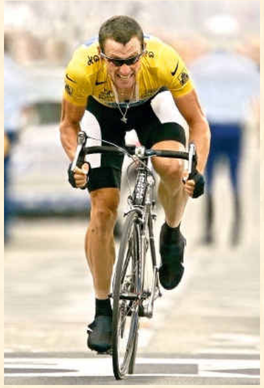
Bergstrom *et al.*, 1967

Optimising CHO reserves

- Athletes: endurance (but also power)
  - Training increase capacity to use fat for energy
  - Ensure adequate CHO reserves
  - High CHO intakes (up to 70% of diet)
  - Complex CHO best...but not always easiest!
  - Pasta meals before a marathon (CHO loading)
- Recovery to train again
  - Important for training.........
  - Replace reserves when depleted
  - Liquid with CHO present

Essential replacement of CHO

- Sedentary individual 10.6 MJ/day
  - Approx 2,500 kcal
- Tour de France
  - average expenditure 25.4 MJ/day intake 24.7 MJ/day
  - peak expenditure 32.7 MJ/day intake 32.4 MJ/day
- 24 hour cycle race
  - 43.4 MJ/day



The difficulties of eating……..

- Recommend: health carbohydrate
  - Complex CHO not simple sugars
  - 70% energy of intake
  - A “hard” day in the Tour de France

  - How much bread?

  1, 2, 3, 5, 7, 10 loaves

  - How much cooked pasta

  0.2, 0.5, 1, 2, 4, 6, 10 kgs

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  - How much glucose (simple sugar)

  1.4kgs

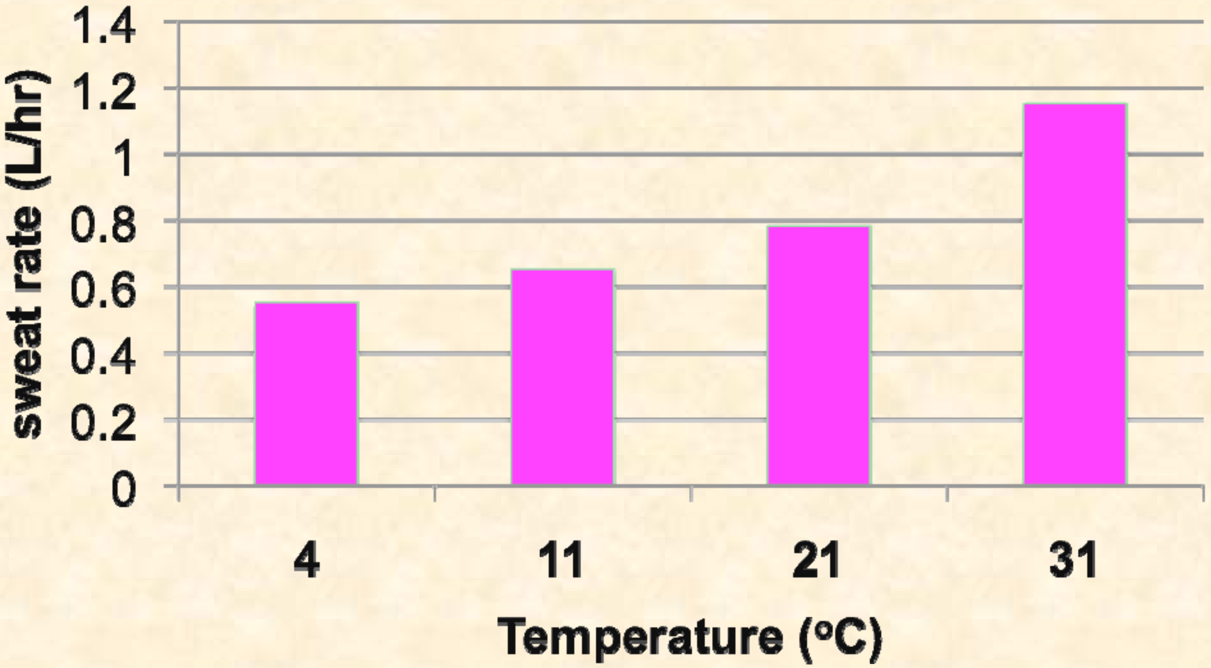
Tour de France - nutrition

To maintain CHO availability

- Continuous CHO drinks
- High CHO intake (~ 1kg)
  - High glycaemic index
- 60% of intake is on the bike
- Any mismatch of intake to expenditure
  - ↓ weight = ↓ ability to compete

Hydration

- Sweating – environment and exercise intensity



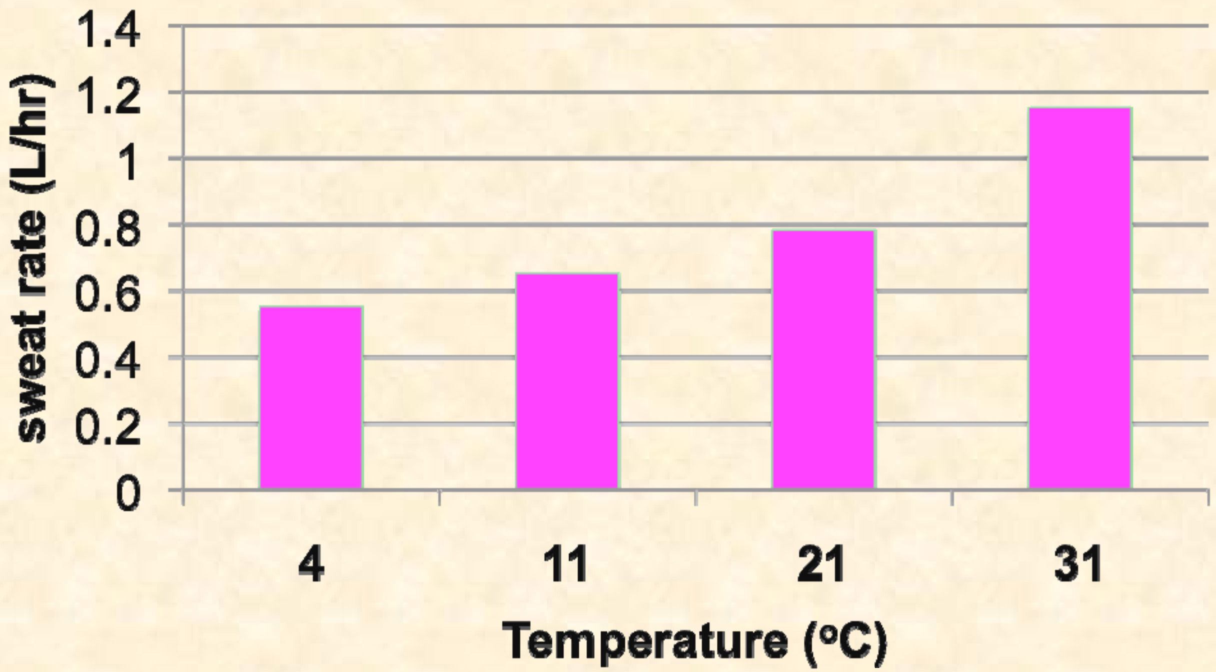
Marathon pace

- Detrimental losses - dehydration
  – How much loss affects performance?

0.5, 1, 2, 4, 6 litres

Hydration

- Sweating – environment and exercise intensity



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Hydration……..big business

- Dehydration requires 48hr recovery
  - Endurance……..but training in all sports
- Incorporation of CHO into drinks
  - Too much affects gastric emptying

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- Liquid before, during and after exercise
  - Before: too much and more is lost (<0.5L, 2-3hrs)

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  - Before: too much and more is lost (<0.5L, 2-3hrs)
  - During: at the start….~0.5L/hr @ 4-8% CHO
  - After: aids recovery of CHO reserves …... ~100g/hr

    Required within 30-60min of exercise.

Vitamins and minerals

- Deficiencies can occur and will cause a decline in performance
  - Concerns over oxidative stress
- BUT supplementation of vitamins and minerals is generally not required as long as balanced diet is followed (increased energy demand)
  - potential deficiency should be shown first
  - Only special conditions are likely to require supplements
  - Difficulties in maintaining a balanced diet
- Potentially over supplementation can be toxic
  - vitamin A

Summary

- The type of exercise will dictate the metabolic demand
  - Dependence on energy demand
- Determining what type of metabolism is being used will dictate what nutrients are required.
  - Dependence on oxygen
- Manipulation of diet can enhance performance but also allows training to be done effectively

BUT ability and doing the training are the main determinants for how good you are

Adequate nutrition will support performance

✓ Areas covered

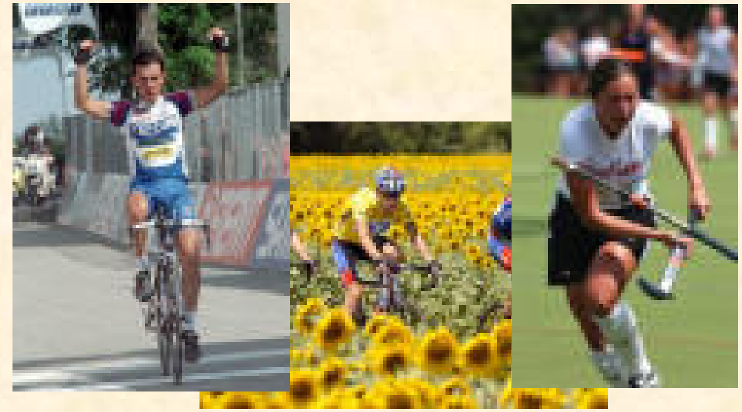
- Introduction- Energy metabolism
- Metabolism (nutrition) for high power events
  - Sprinting
- Metabolism (nutrition) for low power events
  - Endurance
- Nutrition considerations for sporting performance

✓ Objectives and learning outcomes

- Indication of exercise energy demands and metabolism
- Metabolic demands of differing types of exercise
- The metabolic and nutritional adaptations that athletes make to meet these demands

- A revision of energy metabolism.
- Identify what the metabolic and nutritional requirements of athletes are and their dependence on their sporting activity
- Identify the metabolic basis of certain dietary manipulations adopted by athletes used to enhance performance.

✓ An individuals inherent ability determines how good you are



Adequate nutrition will support and optimize ability.

Nutrition will not make a world beater but could improve performance.

✓ Introduction

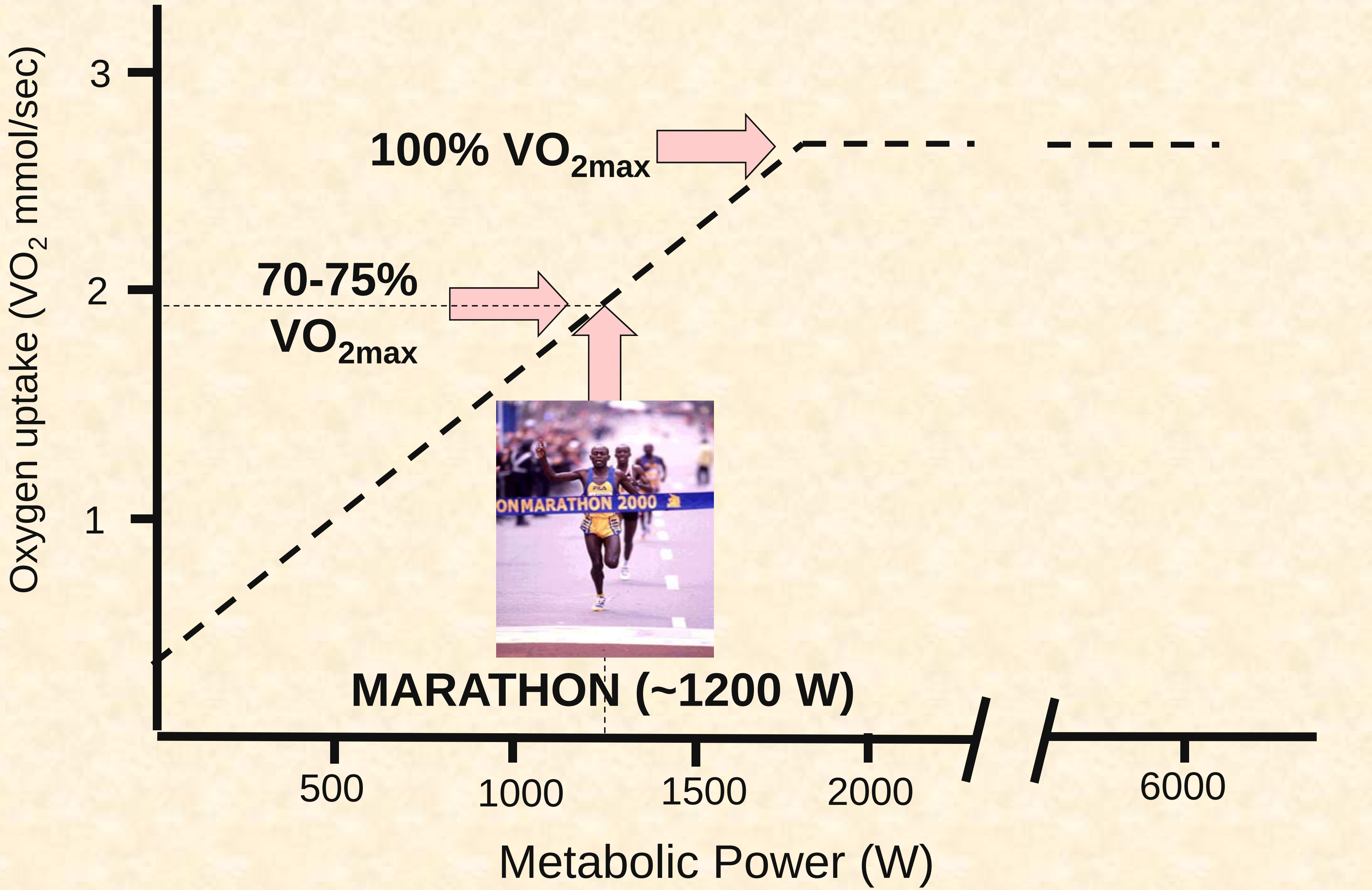
- Exercise leads to ↑ metabolism and the resulting maintenance of homeostasis
- Exercise results in a change in skeletal muscle metabolic rate from low to high
  - 0.2 → 200kJ/min in milliseconds
  - Nutrients used to generate energy

