"The theory and practice of getting fitter and stronger"

David Docherty, PhD,
Professor Emeritus
School of Exercise Science, Physical and Health Education
University of Victoria

Four part series

1. Developing aerobic (cardiovascular) fitness (March 3rd)
2. Developing strength and muscular endurance (March 10th)
3. Developing the core or back stability (March 17th)
4. Effective warm up and developing flexibility (March 24th)

- All the presentations are accessible at:
- https://onlineacademiccommunity.uvic.ca/elderacademy/

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Developing the Energy Systems

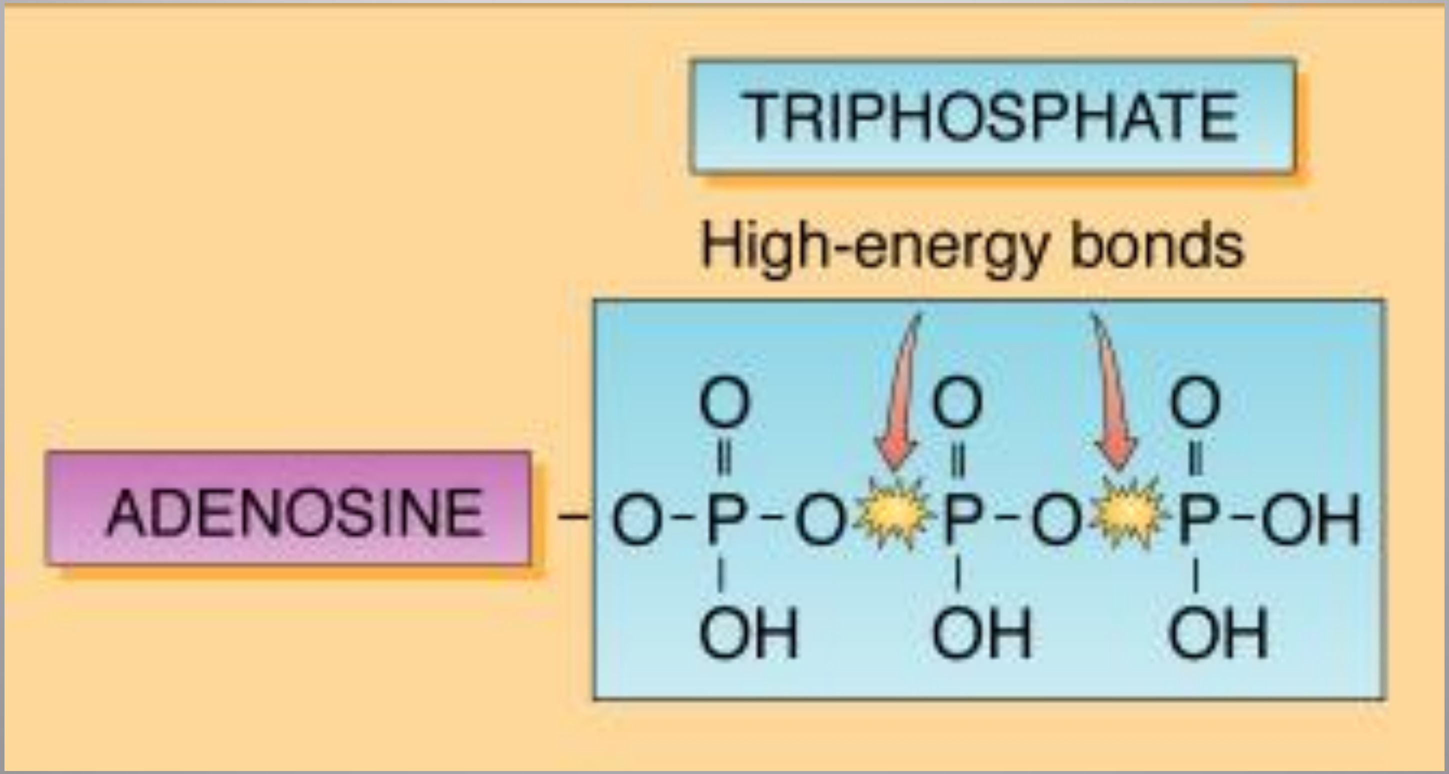
David Docherty

With special thanks to Ben Sporer, Howie Wenger, and Lynneth Stuart-Hill.

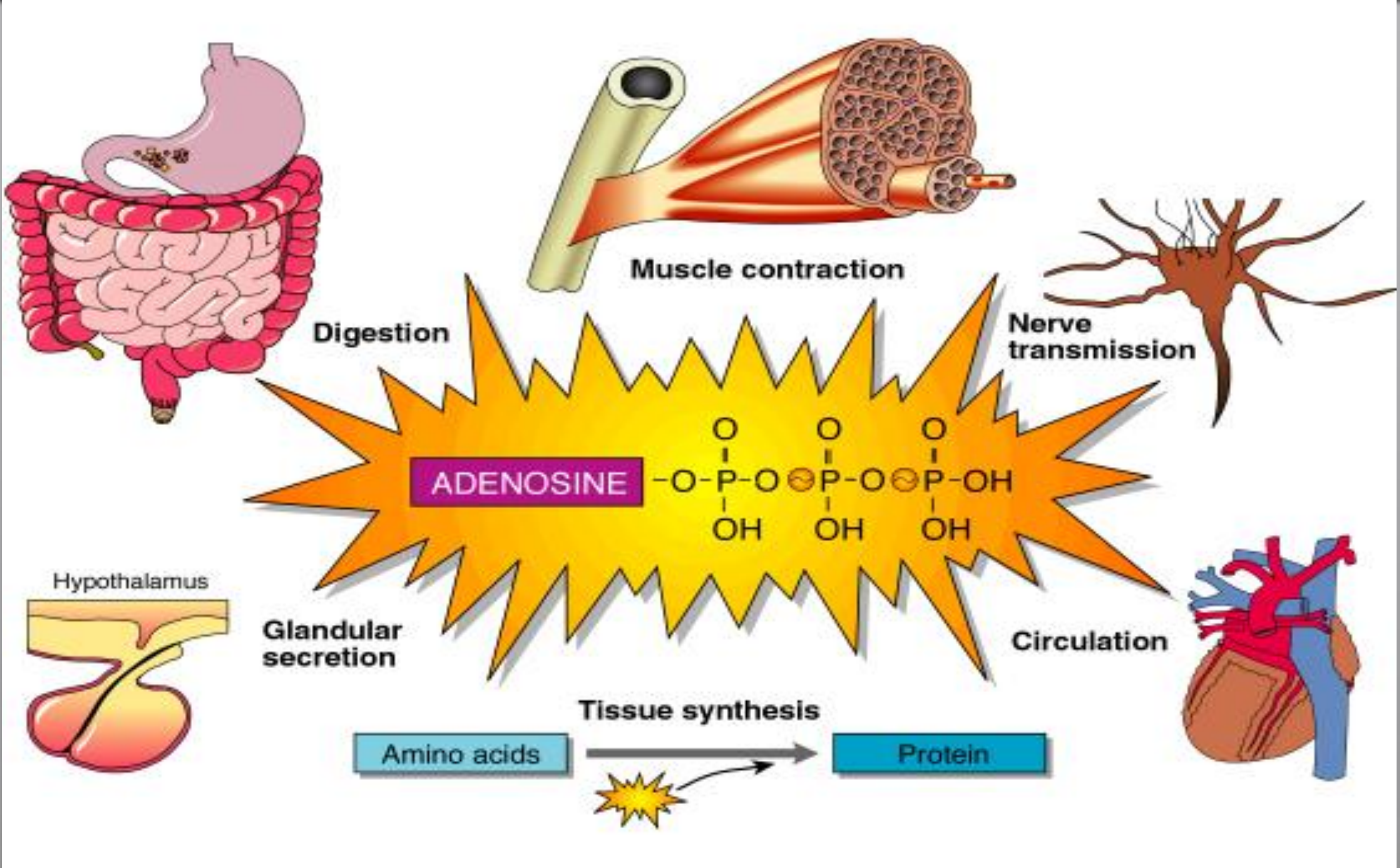
What is Energy?

Capacity for doing work

ATP – Human Energy

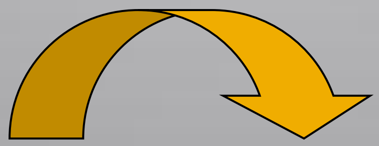


Why do we need ATP?



So.......when **ATP** is used to do cellular work
the products are ADP + Pi which must be re-converted to ATP if work is to be continued.