- High power output - **short** periods
- Lower power output - **long** periods
- outputs which cycle between the two

Intensity of exercise - energy demand

- power 1 W = 1J x 1 sec^{-1}
- 6000W for short periods equiv to 360 kJ/min
  - Marathon 2+hrs @ ~1200W equiv to ~72 kJ/min
- low power for long periods (to hours): a variable oxygen uptake (VO_2)
- before maximum power output reached no more oxygen taken up.
  - **VO_{2max}** = maximal oxygen uptake
  - **aerobic**, low intensity to high intensity exercise
  - **anaerobic**, high or very high intensity exercise (>2000W)
- limited power output achievable only using oxygen

O_2 uptake at steady state power output



✓ Energy to do exercise

- Chemical energy
  - "unit currency" is hydrolysis of ATP to ADP

$$ATP + H_2O \xrightarrow{31\ \text{kJ/mol}} ADP + H^+ + P_i$$

- metabolism regenerates ATP
- multiple nutrients can be used
- which nutrient is used is determined by energy demand, oxygen availability and fuel stores,
- nutrient availability influences performance

Missing words are

amino acids

H_2O

Protein

glycolysis

CO_2

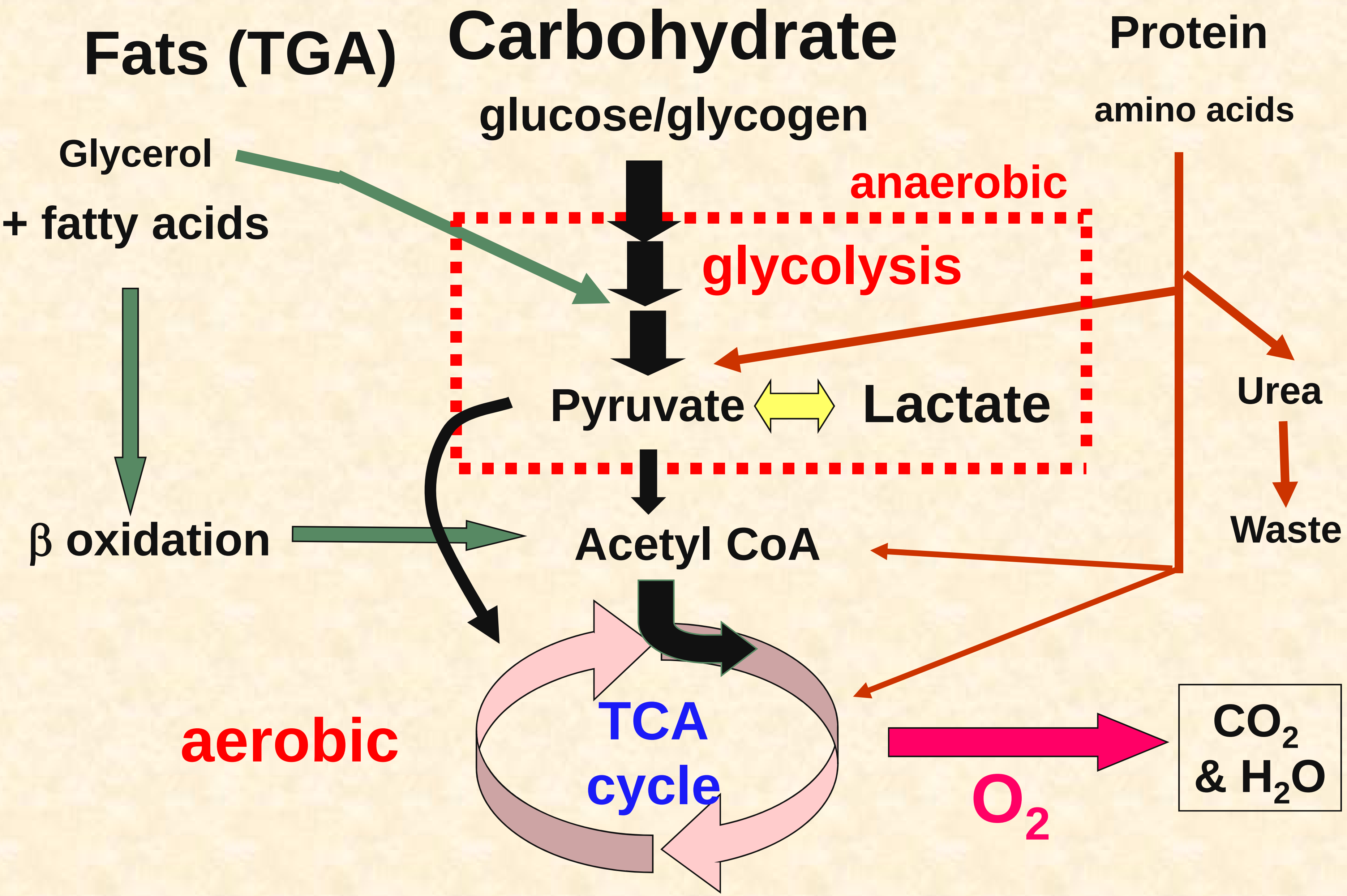
fatty acids

Carbohydrate

Lactate

Acetyl CoA

Pathways for energy metabolism



Anaerobic vs Aerobic nutrient substrates

- energy demand is greater than can be supplied using O_2

ATP regeneration by ____________________ metabolism

Nutrients used:

- adequate O_2 supplied, energy by oxidation of nutrients

ATP regeneration by _____________________ metabolism

Nutrients potentially used:

Anaerobic vs Aerobic nutrient substrates

- energy demand is greater than can be supplied using O_2

ATP regeneration by <u>Anaerobic</u> metabolism

Nutrients used: CHO

- adequate O_2 supplied, energy by oxidation of nutrients

ATP regeneration by <u>Aerobic</u> metabolism

Nutrients potentially used: CHO, Fats and protein

Aerobic vs anaerobic exercise

- Energy Metabolism for exercise is generally not made up of absolutes.
  - ONLY at extremes is it absolute
  - The contribution of each is on a “sliding scale”

Calorific values for Nutrient Fuels
oxidation of nutrient

Carbohydrate CHO (glucose) ________kJ/g

Fat ________kJ/g

- exercise energy substrates
- fat more energy per unit weight than CHO

Protein 15.9 kJ/g

- not a substrate for “energy” metabolism
  - nitrogen produced is toxic

Stores of fuel

- CHO (glucose polymer glycogen)
  - 300-400g in skeletal muscle - **TRAPPED**
  - ~90g in liver releasable maintains $[\text{glucose}]_{\text{blood}}$ 0.9g/l
  - stored with ~ 2g of water per 1g glycogen
- Fat
  - adipose stores, 15% in 70kg = 10.5kg
  - releasable Free Fatty Acids (FFA) into circulation
  - huge stores - excess of that required for most exercise
- Protein
  - **functional,** not selectively “stored”, ~12kg in 70 kg
  - not free, structural and functional role.

✓ Potential Energy for a marathon

- Energy expenditure 12 000kJ (marathon)
- If only CHO used…... there is not enough.
  - 750 g of CHO (approx 10g of blood glucose at any one time)
  - associated water 2.3 kg
- If only fat used
  - 320 g of fat
  - no associated water
- **BUT** CHO is the main energy source at high intensity exercise.
  - Both high POWER EVENTS and ENDURANCE
  - Marathon runners go to extremes to optimise CHO stores. Why ?

✓

fuels for generation of energy

MUSCLE SOURCE OF FUEL

- Phosphocreatine (immediate energy source)
- Glycogen (stored glucose)
  - anaerobically to lactate
  - aerobically to CO_2
- triacylglycerol within muscle, aerobically
- some amino acids (alanine and branched chain aas)

FUEL SUPPLY (mobilised)

- blood glucose (diet or from liver glycogen)
- blood fatty acids (from adipose tissue)
- blood triacylglycerol (chylomicrons or VLDL)

✓Oxygen and substrate utilisation

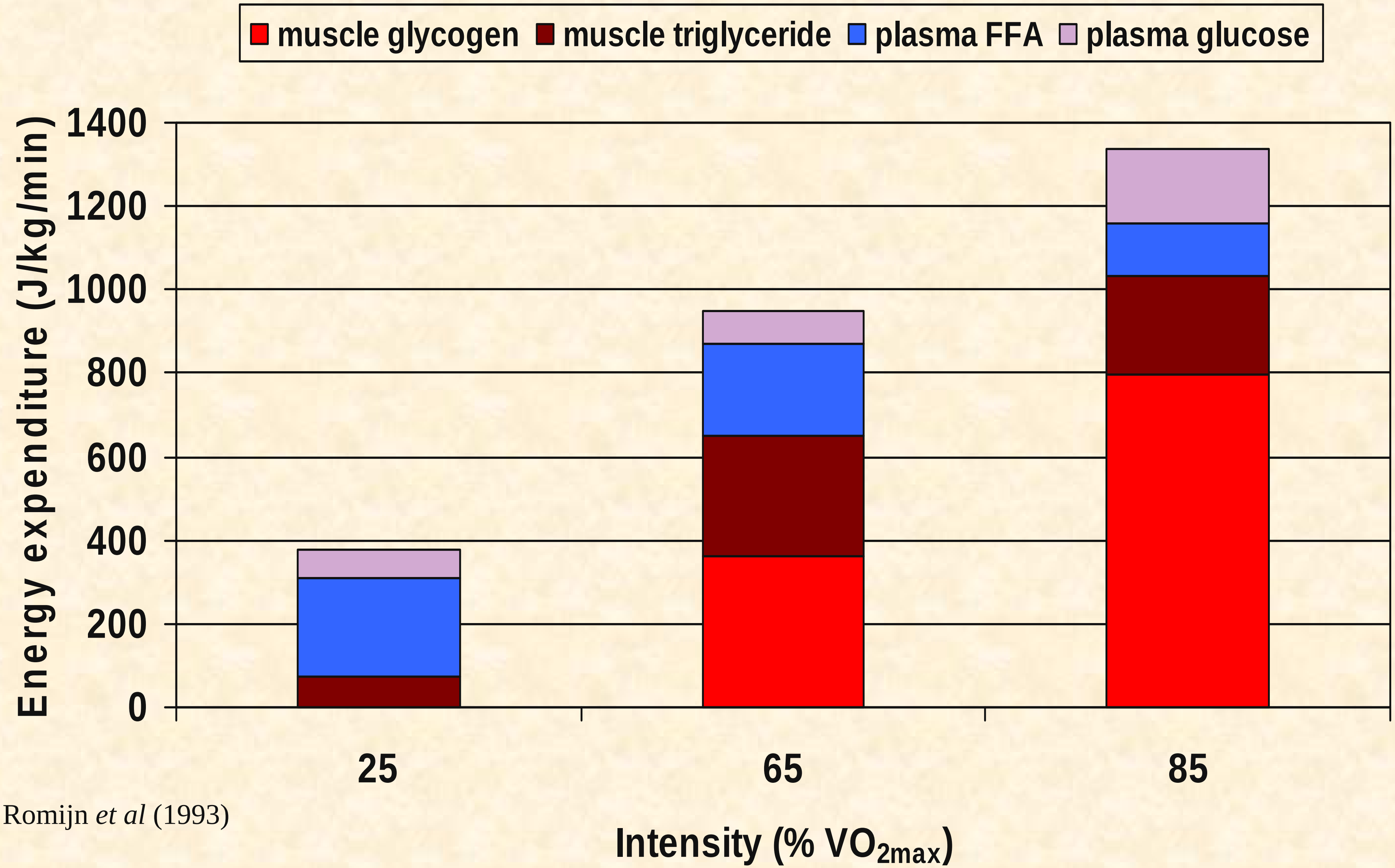
- Oxygen uptake is a limiting factor
- Maximal energy per unit oxygen
- Protein 15.9kJ/g 19.3kJ/lO_2
- **Fat** **37.1kJ/g** **19.8kJ/lO_2**
- **Carbohydrate (glucose)** **15.4kJ/g** **20.7kJ/lO_2**