These conversions are called



PHOSPHORYLATIONS

Energy Systems

- Regeneration of ATP is what the energy systems are all about
- There are 3 energy systems to regenerate ATP:
  - ATP-CP system (Alactic system)
  - Anaerobic glycolysis (Lactic system)
  - Aerobic system

Energy Systems

- ALL ATP used for movement is regenerated from one of these systems
- all movement can be classified into one or a combination of these systems

The three energy systems differ in the rate and amount of ATP that can be resynthesized referred to as:

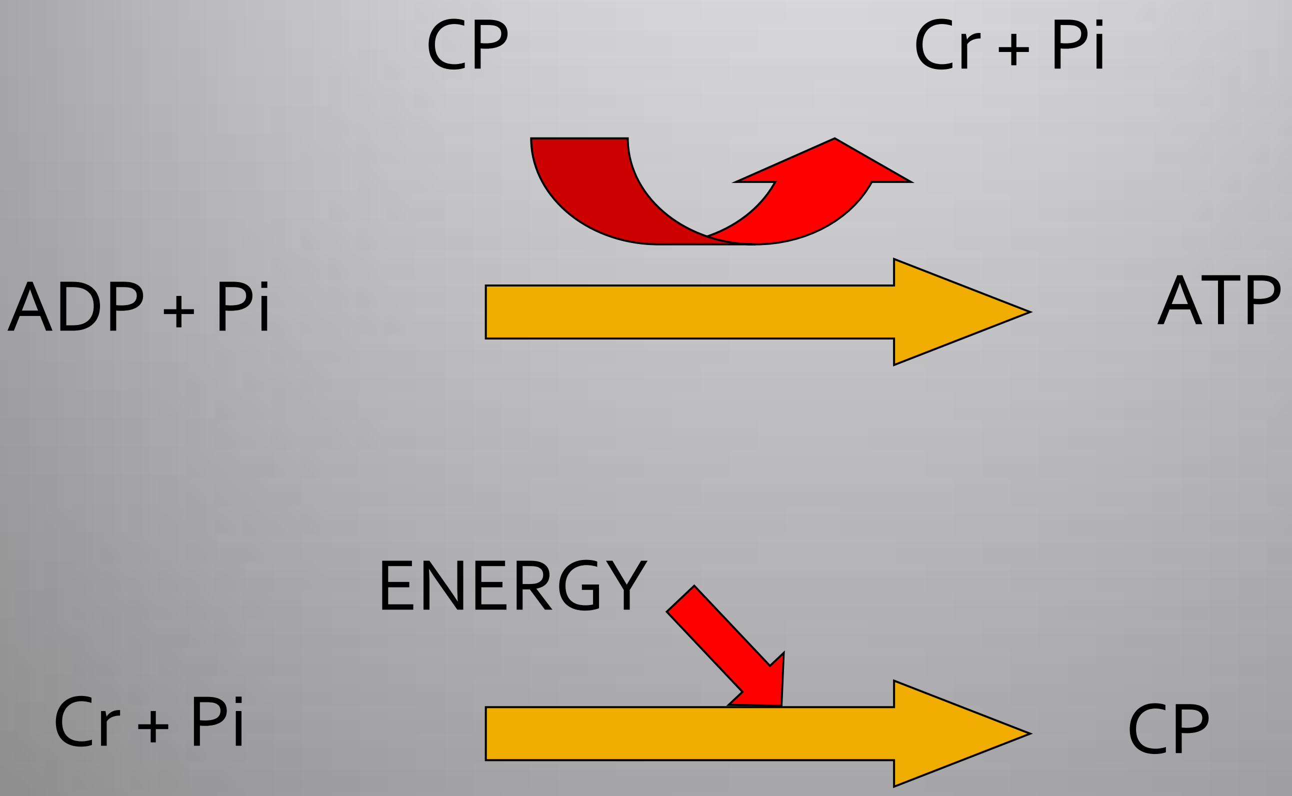
POWER = the **rate** at which ATP can be produced

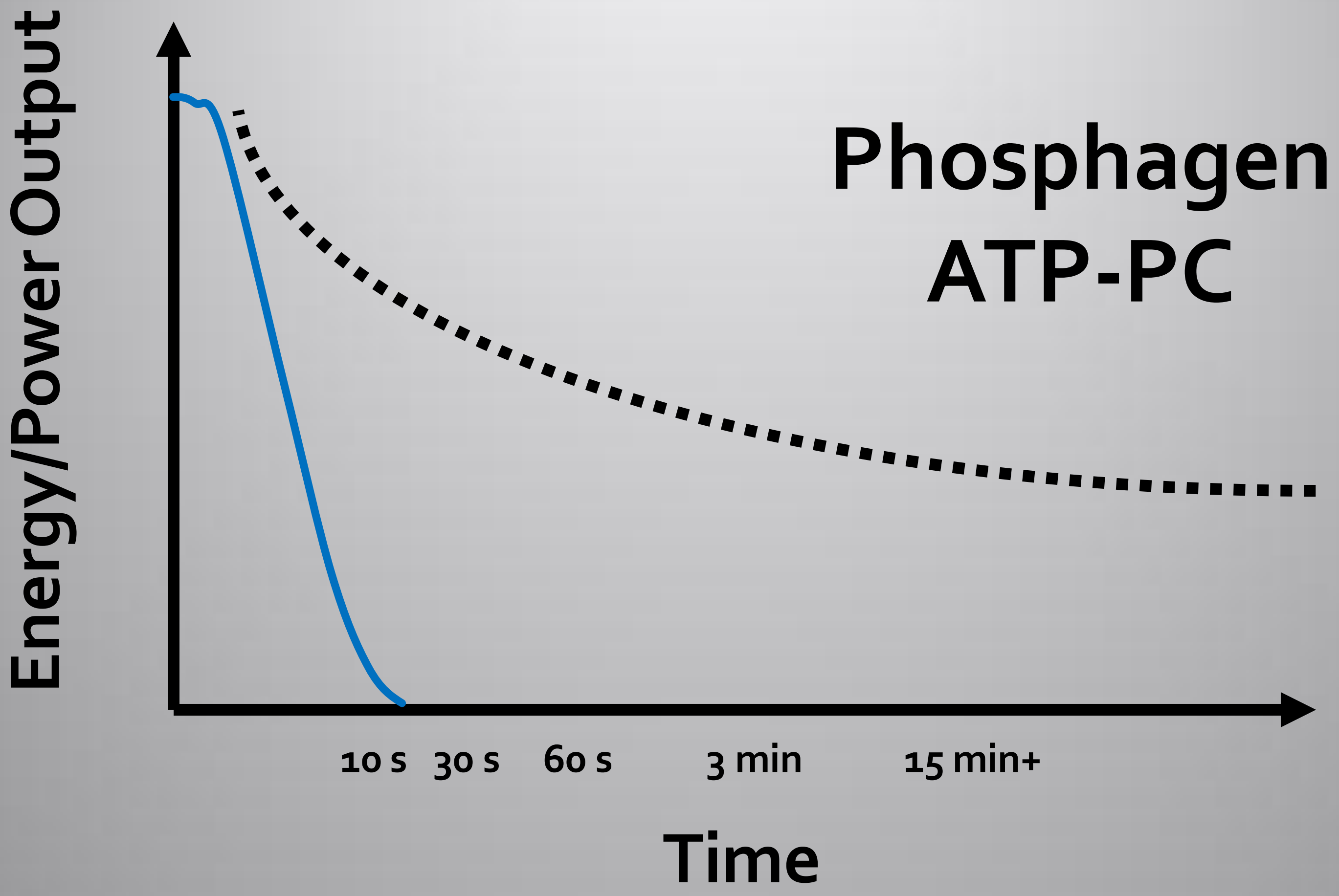
CAPACITY = the **total** amount of ATP that can be produced

ATP – CP System

- muscles store some ATP for immediate use
- muscles also store creatine phosphate, CP
  - sometimes called phosphocreatine, PCr
- CP is a “high-energy phosphate” that can be used to quickly regenerate ATP from ADP and Pi
- this system is important in high energy, short duration events
- the amount of [CP] in the cell is 4-6X greater than [ATP]

ATP – CP System





- Very high power
- Very low capacity
- Time to peak power (ms)
- Peak power & capacity (~7 – 10s?)

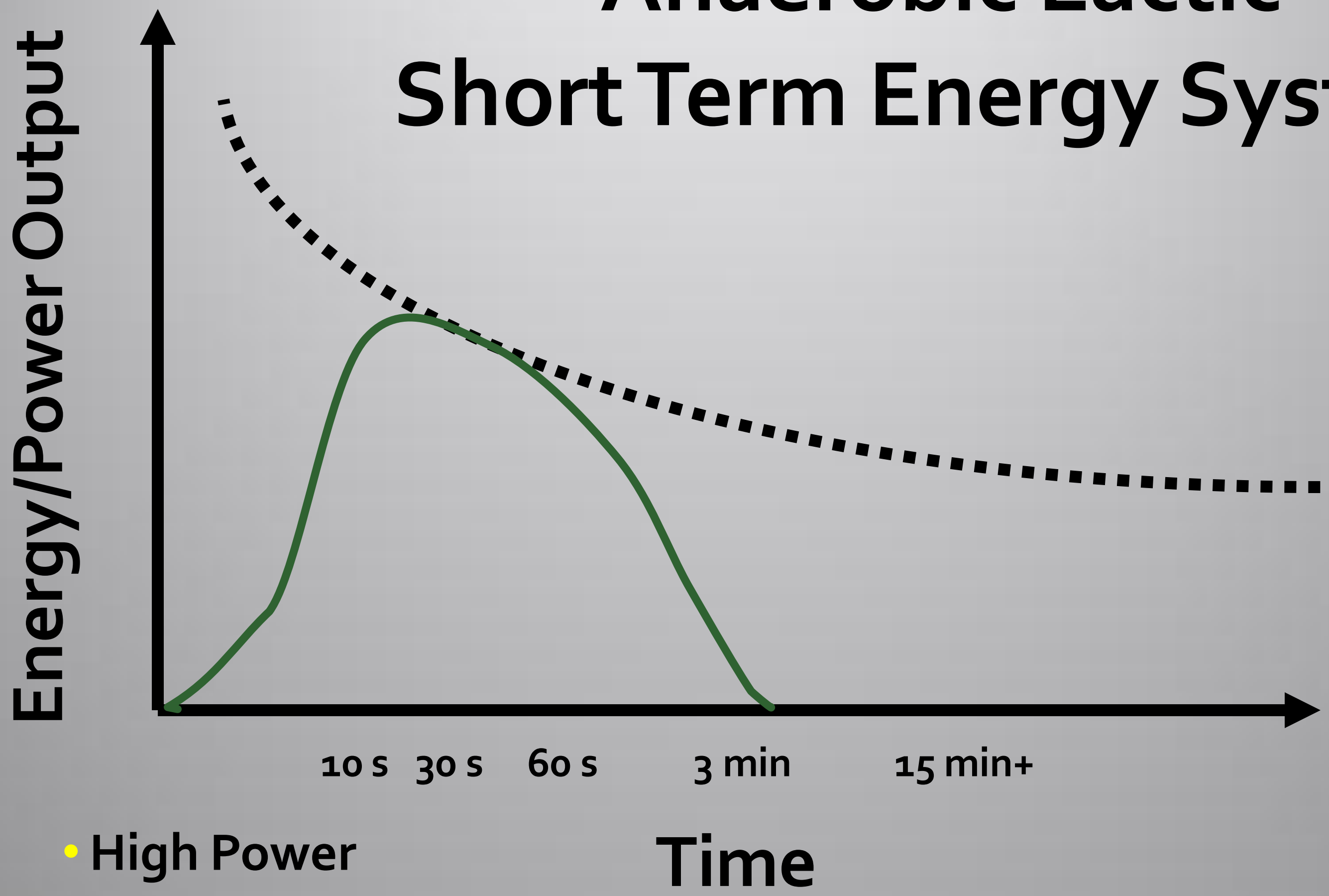
Anaerobic Lactic System (Anaerobic glycolysis)