- fat's oxidation requirement is partially the problem
- IN ADDITION there is a limitation on the rate at which muscle can take up fat and oxidise it.
- **FAT can only significantly support an intensity at ~ 60-70 % VO_{2max}**

✓Oxygen and substrate utilisation

- In high intensity aerobic exercise the maximal quantity of energy is being obtained per unit oxygen
  - Athletes carry out their activity as “fast” as possible.
  - high energy demand per unit time
- carbohydrate is the preferred substrate at high intensity aerobic exercise
- fat is still used but contributes less than carbohydrate at high intensity aerobic exercise
- carbohydrate “stores” are the limited
  - **a limiting factor of the aerobic exercise intensity**

Metabolism at different levels of intensity %VO_{2max} (at a steady state of exercise)



Romijn *et al* (1993)

Increasing exercise intensity

✓

The most important factor in influencing the metabolic response to exercise is exercise intensity

- Exercise intensity will determine the nutrient used to generate energy

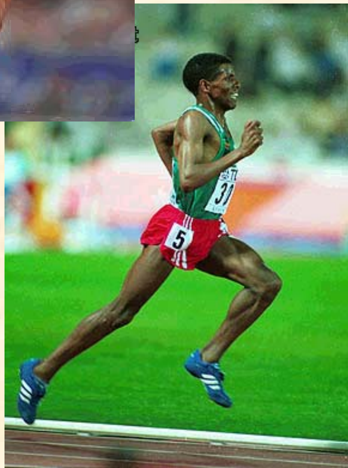
- In turn the ability to utilise a nutrient will be a limiting factor in the capacity to do the exercise at a specific intensity

✓ Anaerobic vs aerobic metabolism

- **Only** glucose, glycogen & phosphocreatine provide ATP under **anaerobic conditions**
- In aerobic exercise fat is also available to provide ATP
  - the level of use is dependant on exercise intensity
- Anaerobic generated ATP from glycogen is very small compared to aerobic
  - anaerobic can only be sustained for a short period
- Major limitation in performance is supply of oxygen to muscle.
  - Exercise intensity can be increased by generating some ATP from anaerobic breakdown of glycogen……but not for long.

✓ Contribution of anaerobic metabolism in some Olympic events

Event	% total energy
100	100
200	80
400	70
800	50
1500	40
5000	12.5



✓Determining Metabolic Fuel Choice

- Oxygen available
  - oxidative phosphorylation of ATP
- Substrate available
  - CHO + lipid stores in muscle
  - glucose from liver and blood flow
  - fatty acid production and blood flow
- Activity of enzymes (rate limiting)
  - concentration
  - balance activator vs inhibitor, feedback control
  - pH effects (inhibition of enzymes)
- Endocrine effects
  - stimulatory, substrate mobilisation

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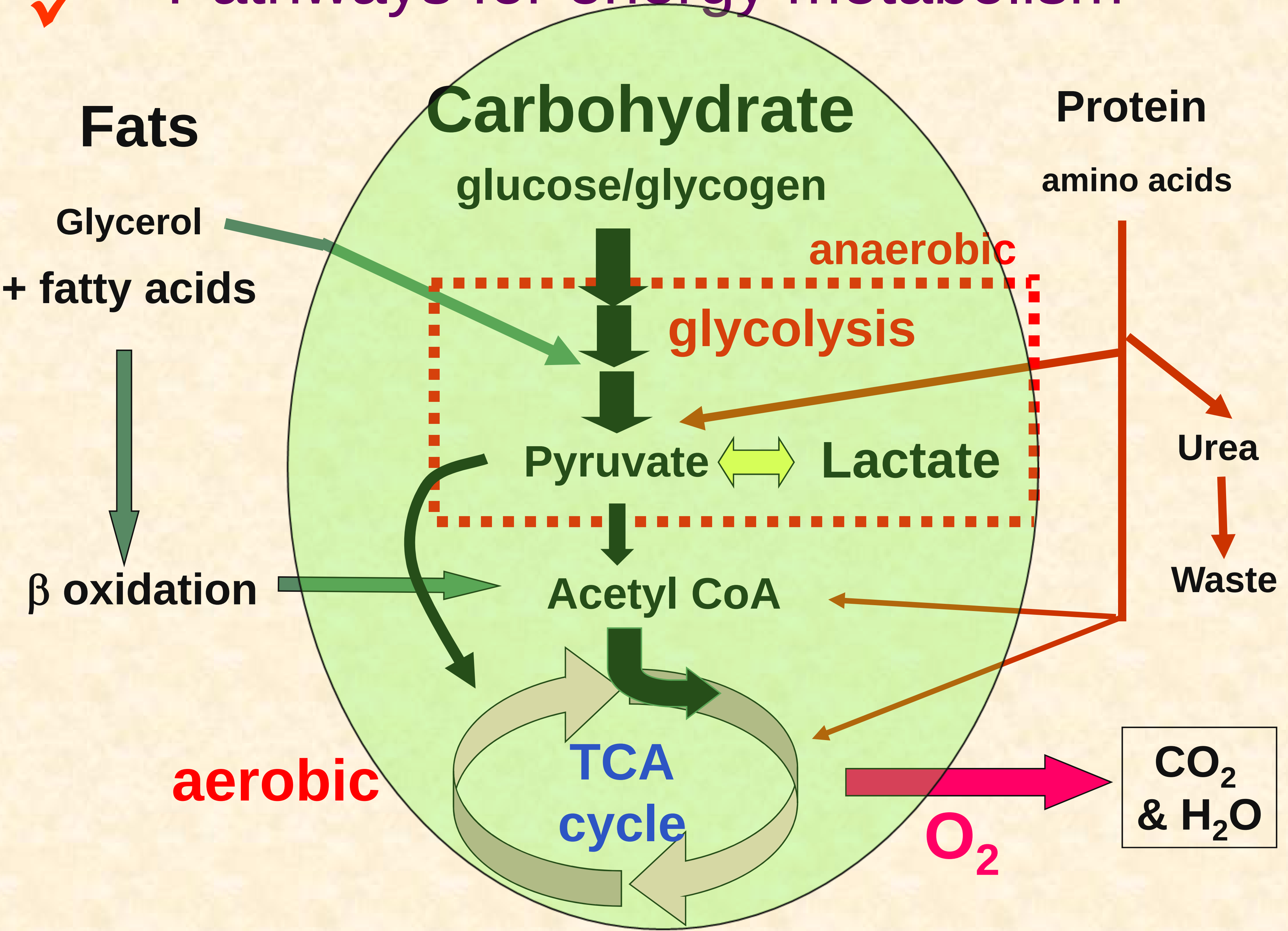
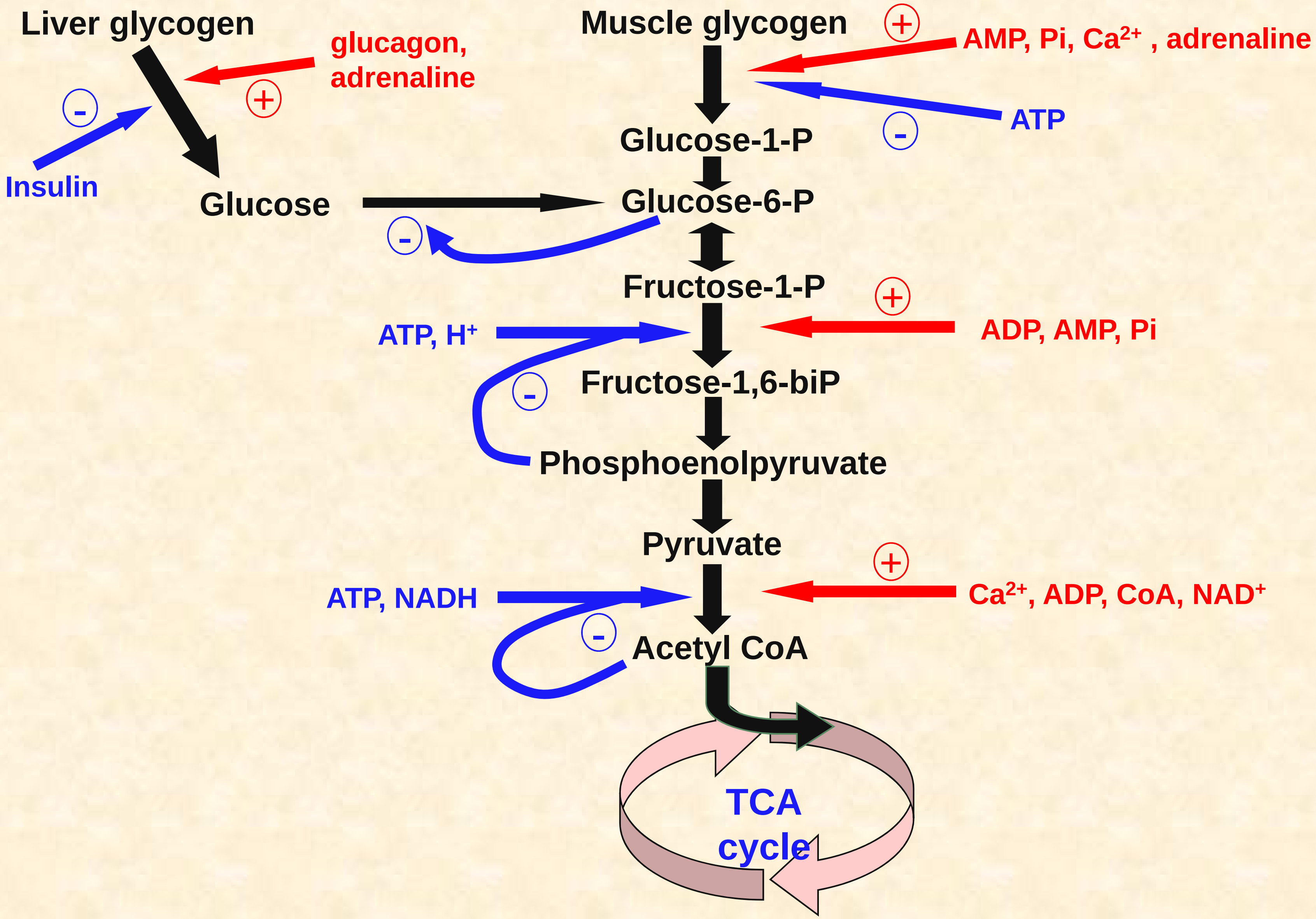
Pathways for energy metabolism



Hormonal effects plus activators and inhibitors influence CHO metabolism



✓ Factors influencing choice of fuel

- Previous diet and exercise
  - how much fuel is available
- Fibre composition of muscle
  - different fibres are suited for different fuel use (see later)
- exercise type: duration and intensity
  - high power anaerobic, low power aerobic
- training - fitness
  - adaptation
- where it takes place - environment
  - metabolic rate adaptation to temperature
- drugs (caffeine)

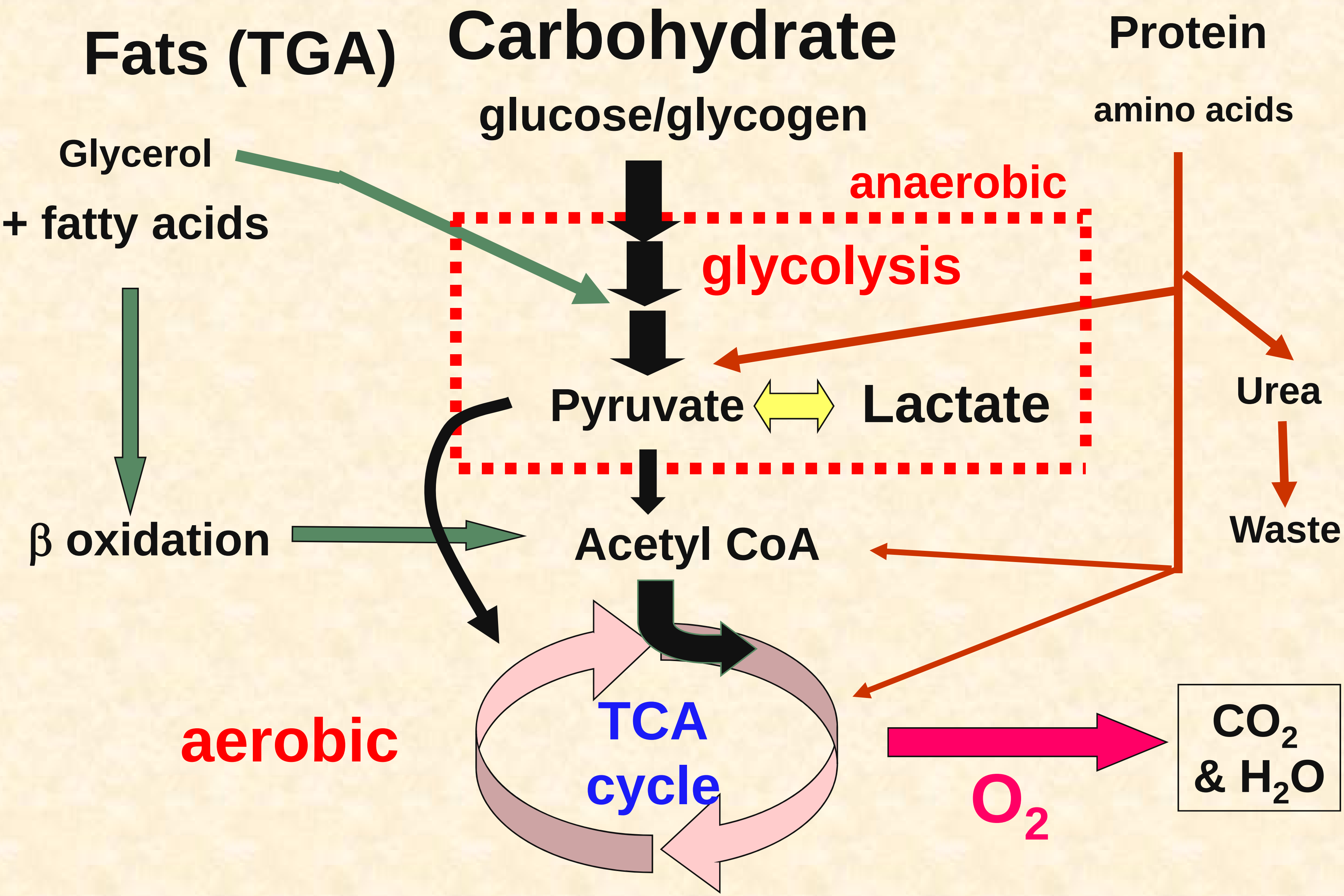
summary

- Exercise done at differing energy demand
- High power, anaerobic sustained for short period
  - energy produced in absence of oxygen, limited fuel available
- Lower power, aerobic sustained for longer period
  - oxygen and substrate availability
- Multiple fuels available
  - the proportion of differing fuels used depends in part on energy demand
- Oxygen availability dictates what can be used

Lecture 2

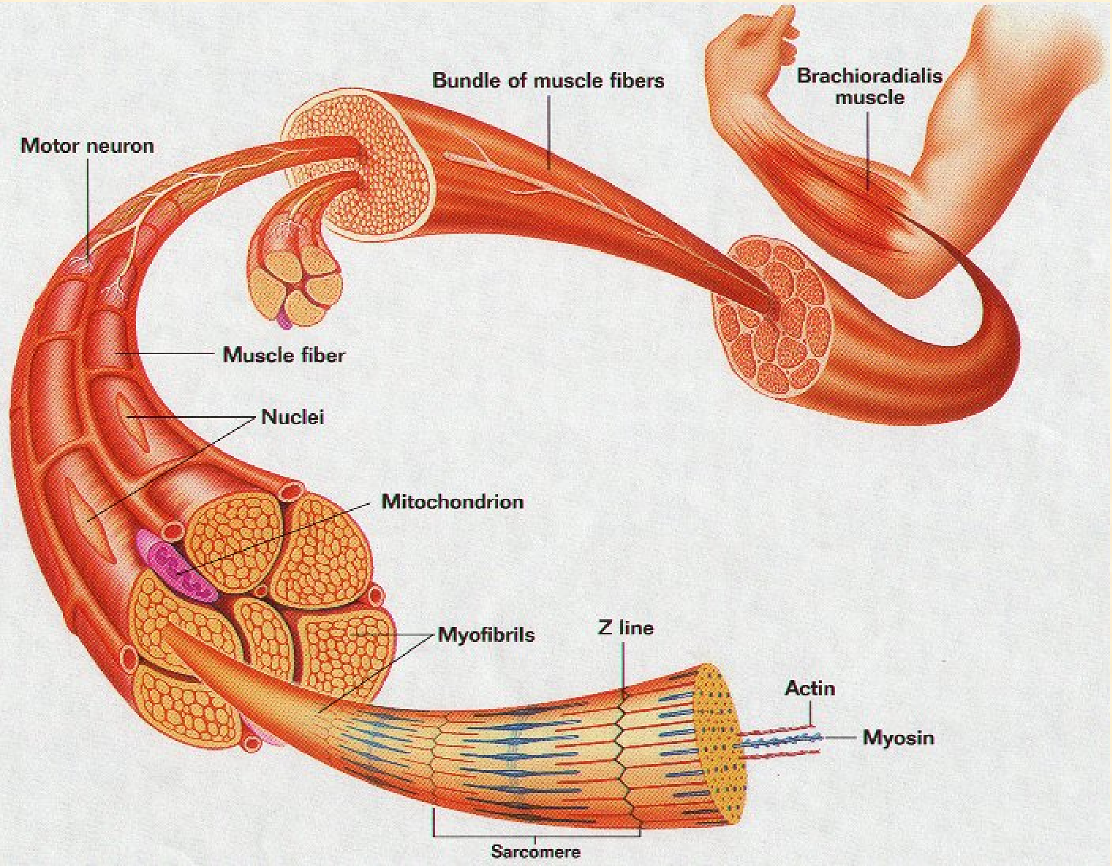
- Last time
  - Energy required per unit time: power vs endurance
  - Aerobic vs Anaerobic
  - Substrates available: high intensity CHO is used
  - Determining fuel choice
  - Influencing factors
- This lecture
  - The role of differing muscle fibre types
  - Characteristics of metabolism for power events
  - Concepts of fatigue
  - Indication of the nutrition required for this

Pathways for energy metabolism



Muscle fibres

- Muscles are made up of fibres
  - slow twitch (type I)
  - fast twitch (type II)
- fibres have distinct
  - Physical, metabolic and physiological characteristics
  - Suited to aerobic or anaerobic exercise



% muscle fibres in different athletes

- Particular fibre type associated with different sports

	slow Type I	fast Type II
Untrained	53	47
Sprinter	24	76
Middle-distance	62	38
Long- distance	79	21
Greyhound	3	97

- Fibres have differing metabolic characteristics

Fibre type and type of exercise

- Fibres are suited to meet a particular metabolic demand
  - The successful athlete will have specific muscle fibre types that have a metabolic capacity suited to their sport

- Do Endurance (marathon) athletes (low intensity exercise) have predominantly fast or slow ?

- Do power (sprint) athletes (high intensity exercise) have predominantly fast or slow ?

Muscle fibres

Property	Type I (slow twitch)	Type IIa (fast twitch-oxidative)	Type IIb (fast twitch-glycolytic)
Speed of contraction	slow	fast	
Glycolytic capacity		moderate	high
Oxidative capacity		moderate	
Glycogen store	moderate-high		moderate-high
Triacylglycerol store	high	moderate	
Capillary supply		moderate	poor

Muscle fibres

Property	Type I (slow twitch)	Type IIa (fast twitch-oxidative)	Type IIb (fast twitch-glycolytic)
Speed of contraction	slow	fast	**fast**
Glycolytic capacity	**low**	moderate	high
Oxidative capacity	**high**	moderate	low
Glycogen store	moderate-high	**moderate-high**	moderate-high
Triacylglycerol store	high	moderate	**low**
Capillary supply	**good**	moderate	poor

Metabolism in high intensity exercise

- Energy expenditure in very high power events (weight lifting)
  - > 300kJ/min
  - extremely high intensity exercise
  - **Immediate** energy utilisation

- Energy expenditure in high power events (100m sprint at top level)
  - > 200kJ/min
  - very high intensity exercise

- **energy by anaerobic metabolism**

✓

Maximium power for sprinting

- Quick contraction
- deliver ATP + regenerate quickly

- large muscle cross sectional area
  - size of cross sectional area directly proportional to the power developed
- bigger muscles that contract quickly
  - Steriods (nandrolone, THG (tetrahydrogestrinone))
  - beta-adrenergic agonists (clenbuterol)

Both stimulate growth (hypertrophy)

✓ Trained sprinter - II B muscle fibres

- **The Benefits of type IIB fibres:**
- Innervation
  - large motor neurones which transmit impulses very rapidly
  - virtually all type II fibres contract simultaneously - maximum power
- Contractile machinery
  - express fast type myosin and associated proteins
  - cross-bridges between actin & myosin filaments are such that contraction-relaxation cycle is short

Metabolic Fuels in the Sprinter

Type IIB fibres have:

• blood supply, capillary density	high or low
• mitochondria density	high or low
• aerobic respiration enzymes activity	high or low
• glycolytic enzymes activity	high or low
• phosphocreatine content	high
• creatine kinase activity	high

Metabolic Fuels in the Sprinter

Type IIB fibres have:

• blood supply, capillary density	low
• mitochondria density	low
• aerobic respiration enzymes activity	low
• glycolytic enzymes activity	high
• phosphocreatine content	high
• creatine kinase activity	high

✓ Metabolic fuels

Poor blood supply - use fuels within the muscle

- Phosphocreatine (PCr)
- Glycogen
  - storage form of glucose
- triacylglycerol, very low, **not** used

Phosphocreatine (PCr)

- 60% of creatine at rest is Phosphocreatine (PCr)
- A high phosphate-group transfer potential
  - hydrolysis of PCr gives -43 kJ/mole
  - hydrolysis of ATP gives -31kJ/mole
- energy transfer from PCr to ADP to reform ATP
  - **the immediate energy source**

Creatine Kinase

$$\mathbf{PCr + ADP^{3-} + H^{+} \xrightleftharpoons[]{\textit{Creatine Kinase}} Cr + ATP}$$

✓ Phosphocreatine

- Rate of PCr hydrolysis exceeds that for ATP and becomes degraded in maximal exercise
- PCr is used almost exclusively for the first 4 seconds of exercise
- Creatine kinase reaction very close to equilibrium. Thus, responds very quickly to rise in ADP conc.
  - **ENERGY DEMAND RESPONSE**
- This allows time for increased flux through non-equilibrium reactions of glycolysis.
  - **AN ENERGY BUFFER**

✓

Change in phosphocreatine in a sprint

✓ Glycogen - fuel for anaerobic exercise

- Muscle contains approx 88 μmol glycogen /g which could theoretically yield **3** x 88 = 264 μmol ATP /g glycogen via **GLYCOLYSIS to LACTATE**
- This should be enough for 88 seconds of sprinting
- BUT the maximum speed can not be kept up for more than 20 seconds - 200m
- **WHY?**

Changes in muscle on exhaustion

Exhaustion caused by 3 periods of sprinting for 1 minute separated by 1 minute rest. Units:μmol/g

		After excercise	
Contents	**Rest**	**15 sec**	**30 min**
Phosphocreatine	**17**	↓ or ↑	**18.8**
Glycogen	**88**	↓ or ↑	**70**
Lactate	**1.1**	↓ or ↑	**6.5**
ATP	**4.6**	↓ or ↑	**4.0**
Pi	**9.7**	↓ or ↑	**-**
pH	**7.1**	↓ or ↑	**7.0**

Changes in muscle on exhaustion

Exhaustion caused by 3 periods of sprinting for 1 minute separated by

1 minute rest. Units:μmol/g

		After excercise	
Contents	**Rest**	**15 sec**	**30 min**
Phosphocreatine	**17**	**3.7**	**18.8**
Glycogen	**88**	**58**	**70**
Lactate	**1.1**	**30.5**	**6.5**
ATP	**4.6**	**3.4**	**4.0**
Pi	**9.7**	**22.0**	**-**
pH	**7.1**	**6.3**	**7.0**

Metabolic Basis of Fatigue

- Fatigue
  - Inability to maintain a given power output
- Peripheral Fatigue
  - within muscle
- Central Fatigue
  - within CNS

✓ Peripheral Fatigue

- ↓pH by ↑H^+ generated from glycolysis
  - **lactate acid** dissociation to lactate + H^+
- probably not due to accumulation of lactate
- associated changes in [P_i] (🡅) effect fatigue
- low pH
  - disrupts myosin and actin interaction, 🡇 force production.
  - 🡇 activity of enzymes involved in glycolysis
  - 🡇 Ca^{2+} release in response to nerve stimulation slowing of Ca^{2+} uptake, smaller Ca^{2+} transients
- Bicarbonate supplements to reduce pH **decrease**
  - 300mg/kg body weight , events of 1-10 minutes

Central Fatigue

- Muscles can still contract but don't
  - a fatigued muscle can be electrically stimulated to contract
  - a reduced neuronal drive to muscle
- central nervous system fatigue
- associated to serotonin (5HT) production
  - perception, arousal, lethargy
- Motor neurones inhibited, drive decreased
- Probably in response to some signal from muscle
  - changes in amino acid metabolism

✓ Training for Sprinting

- Weight/sprint training
  - ↑ muscle fibres size (↑cross sectional area = ↑ FORCE)
  - ↑ capacity of glycolysis & creatine kinase,
  - ↑ lactate tolerance
- Speed training (changes in running speed)
  - Develop co-ordination of fibre contraction/relaxation cycle
- “Explosive” training
  - May enhance response of glycolysis to catecholamines
- to do this high intensity training the athlete will need adequate supply of which energy substrate

protein (?) fat (?) carbohydrate(?)