2 challenges for this system:

1. very inefficient (2 molecules of ATP / glucose used)
2. produces lactic acid as a by-product that reduces ability to perform work (burning feeling in muscles)
3. Requires 12 steps to create ATP (therefore slower than ATP-CP system but creates more ATP)

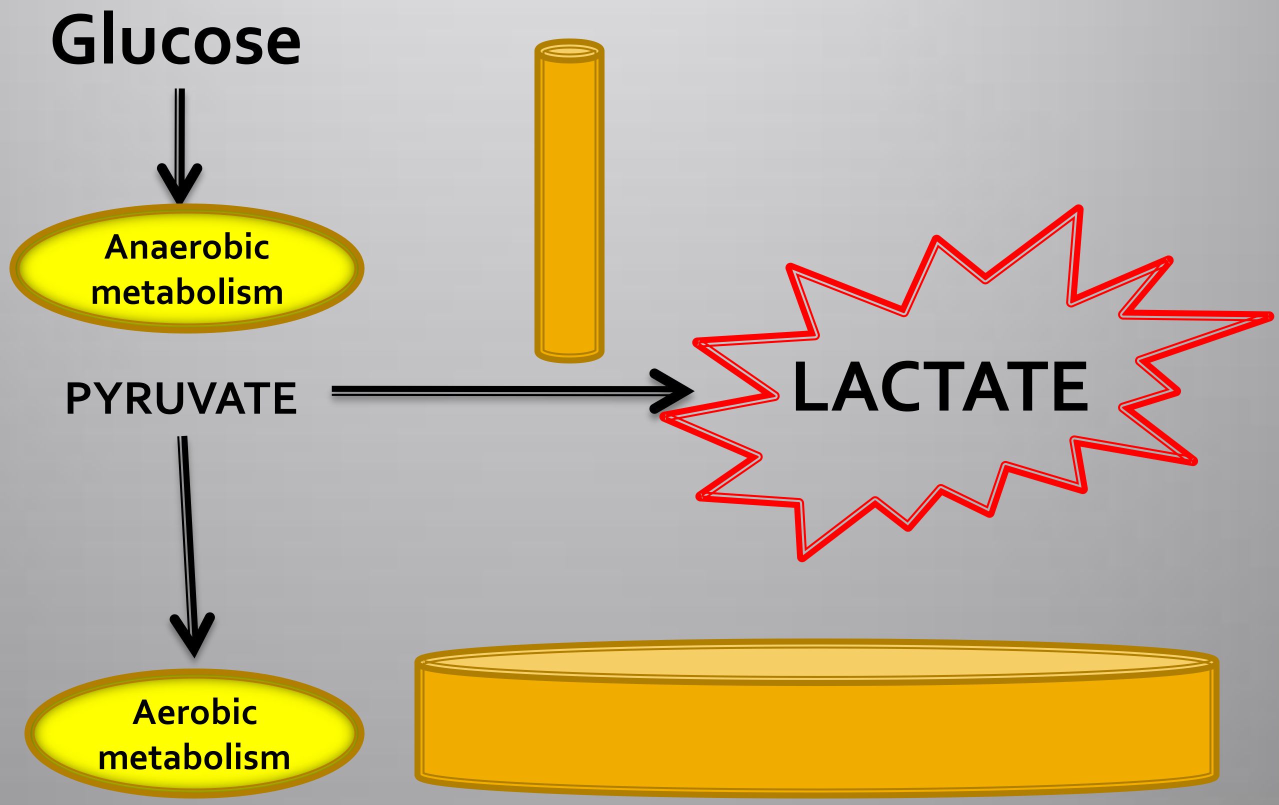
- this system *only uses carbohydrate* as fuel
- Where does the carbohydrate come from?
  - muscle glycogen, blood glucose, liver glycogen.

Anaerobic Lactic
Short Term Energy System



- High Power
- Limited Capacity
- Time to peak power (~8s)
- Peak power (~40 – 70s)
- Power capacity (~90 – 120s)

Anaerobic -> Aerobic???



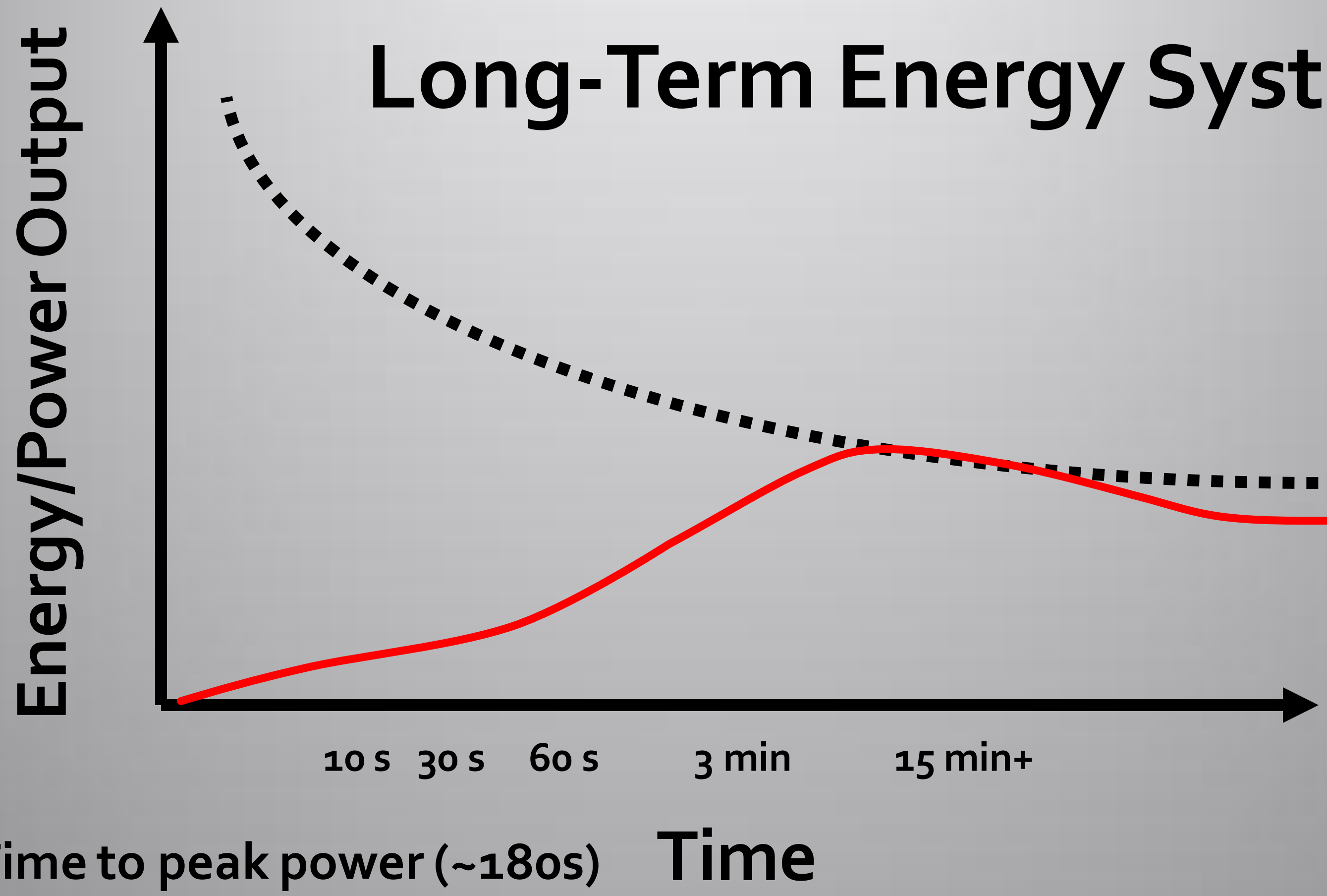
Aerobic System

- after 1 – 2 min exercise, the anaerobic systems cannot “keep up” with the energy demands of the muscles → need a more efficient system
- when **oxygen** is freely available to the muscle cells:
  - all food types (fat, carbohydrate, proteins) can be oxidized to carbon dioxide and water to produce energy
  - this process produces 36 molecules of ATP / glucose molecule
  - waste products are CO_2 and H_2O.

Aerobic System

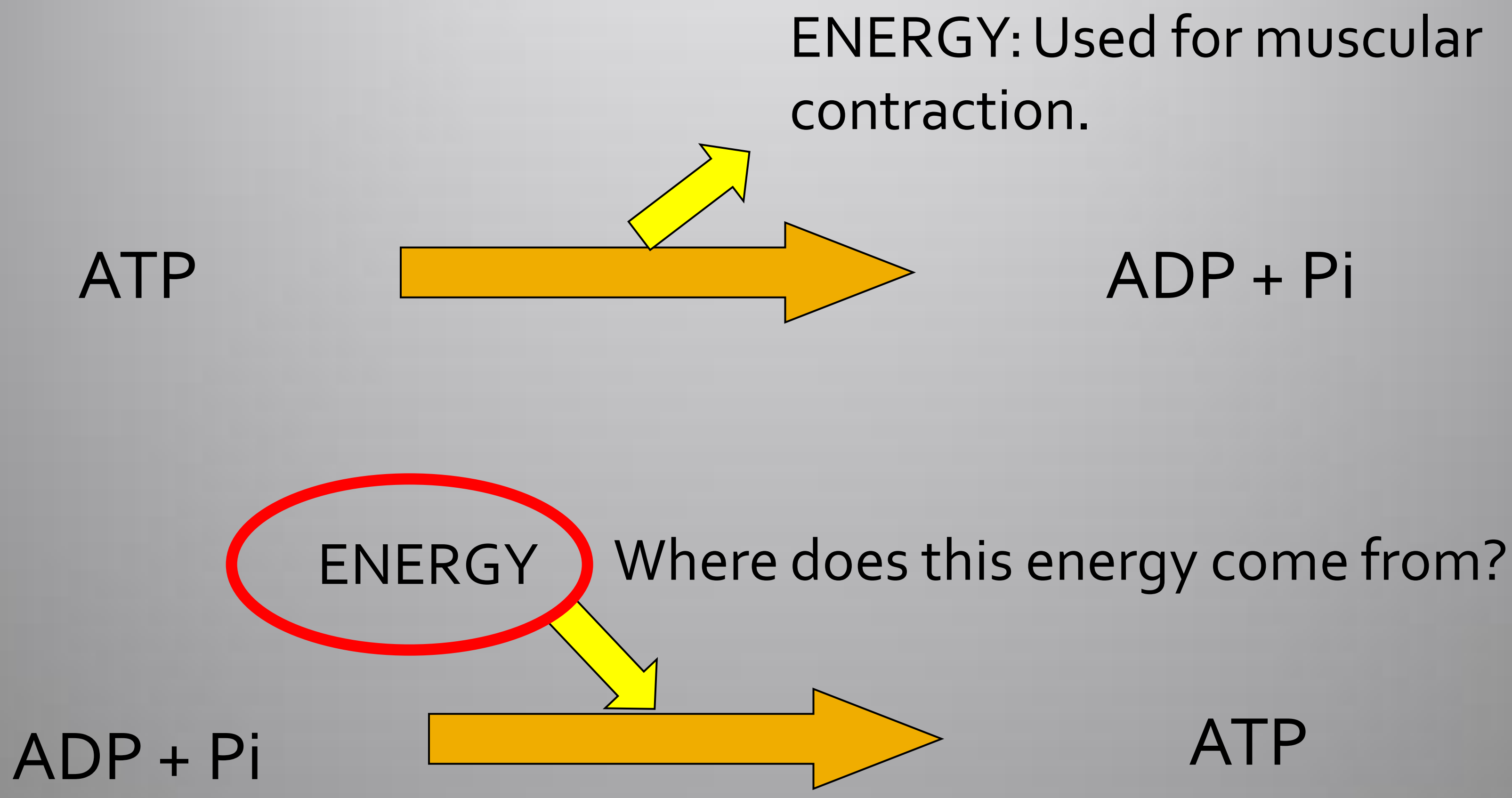
- BUT: What is the problem?
  - problem is the delay in getting oxygen to the muscle cells (otherwise the aerobic system could be used right from the start of exercise). It takes about 30 chemical reactions to produce the ATP.
- SO: you can see the link between cardiovascular fitness & aerobic fitness:
  - need to move large amounts of oxygen to the muscle cells quickly: requires a strong aerobic (CV) system

Aerobic
Long-Term Energy System

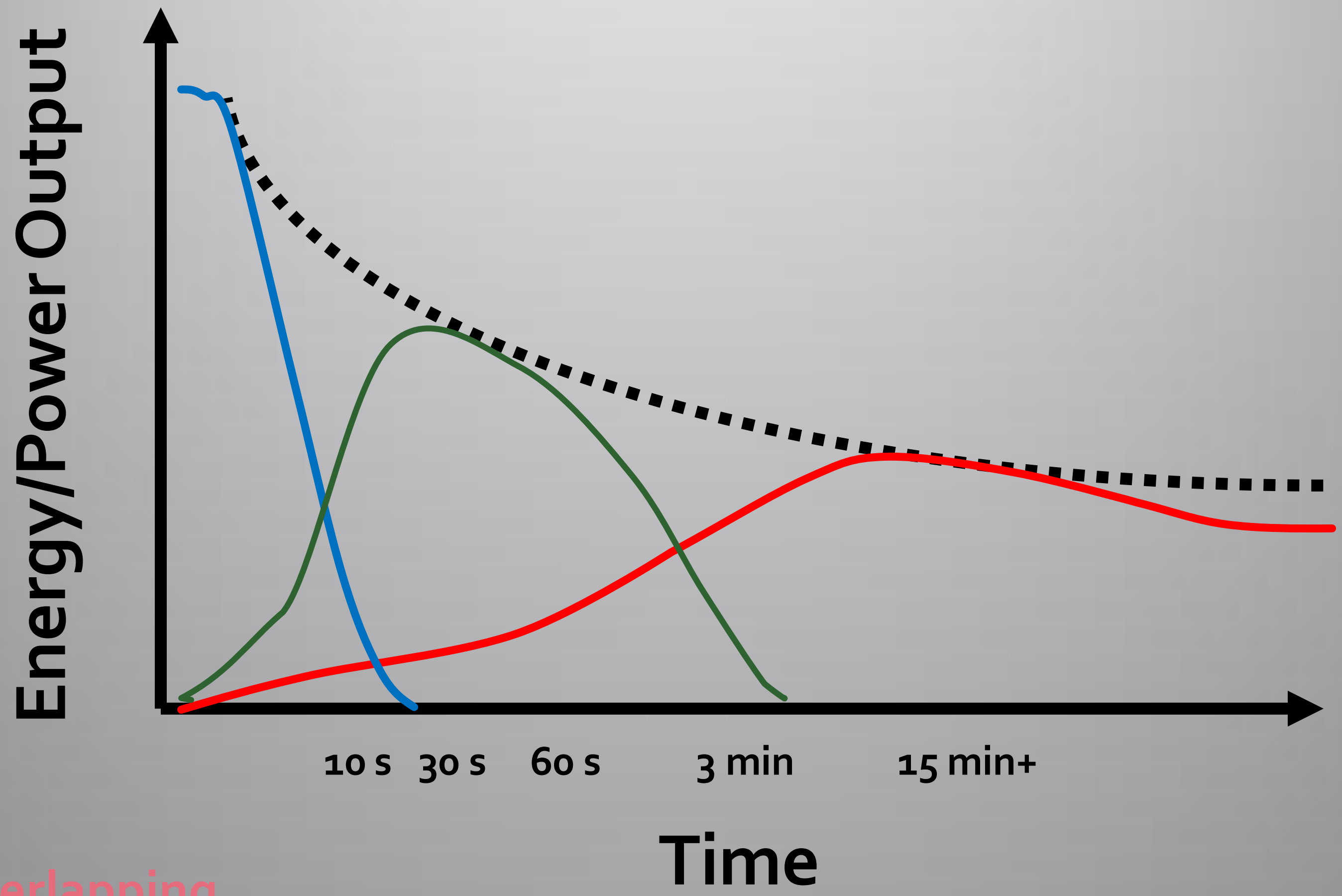


- Time to peak power (~180s)
- Peak power (~3 – 5min)
- P Low power
- Very high capacity
- lower capacity (extensive / hours)