What are the dietary strategies of a Power athlete ?

- What do they tend to have in their diets ?
- What do they supplement with?
- What substances would benefit them but are illegal?

What are the dietary strategies of a Power athlete ?

- What do they tend to have in their diets ?

High protein intake ……perhaps CHO is a concern

- What do they supplement with?

Creatine…….specific amino acids

- What substances would benefit them but are illegal?

Steroids, beta-agonists, growth hormone, insulin (!!)

✓ What about dietary protein ?

- "bigger muscles need extra dietary protein"
- Is this true ?
  - sedentary individual basic requirement 0.8g/kg/day
  - **actual** at 10% energy protein (10.5MJ/day) 0.9g/kg/day
  - Recommended strength athletes 1.2-1.8g/kg/day
  - BUT higher energy intakes during training (> 15MJ/day)
  - Therefore intake will be > 1.4g/kg/day

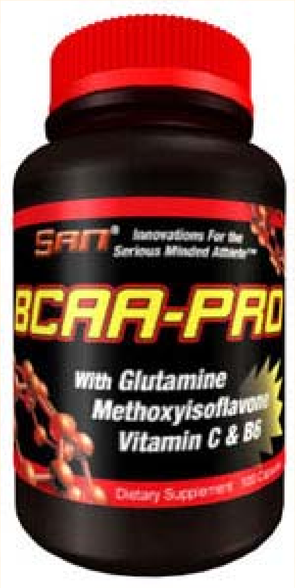
- Training energy requirement must be met
- carbohydrate intakes high 60-70 % (7-8g/kg/day)
  - glycolysis requires glycogen
- Diets tend to be high in protein 15% energy

Creatine supplementation

- Phosphocreatine is an important source of energy in high intensity exercise
- Optimize performance by increase dietary creatine - direct creatine supplementation
- Can increase muscle creatine by 20%
  - increased work output in maximal exercise only
- flooding dose 20g/day (4x 5g) for 6 days
- maintenance 2g/day
- side effects long-term doses (?)

✓ Amino Acid supplements

- Arginine, lysine and ornithine (urea cycle)
  - Suggested to have +ve effect on growth hormone
  - Growth hormone is anabolic
  - Evidence is not conclusive



£17.99/100 tablets
http://www.fitsense.co.uk/san-bcaa.htm

- Branched chain amino acids

  "BCAA's can increase protein synthesis and suppress muscle protein breakdown."

  http://www.fitsense.co.uk/san-bcaa.htm

  "No valid scientific evidence supports the commercial claims that orally ingested BCAAs have an anti-catabolic effect during and after exercise in humans or that BCAA supplements may accelerate the repair of muscle damage after exercise."

  Michael Gleeson J. Nutr. **135**:1591S–1595S, 2005.

✓Changing Muscle Fibres?

- Anaerobic training ↑ proportion Type IIb fibres
  - not just hypertrophy, it is a process of "switching" Type II fibre type IIa→IIb

- Aerobic training ↑ proportion Type I fibres
  - evidence is not conclusive

✓ Sprinting (Power events) summary

- High energy demand over very short period
- Anaerobic metabolism
- Limited fuels available
  - both supply and the lack of O_2
- Fibre types suit metabolic demand
- Training adaptation
  - nutrition
- Specific nutrition unlikely to be require for the competitive event.

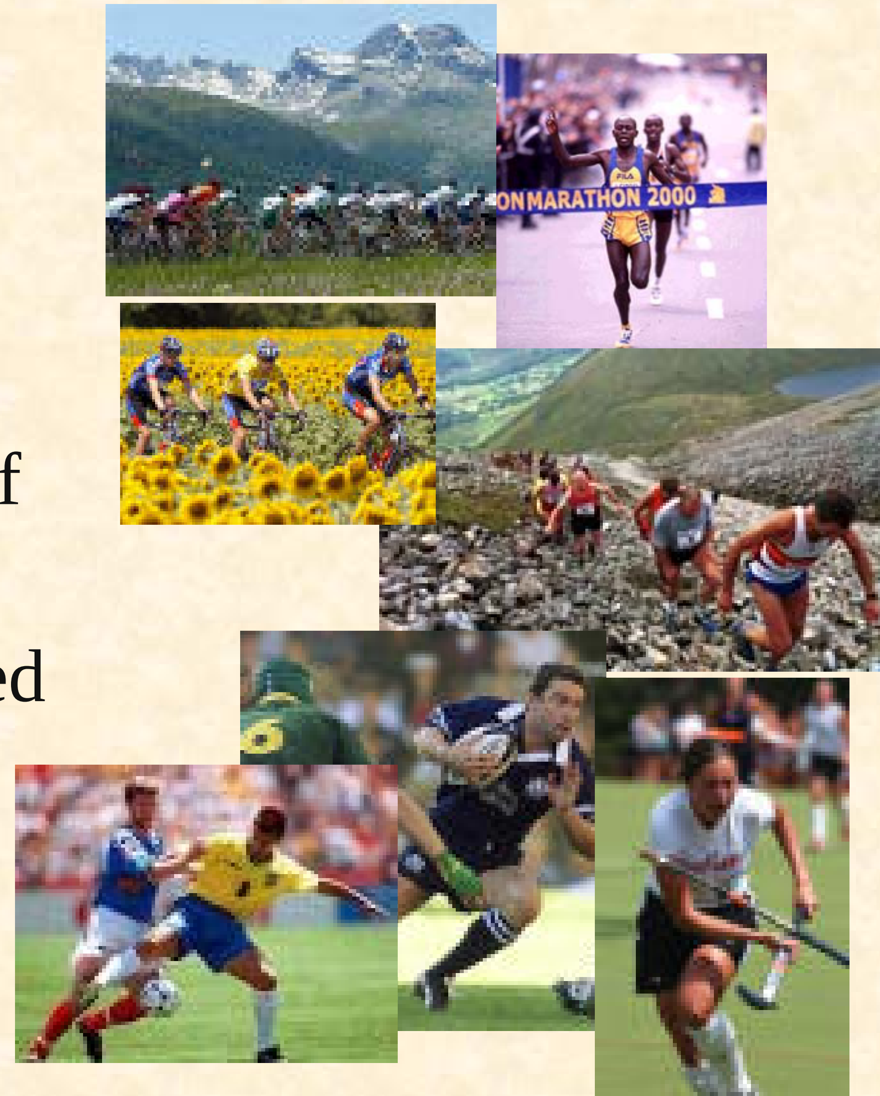
PART II

Lecture 3

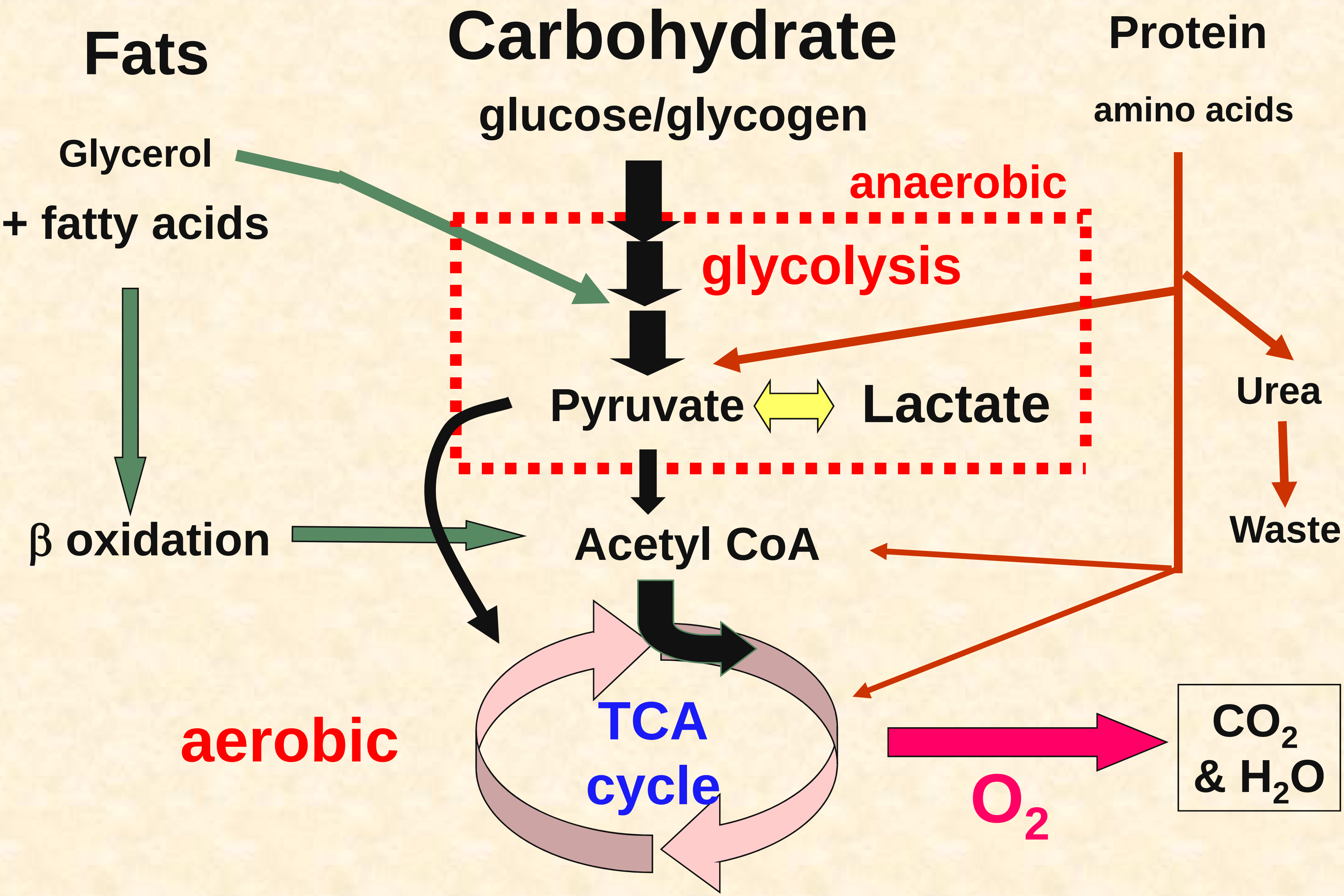
- Last time
  - Power events (anaerobic)
  - Suited to Type II muscle,
  - Dependence on CHO
  - Training adaptations to allow maximal energy product
  - Beneficial nutrients (creatine)
- Today
  - Endurance exercise (aerobic)
  - what nutrients are used for energy production
  - Critical importance of CHO in exercise and fatigue
  - Water and others (?)

✓ Endurance exercise

- Prolonged exercise
  - 30-180 min
  - lower intensity compared to anaerobic exercise
  - intensity range at 60- 85% of VO_{2max}
  - intensity determines fuel used



Pathways for energy metabolism



✓ metabolism for aerobic exercise?

high intensity aerobic : “long” exercise period

- Oxygen required
- glycogen is required (must be replaced after exercise)

Lower intensity aerobic : extended exercise period

- lower power output
- Can not use CHO as the sole substrate
- glycogen-sparing **FAT METABOLISM**
- glycogen maintenance
- ↑glycogen stores prior to exercise **MAXIMISED CHO**

- Try to ↑ fat metabolism “spare” glycogen
  - This requires a good oxygen supply.