Bioenergetics Simplified

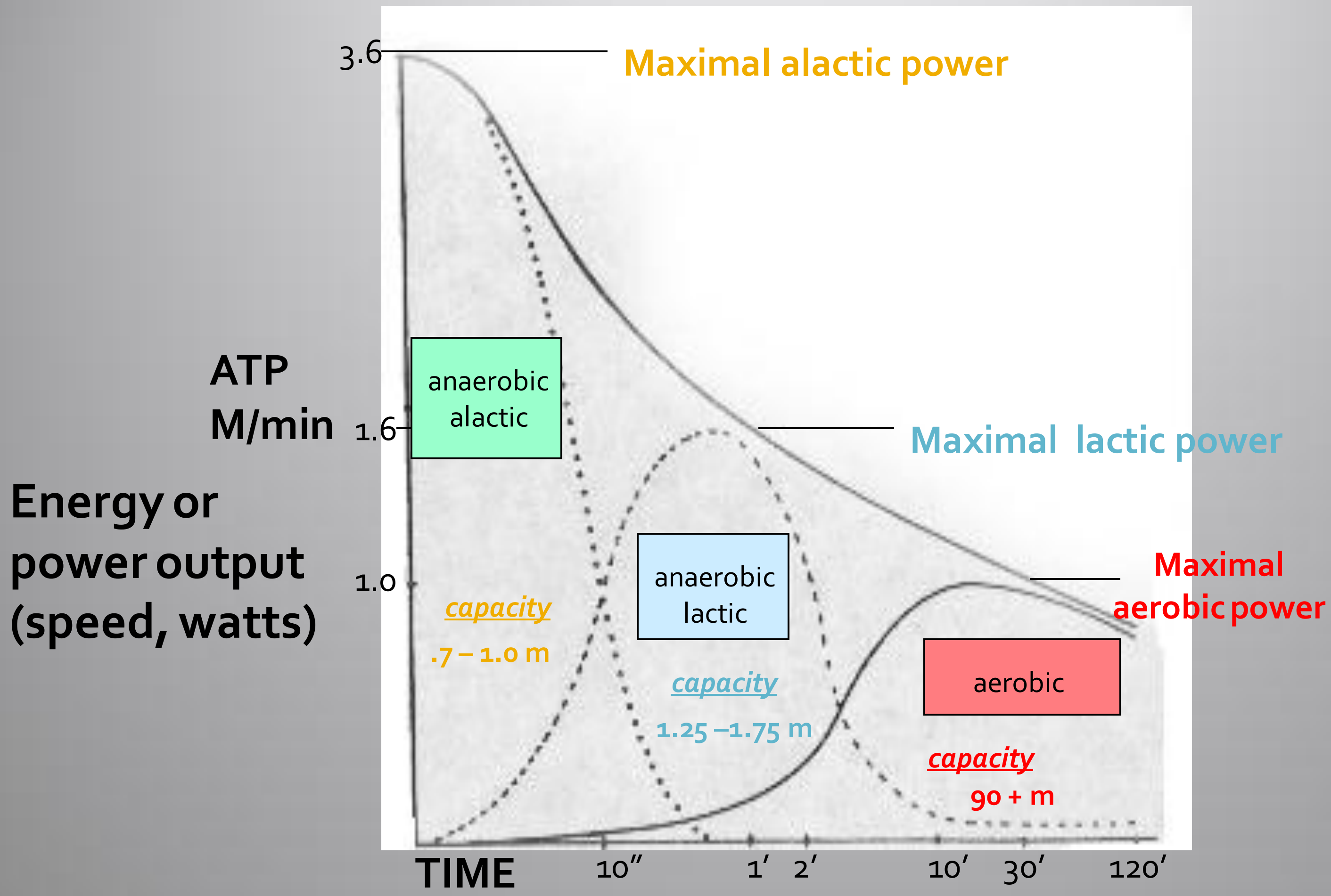


Energy System Continuum



• overlapping
• rarely independent but at times dominant

THE ENERGY SUPPLY CONTINUUM



Adapted from
Howald et al. 1978

Training the energy systems

Specificity of Training

- For design of training session, consider...
  - the energy system utilized
  - the type or mode of activity
  - muscle recruitment pattern
  - work:rest/recovery ratios
  - range of motion
  - etc.

Measuring Exercise Intensity

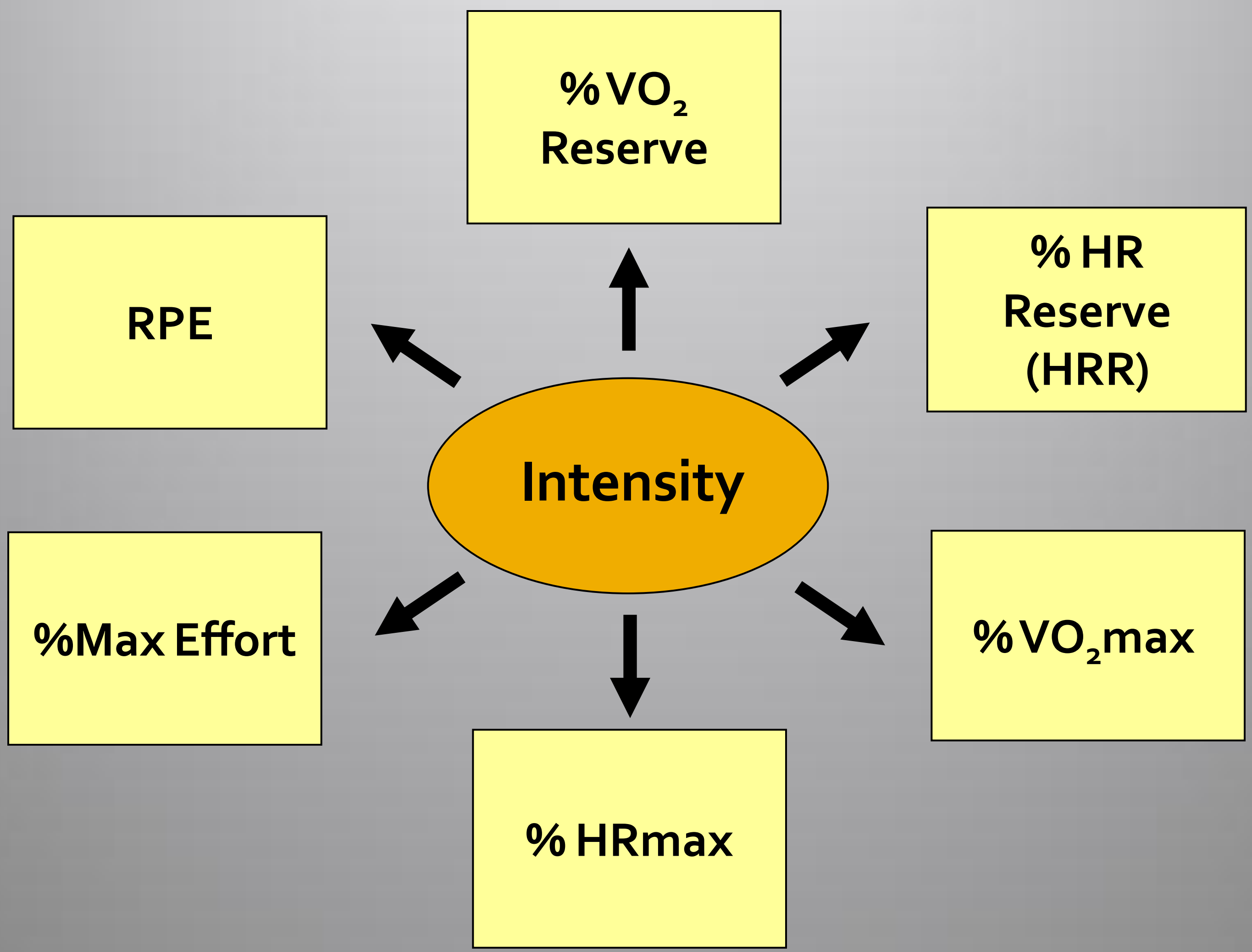
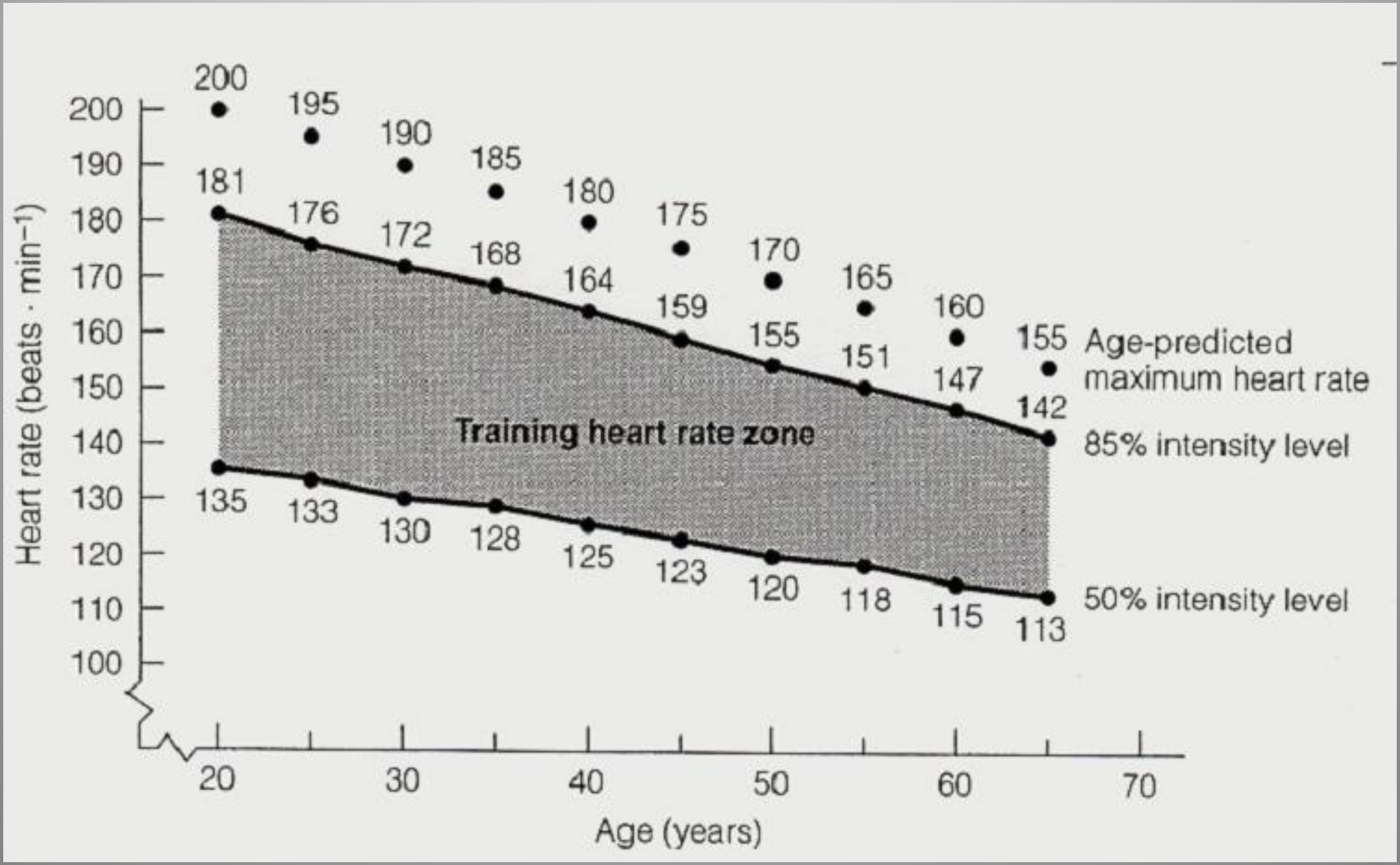


TABLE 8.5 Perceived Exertion Category Scales

Fifteen-Category RPE Scale		Category-Ratio RPE Scale	
Light Intensity			
6	No exertion at all	0	Nothing at all
7	Extremely light	0.5	Very, very weak (just noticeable)
8			
9	Very light	1	Very weak
10		2	Weak (light)
11	Light	3	Moderate
Moderate Intensity			
12		4	Somewhat strong
13	Somewhat hard	5	Strong (heavy)
14		6	
Vigorous Intensity			
15	Hard (heavy)	7	Very strong
16		8	
17	Very hard	9	
18		10	Very, very strong (almost max)
19	Extremely hard		
20	Maximal exertion	•	Maximal

HR Training Zones



Remember……

- The energy sources for a given activity are time- and intensity-dependent
- Must do ***progressive overload*** by altering intensity, frequency and duration

When *progressively overloading* the energy systems you can:

- Increase the intensity of effort within the energy system
- Increase the training volume (length of time for intervals, number of reps, and the number of sets per session)
- Decrease the recovery time between reps and/or sets
- Increase/decrease the training frequency (sessions per week)

Remember........

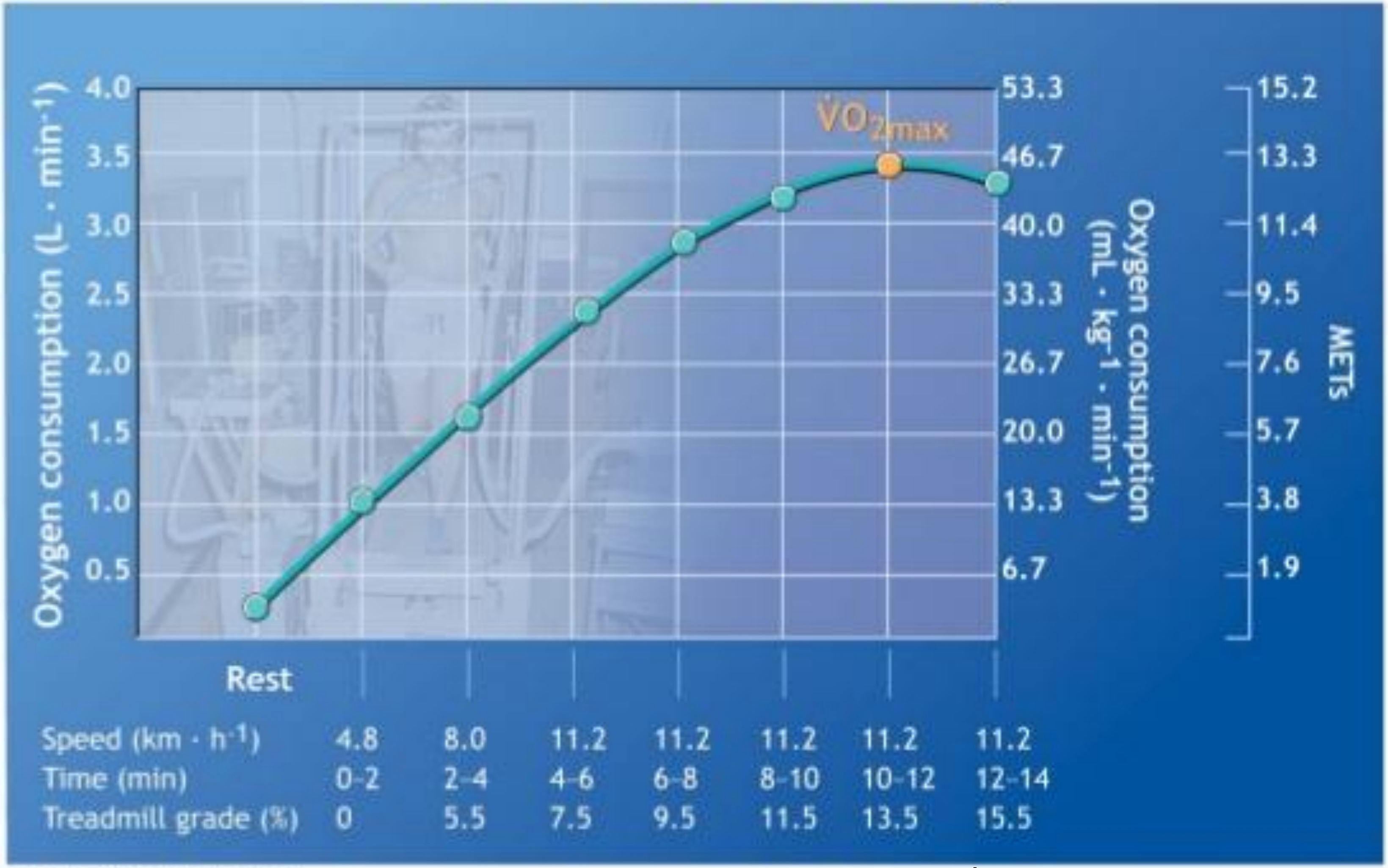
- As we keep training (or competing/ performing) the energy system that is dominant may change, especially if recovery intervals are not long enough (reflected by a drop off in intensity/power output, or effort)

Alactic --> Lactic

Aerobic Power

- **Maximal aerobic power:**
  - maximal rate at which oxygen can be taken in, transported and utilized by the body
  - key aspect; power term…rate…unit time
  - expressed as $ml.kg^{-1}.min^{-1}$ or $L.min^{-1}$

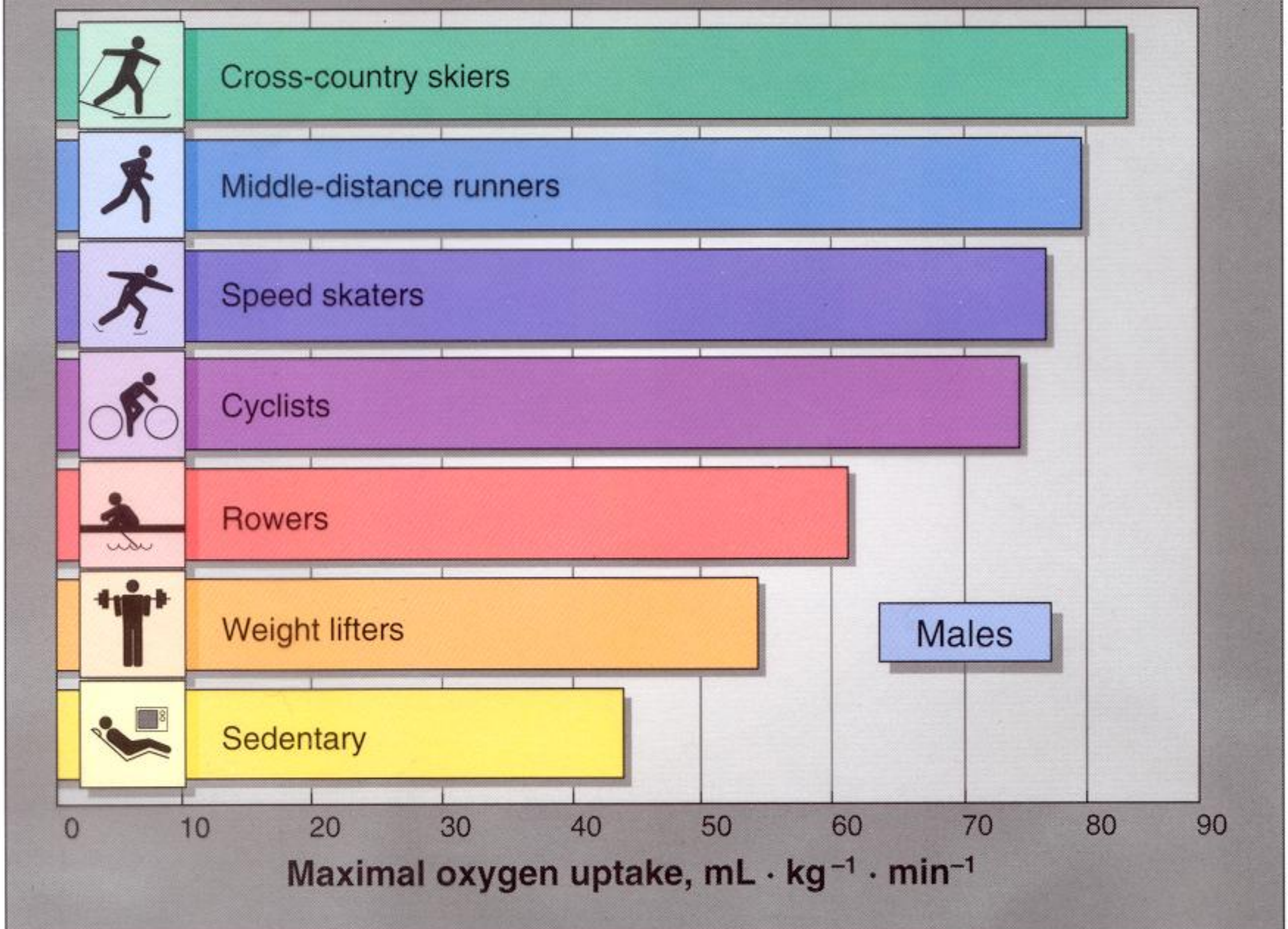
Plateau in VO_2 with increasing exercise intensity