Marathon runner Type I Fibres - suited to aerobic exercise

• maximal power output	high or low
• contraction/relaxation speed	slow or fast
• blood supply(capillary density)	high or low
• phosphocreatine	high or low
• glycolytic enzyme activity	high or low
• mitochondria density	high or low
– aerobic respiration enzyme activity	high or low
• triacylglyceride content	high or low

Marathon runner Type I Fibres

• maximal power output	low
• contraction/relaxation speed	slow
• blood supply(capillary density)	high
• phosphocreatinine	low
• glycolytic enzyme activity	low
• mitochondria density	high
– aerobic respiration enzyme activity	high
• triacylglyceride content	high

A tendency for FATIGUE RESISTANCE

Available Fuels for a Marathon Runner

- From the muscle
  -
  -
- From blood
  -
  -

Available Fuels for a Marathon Runner

- From the muscle
  - **Glycogen**
  - **Triacylglycerol**

- From blood
  - **Glucose (liver glycogen), quickly available**
  - **Fatty Acid (adipose fat), delayed availability**

Exercise Substrates -Muscle Glycogen

- Used more gradually than in a sprint
- principle fuel during initial 30 min
  - Gradually becomes depleted
- Then fat acid mobilisation increases
- fat oxidation rates not meet ATP requirement for exercise approx > 60% VO_{2max}
- time for exhaustion is dependant on exercise intensity (% VO_{2max})
  - the rate of glycogen demand
  - glycogen depletion results in exhaustion

✓ Exercise Substrates - Blood Glucose

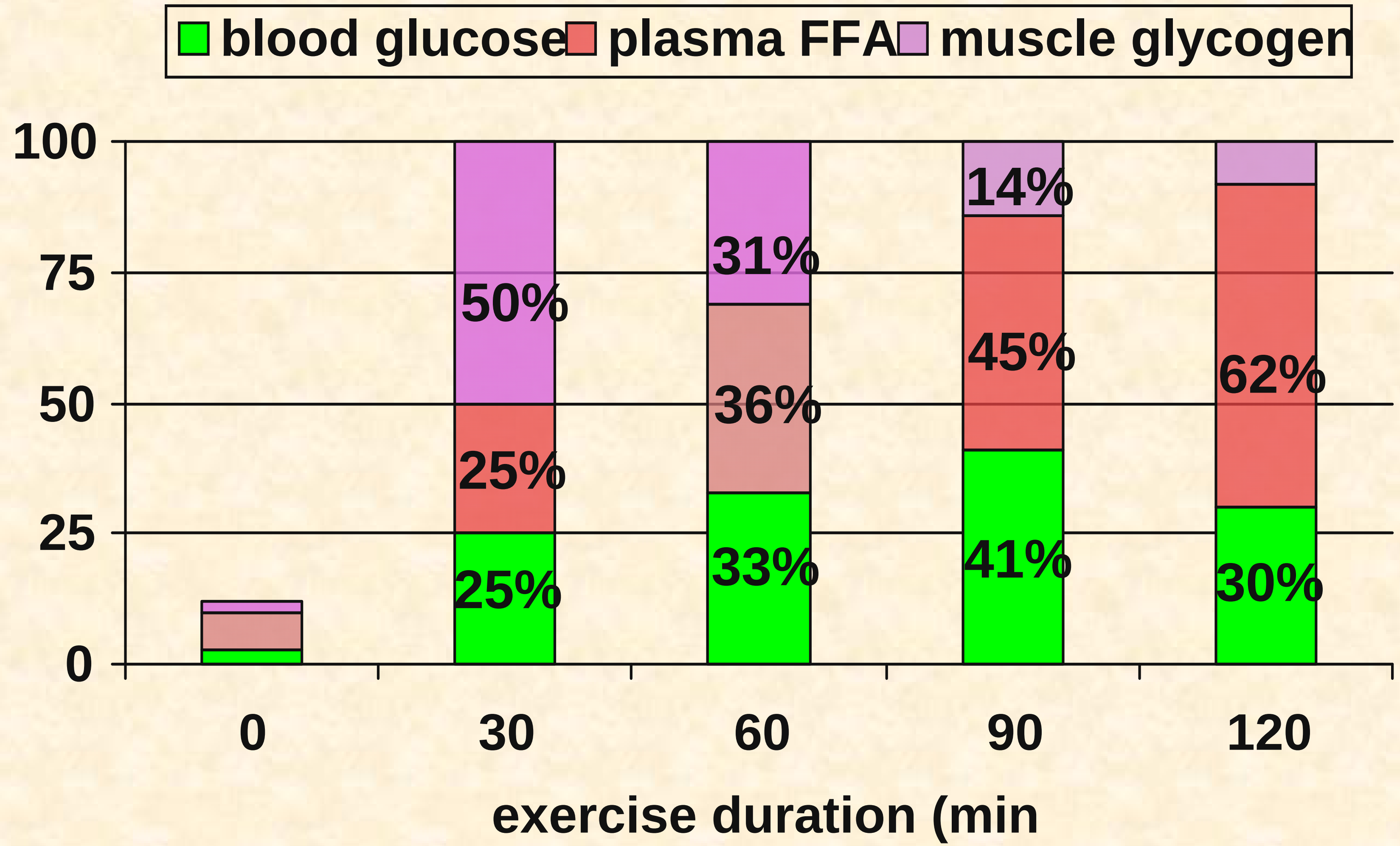
- Blood glucose is maintained
  - 0.07-0.11g/100ml
- Any blood glucose used is replaced by breakdown of liver glycogen
- Elite marathon runner may use equivalent of 5g glucose/minute
- Liver only stores 80g equivalent to 16 minutes; **LIMITED RESERVE**

- **glucose is also required for another organ**

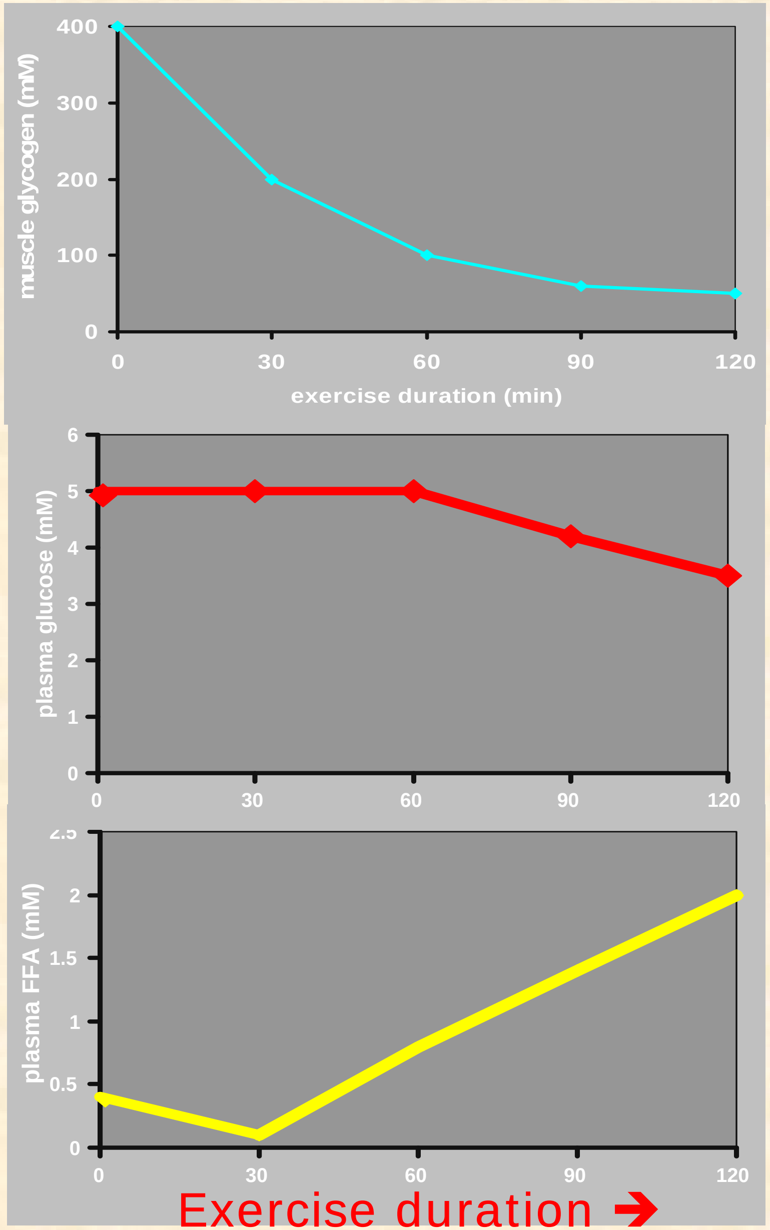
✓ Exercise Substrates - Fatty Acids

- Has to be used to exercise for prolonged periods
  - predominates for lower intensity exercise
- In prolonged exercise up to ~ 60% of energy supply is from plasma fatty acids
  - Released from adipose tissue in response to low insulin and high glucagon/adrenalin concentration
- glycerol to liver then to glucose
- Sparing effect on blood glucose as liver stores decrease
- mobilisation time ~ 30+ min (peak at ~90min)

Relative contribution of major fuels to ATP re-synthesis during prolonged exercise at 70% VO2max



Nutrients mobilisation in endurance exercise



- Continuous endurance exercise (70%VO_{2max})
- Muscle glycogen is utilised first, predominant fuel early on
- Mobilisation of Fatty acids takes time but increases as exercise proceeds
- Plasma glucose starts to fall when muscle glycogen is severely depleted

✓ Fatigue in Marathon Runners

- minimal ↑ H^+
- central fatigue; hypoglycaemia, changes in amino acid metabolism
- Fatigue: muscle & liver glycogen depletion

Fatigue in Marathon Runners

Fatigue develops because

- Inability to rephosphorylate ADP
- ↓ glucose, ↓ TCA intermediates
- ↓ flux through TCA cycle

✓ Fatigue in Marathon Runners

- depletion of glycogen leads to dependence on fatty acids
- CAN NOT make up the deficit of CHO loss as a substrate
- Can only maintain 50- 60% VO_{2max} using Fat as a predominant energy source
  - main problem is not the physical properties as an energy source
  - rate of up take by the muscle (transport) ?
  - rate β-oxidation to provide energy (flux) ?
- **Aim is to "balance" substrate use to run out of glycogen as the race ends**

For endurance athletes using high intensity aerobic exercise (~60-85% VO_{2max})

- The more muscle glycogen you have……
  the greater the time period you can exercise at any fixed high aerobic exercise intensity
  OR
  the higher aerobic intensity you can exercise at for a fixed period time.

- Therefore altering muscle glycogen content alters…….
  the time period exercises is sustained OR the intensity of exercise you can maintain **until exhaustion**

Glycogen levels and exercise

✓ Summary

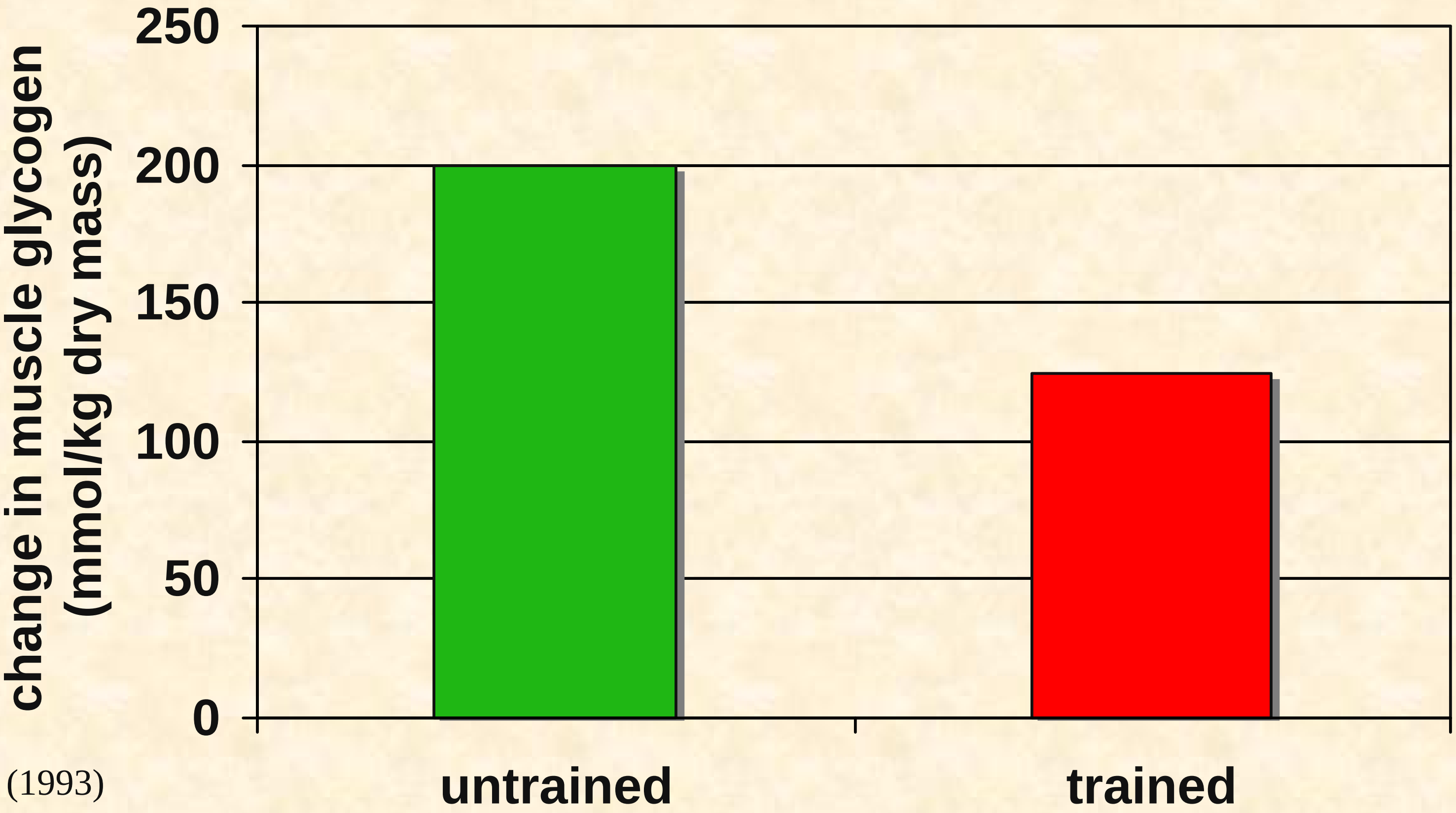
- Fibres of endurance athletes are suited to their metabolic demand
- In order to exercise for long periods
  - intensity is adjusted
  - **balance** between fat and CHO utilisation has to be made
- But exhaustion occurs when glycogen is depleted

- What are the metabolic adaptations that endurance athletes wish to achieve when they train ?

✓ Endurance Training

- Sparing effect on muscle glycogen usage
  - ↓ rate of muscle glycogen usage
  - ↓ utilisation of blood glucose
  - ↓ accumulation of muscle lactate
  - ↑ oxidation of lipid relative to CHO
  - ↑ utilisation of muscle fat triacylglyceride
- **Training aims to make metabolic adaptations**
  - physiological adaptations are also made

Effect of 12 weeks endurance training on muscle CHO utilisation



Coggan *et al* (1993)

↓ glycogen utilisation during 2 hour exercise at 60% VO_{2max}

↑ FA utilisation

✓ Endurance Training

- Increases ability to oxidise fatty acids
  - increased aerobic enzyme activity
- At the same absolute or relative intensity (same % of VO_{2max}) trained athletes use more fat.
- Sparing of muscle glycogen

- Peak mobilisation of fatty acids
- speeded up by **caffeine (?)** - illegal drug
  - ↑caffeine →↑ F.A. release and sparing glycogen ????
- limit is 12μg/ml urine (~ 3-4 mugs of strong coffee)

Drugs and endurance athletes

- Don’t use drugs inducing hypertrophy
  - **NO** Beta-adrenergic agonists, steroids etc
- Requirement
  - Mobilise nutrients, provide O_2 and prevent fatigue
- Erythropoietin (EPO)
  - Kidney hormone stimulating Red Blood Cell production
  - ↑ haemoglobin → ↑ O_2 transport
- Amphetamines
  - Stimulatory, overcome fatigue.
- Both have side effects

Summary

- The ability to do exercise at high intensity in endurance exercise is also strongly influenced by the availability of carbohydrate

- Athletes try to optimise the use of this metabolic substrate through metabolic and physiological adaptation

Special Nutritional needs ??????

What do athletes need ?

What do they need it for ?

REQUIREMENTS FOR PERFORMANCE

✓Nutrition & Sport

- Does exercise create special nutritional needs?

- Possible reasons:
  - Increased energy requirements
    - Increased requirements for nutrients associated with energy production
  - Increased temperature for long periods
    - does this shorten the life of heat sensitive vitamins?
  - Prolonged sweating
    - Does this deplete body stores of certain nutrients?
  - Damage to muscle tissue
    - Does this increase protein & vitamin requirements?

Sweat loss function of temperature and work

Importance of sweating

- 70kg man running 16km/h would produce 4000kJ of heat
- In order to dissipate it without rising “core” body temperature requires ~ 1.0l of sweat per hour
  - Approx 14l of ECF and 50l in total
- Runners can only consume about 500ml of fluid without it causing nausea & discomfort
- To reduce losses
  - fluid before event
  - fluid intake during or immediately after event
  - fluid intake is important for events > 1hour

✓ Loss of water - dehydration

- Sweat loss dependant on environment temp.
- Also significant losses from respiratory tract
  - particularly at low temperatures

- water loss has a significant effect on performance
  - >2% body water loss is likely to affect performance
  - the hotter it is the lower the loss tolerated

- Rehydration after dehydration can take >24h

✓Water vs Electrolyte Solutions

Drink before events

- Drink 400-600 ml in 2-3 hours before exercise.
- More than this results in excretion

- Addition of glycerol can enhance water retention
  - Reduces water clearance….hyper-hydration effect
  - Evidence for a positive effect on performance is not conclusive.
  - 1g/kg body weight in 1.5L of water 1-2 hours before the event!!!!!

  - Events that are > 4hours

✓Water vs Electrolyte Solutions

Drink during events

- small amount of sodium (0.5-0.7g/100ml ~90mM NaCl) will enhance drive to drink and prevent dilution of serum.
- added CHO can improve gastric emptying (4-8% w/v) for events >1hr

Taken after event

- Any electrolyte loss can be compensated by dietary intake but liquid electrolytes can be beneficial
- Added CHO can aid nutrient and hydration recovery

✓ Salt - any need for supplements?

Unit person's sweat	80mM sodium
Athlete	40mM sodium
plasma conc.	140mM sodium
extracellular stores	2000 mMoles

- Does replacement of sweat by drinking water lead to salt depletion?
  - **For a significant effect needs to be a loss 5l of sweat with water replacement**
  - **Can't drink that much (usually about 500ml/h)**
  - **Problems in ultra events (3-4 hours)**
  - **More likely to see increase in serum [sodium]**

✓

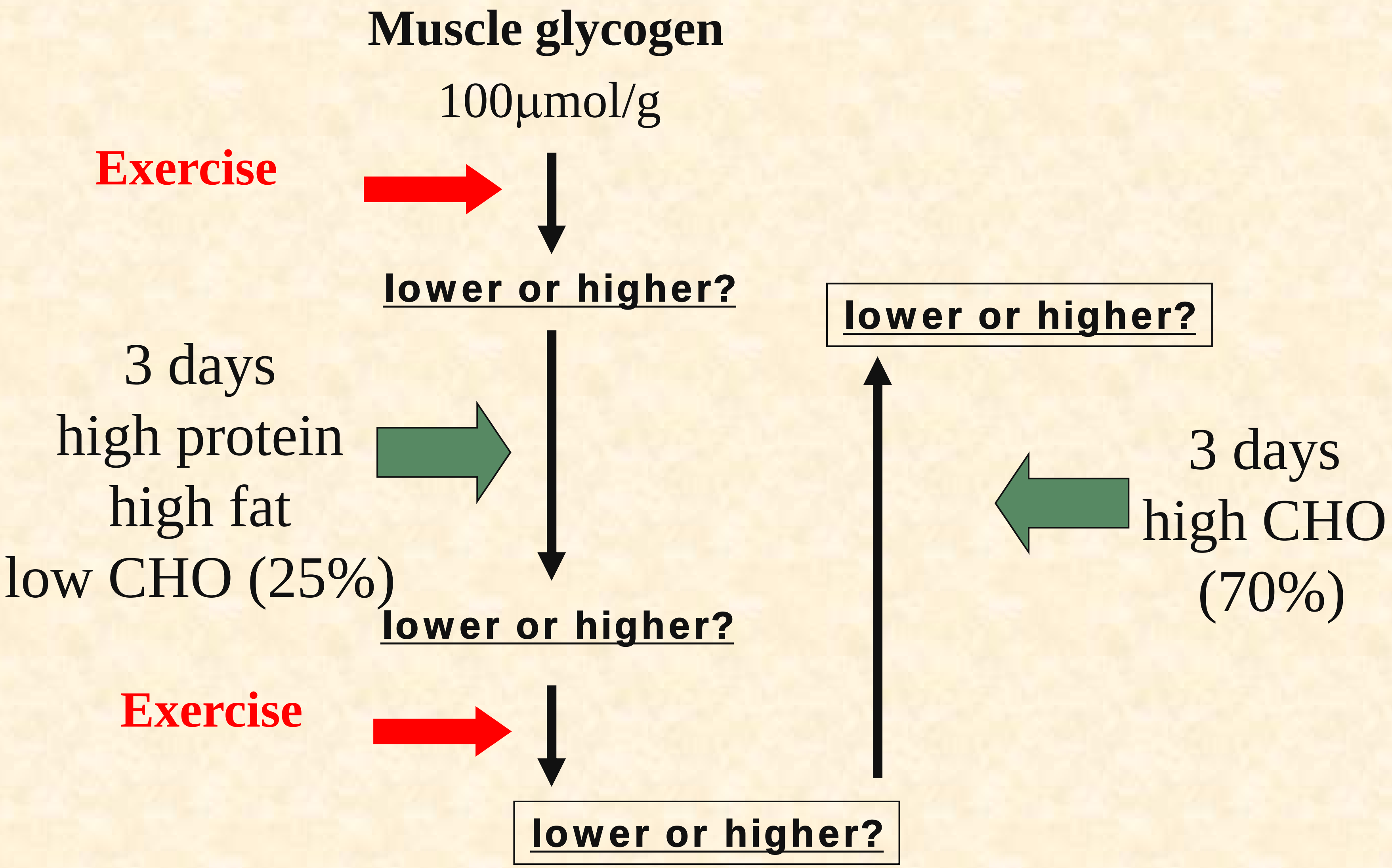
CHO Dietary manipulation for events

- $[\text{glycogen}]_{\text{muscle}}$ determines how long you can exercise at a particular intensity
  - Increase glycogen and run for longer or ↑ intensity