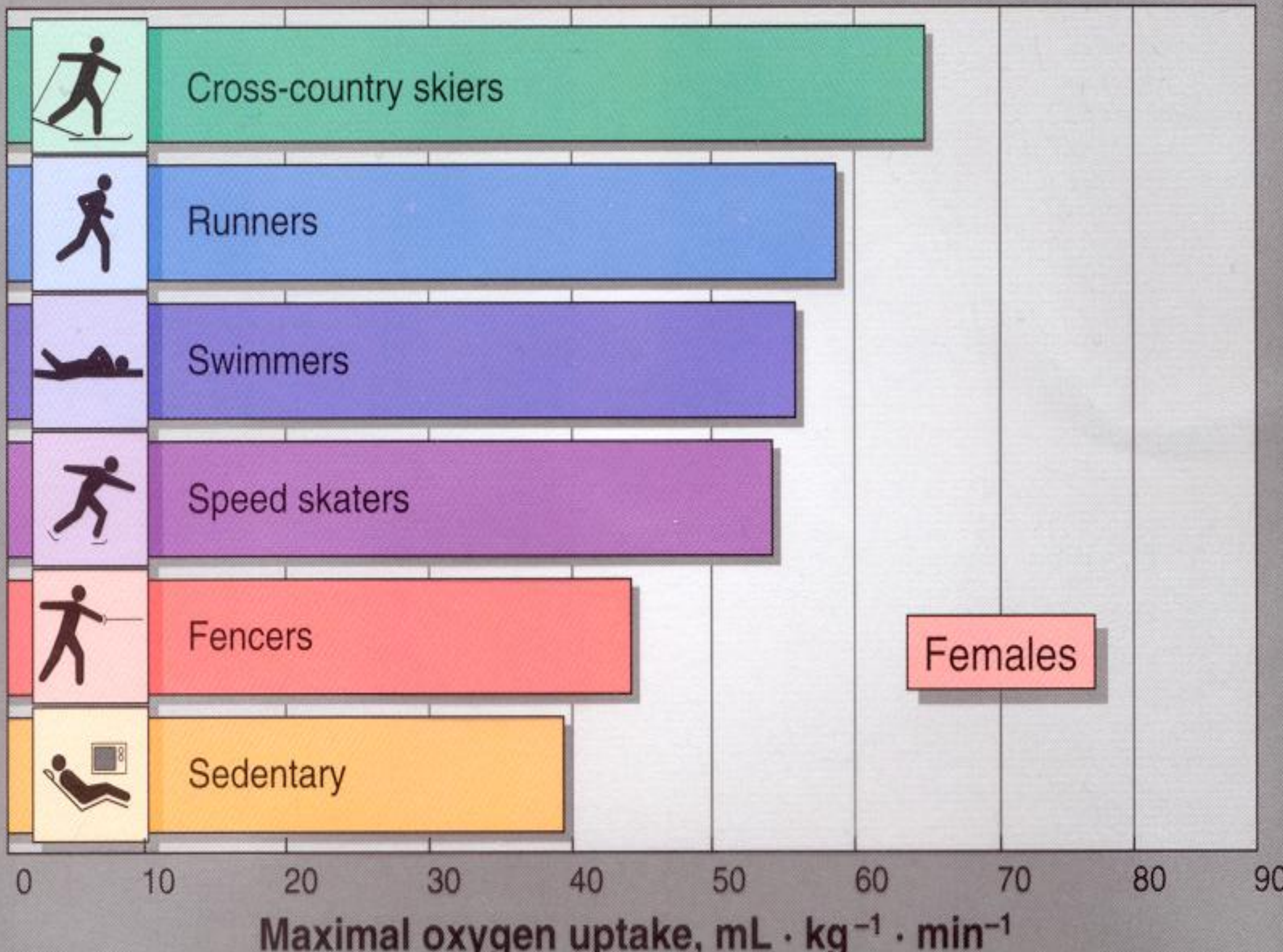


Andrew Coggan

VO2 max test for aerobic power

- https://www.youtube.com/watch?v=fn3Yr-LS_lo


Cross-country skiers
Middle-distance runners
Speed skaters
Cyclists
Rowers
Weight lifters
Sedentary
Males
0
10
20
30
40
50
60
70
80
90
Maximal oxygen uptake, mL · kg⁻¹ · min⁻¹


Cross-country skiers
Runners
Swimmers
Speed skaters
Fencers
Sedentary
Females
0
10
20
30
40
50
60
70
80
90
Maximal oxygen uptake, mL · kg⁻¹ · min⁻¹

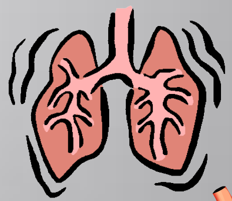
World Records

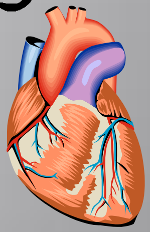
- Men – 96 ml kg-1
- Norwegian Cross Country Skiier
- Women – 78.6 ml kg-1
- 1984 Olympic Marathon Champion

K.L Harrison

Aerobic Power

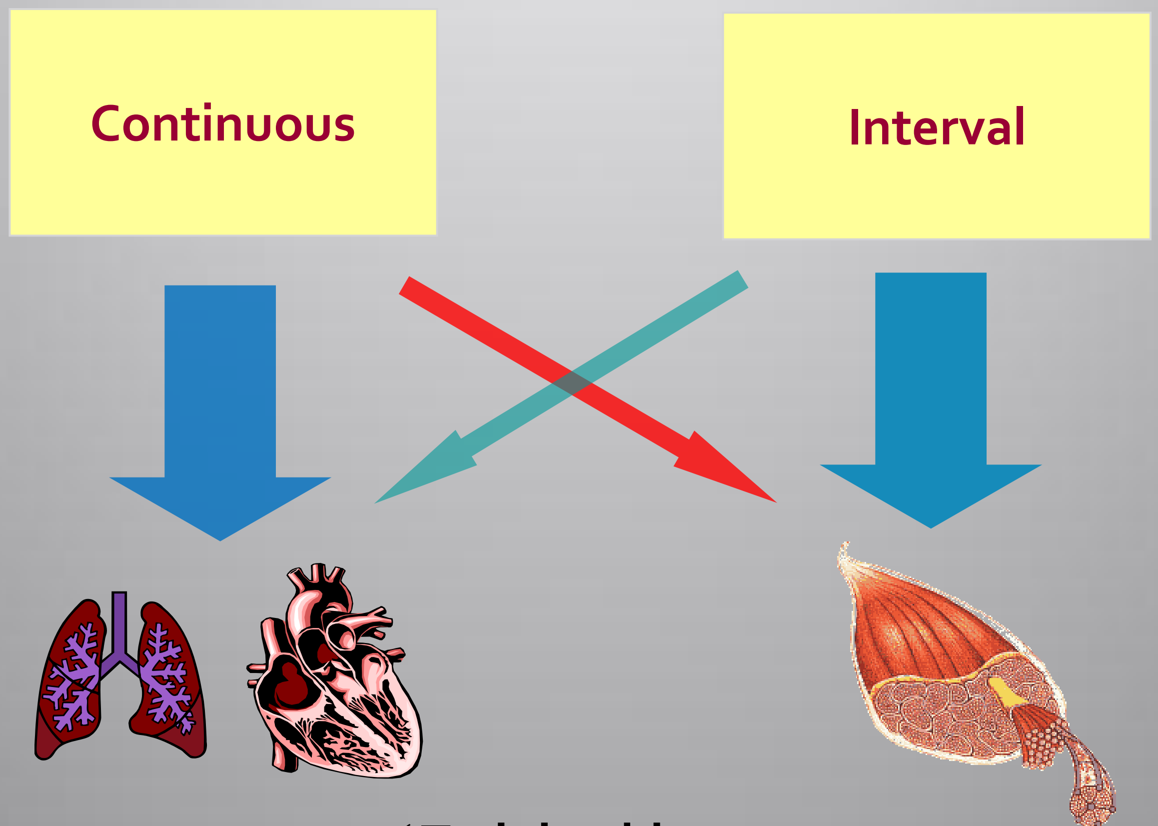
- **Central**
  - oxygen delivery depends upon maximal cardiac output (CO) and maximal arterial oxygen content