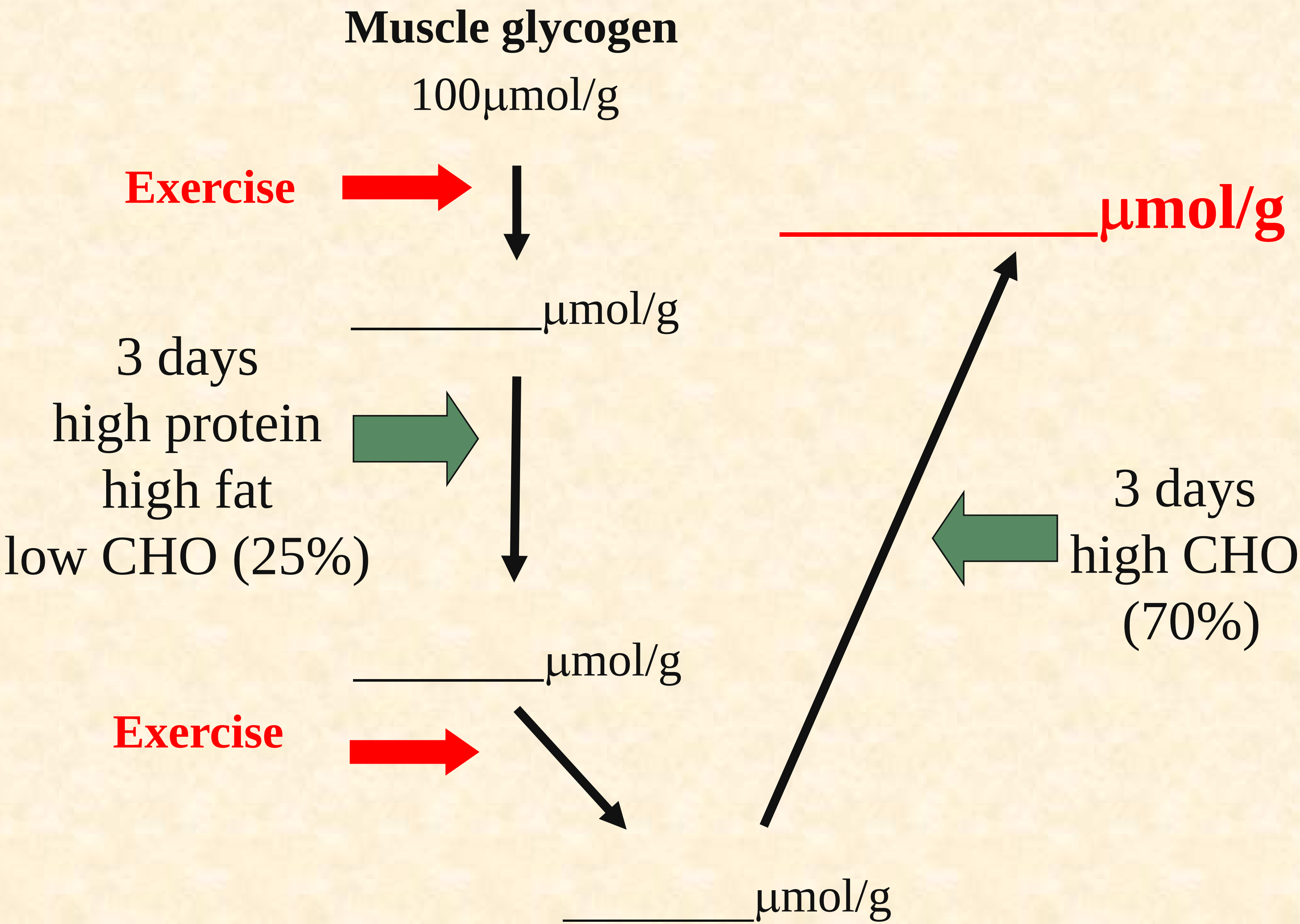
- carbohydrate loading
  - depletion of muscle glycogen
  - followed by high CHO diet
  - result is above normal glycogen recovery

Extreme carbohydrate loading

Effect on glycogen relative to previous measurement



Extreme carbohydrate loading



Extreme carbohydrate loading

Muscle glycogen

100µmol/g

Exercise

<20µmol/g

3 days
high protein
high fat
low CHO (25%)

~40µmol/g

Exercise

<15µmol/g

3 days
high CHO
(70%)

205µmol/g

Modified carbohydrate loading

- Day -7: hard training bout (depletion)
- 3 days
  - 50% CHO diet balanced diet
  - moderate training
- 3 days
  - 70% CHO (approx 10g/kg body weight, ~700g)
  - decreasing training
- RACE at > 200μmol glycogen /g muscle
  - Higher than starting (~ 100μmol glycogen /g muscle)

✓ Carbohydrate for events

- glycogen depletion = fatigue
- CHO loading gives ↑ glycogen stores

- carbohydrate ingestion during event
  - maintain blood glucose
  - liver glucose output ↓ and liver glycogen spared

- Liquid: benefits CHO feeding and hydration

CHO and fatigue

✓ Carbohydrate for events

- Drinks during event prolong endurance in long-distance events (>45min) before fatigue
  - high CHO drinks continuously at the start of exercise
  - must be taken **before** fatigue is reached
  - benefit at 30-60g/hr
  - sports drink (4-8 % (w/v) CHO) 400-850 ml/hr
  - but not CHO at >15-20% as gastric problems result
  - lower [CHO] promote gastric emptying and hydration
  - training to accept volumes

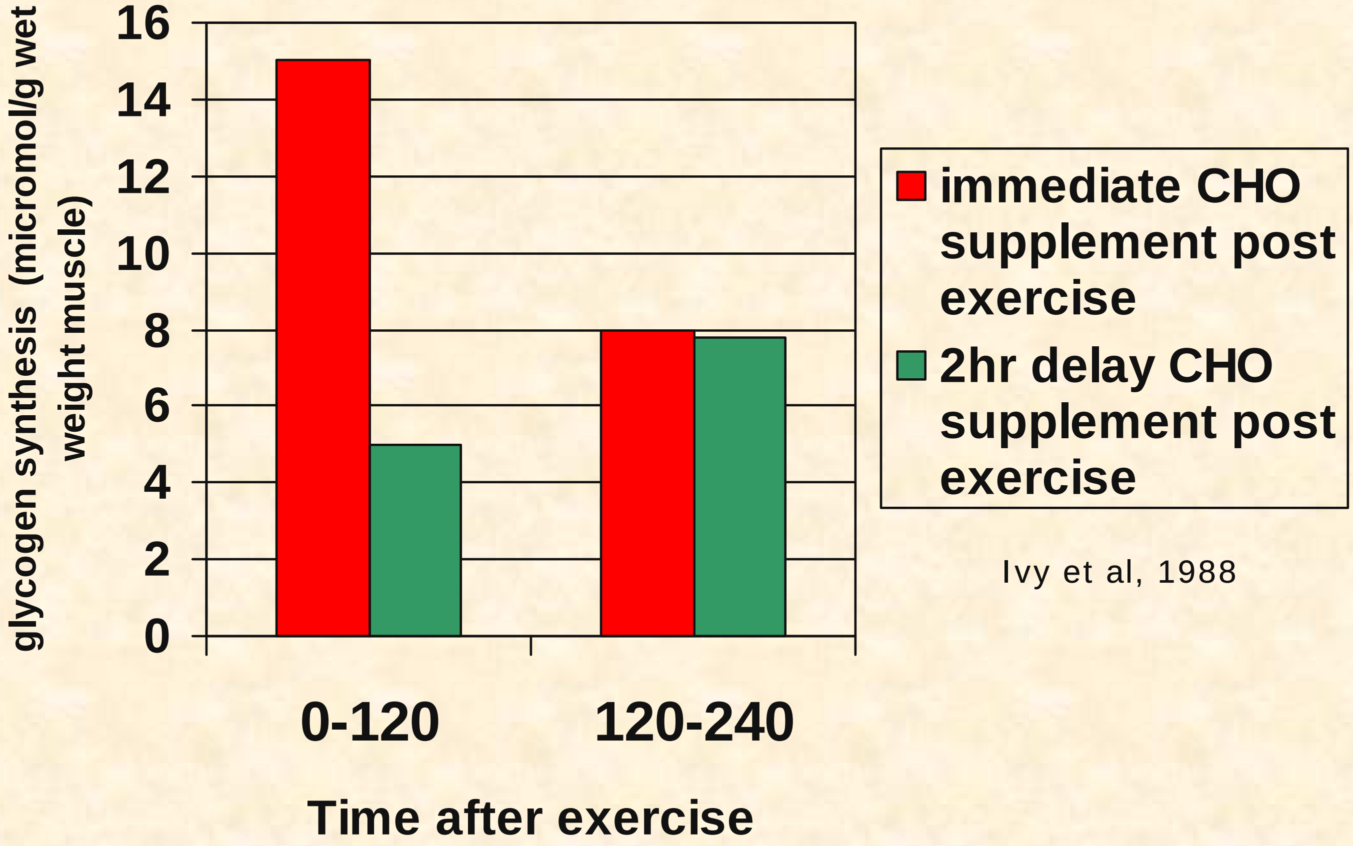
✓ Carbohydrate for events

- carbohydrate just before exercise may produce large insulin response
  - **insulin "rebound"**
    - ➔ tendency to hypoglycaemia — low glucose
    - ➔ ↓ lipolysis — low serum fatty acid
  - **an individual effect**
- cyclist have pre-race CHO-rich meals/drink
  - 2-4 hours before race
  - > 200g
- Start intake in long events immediately at the start of exercise

✓ Carbohydrate and recovery

- CHO drinks are potentially important in recovery
- Promote glycogen recovery and hydrate
- Glycogen re-synthesis maximal with ingestion of CHO at ~100g/hr (1.5g/kg body weight)
  - Recommended to do this within 30min of exercise
  - Then repeat every 2 hours for 4-6 hours
- Sodium is also beneficial
  - Better to use drinks with high Na levels (60-90mmol/l)
  - relative high sodium allows better hydration
- Tolerance is individual specific

✓Carbohydrate and muscle glycogen recover



Ivy et al, 1988

If CHO (2g glucose/kg body weight) is given immediately after exercise recovery of glycogen is enhanced.

✓ Energy nutrients -summary

- high dietary CHO requirements
  - 50-70% energy is CHO
  - Allows training to be done
  - Complex CHO are best but not always used
- Dietary regimes are used to
  - Maximise CHO before events
  - Maintain CHO in exercise (benefits hydration)
- Fats
  - lower than sedentary individuals in most sports

✓ Essential replacement of CHO

- Sedentary individual 10.5 MJ/day

- Tour de France
  - average expenditure 25.4 MJ/day intake 24.7 MJ/day
  - peak expenditure 32.7 MJ/day intake 32.4 MJ/day
  - average metabolic power at 1100 W over 6 hours

- 24 hour cycle race
  - 43.4 MJ/day

Energy expenditure and intake

Tour de France what would you recommend?

- Is the exercise at one intensity?

  high intensity | low intensity | variable intensity

- What substrates are they using to exercise ?

  Protein | CHO | Fat

- What becomes depleted ?

  Protein | CHO | Fat

- What do they need to eat a lot of ?

  Protein | CHO | Fat

- What is the likely glycaemic index of there meals ?

  low or high

Tour de France - nutrition

- Spend 4-6 hours on the bike
- not all high intensity - fat oxidation
- eat whilst compete
- CHO availability must be maintained

Tour de France - nutrition

To maintain CHO availability

- Continuous CHO drinks
- High CHO intake (~ 1kg)
  - High glycaemic index
- 60% of intake is on the bike
- Any mismatch of intake to expenditure
  - ↓ weight = ↓ ability to compete

✓ Protein

- Do athletes need more protein?
  - Both endurance and power events do
- Both "strength/power" and endurance athletes probably need about < 2 x recommended intake (range 1.2-1.8 g/kg body weight/day)
- Primarily because of increased muscle protein turnover
- Should be matched from the diet
  - but in power events is often supplemented
  - believed certain amino acids stimulate growth (arginine, ornthine and branched-chain amino acids)

✓ Iron

- Studies indicate that female endurance atheletes are iron-deficient
- vegetarian athletes at risk
- Probably a combination of factors
  - Bioavailability
  - menstrual losses
  - some loss in sweat
  - some gastro-intestinal loss (particularly if on aspirin containing pain-killers)
- iron supplements only considered where proven iron deficiency

✓ Vitamins and minerals

- Deficiencies can occur and will cause a decline in performance
  - Concerns over oxidative stress

- BUT supplementation of vitamins and minerals is generally not required as long as balanced diet is followed (increased energy demand)
  - potential deficiency should be shown first
  - Only special conditions are likely to require supplements

- Potentially over supplementation can be toxic
  - vitamin E

Summary

- The type of exercise will dictate the metabolic demand
  - Dependence on energy demand
- Determining what type of metabolism is being used will dictate what nutrients are required.
  - Dependence on oxygen

- Manipulation of diet can enhance performance but also allows training to be done effectively

BUT ability and doing the training are the main determinants for how good you are

Adequate nutrition will support performance

Do a version session with the selector

Nutrition & Sport

- **Enhanced Nutrition or is required for which component of an athletes activity?**

  Power events ; training the event

  Endurance; training the event

- **Which nutrients are used for energy production and which is the most important in sports exercise?**

  Proteins Fats CHOs vitamins minerals water

- **In the short term, an inadequate intake of which nutrients will have the greatest effect the ability to train?**

  Proteins Fats CHOs vitamins minerals water

- **Which of the following are likely to become depleted after prolonged training session?**

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- **Which nutrients do athletes usually focus on during immediate recovery from exercise?**

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- **Of which of the following will a 2% drop in body content (resting state) have a significant effect on performance?**

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✓Nutrition & Sport

- Which vitamins and directly involved in metabolism associated with energy production

  Folic acid Thiamine Riboflavin Vit E Vit C Niacin Vit D Biotin

- Which type of energy metabolism would you expect to generate the largest quantity of free radicals

  Anaerobic Aerobic

- Which vitamins are associated with protection from free radical damage

  Folic acid Vit E Thiamine Riboflavin Vit C Niacin Vit D Biotin

- Low intakes of which micronutrients are more likely in a vegetarian athlete?

  Riboflavin Fe Vit A Vit B_{12} Ca Vit C Vit D Na Zn K

- Which single mineral is of most concern for vegetarian women athletes?

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