- **Peripheral**
  - ‘peripheral’ extraction of the delivered oxygen traditionally expressed as...(a-v) O_2 difference)

Training to Enhance Aerobic Energy System

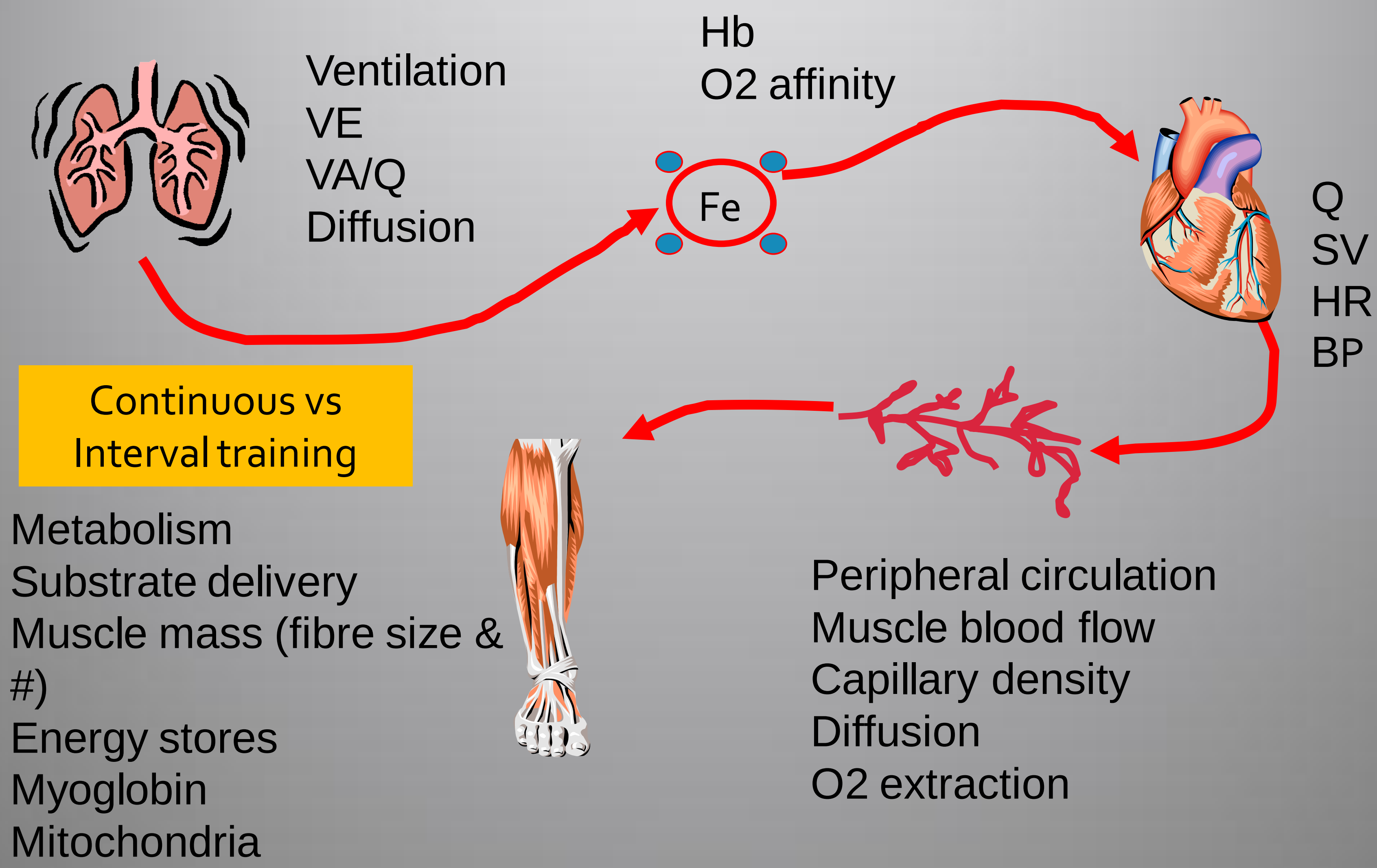


- ✓ Training history
- ✓ Training age
- ✓ Genetics

Aerobic Power

VO_2 = CO x $(a\text{-}v)O_2$ difference

Factors affecting aerobic power



Training to Enhance Aerobic Energy System

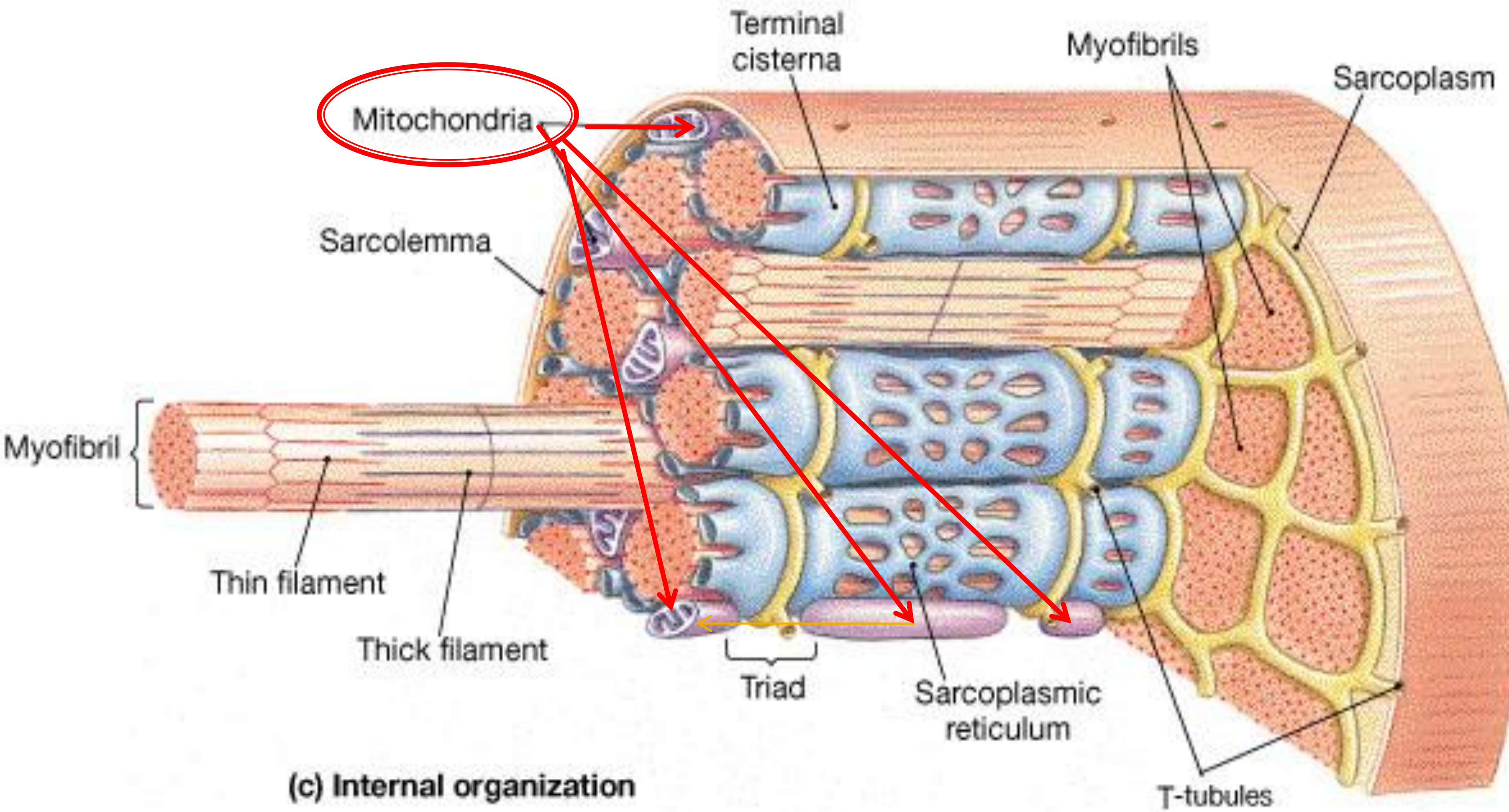
Continuous

- ✓ Maximize load on heart and lungs
- ✓ Extend duration > 30 min
- ✓ Sub-Threshold
- ✓ Maximize blood changes
- ✓ Increase utilization of fat

Interval

- ✓ Maximize load on metabolic machinery
- ✓ Maximize buffering capacity
- ✓ Above threshold
- ✓ Optimum time is 3 min at VO_2max?
- ✓ Total work > ? min

Myofibril packaging (internal organization)



(c) Internal organization

- https://www.youtube.com/watch?v=dWe8vtztW-4

- https://www.youtube.com/watch?v=NN5Y57NbnrU

- https://www.youtube.com/watch?v=8Y_FdjI2v4l

Sample Aerobic Training Zones

Zone 1	This zone is primarily used for recovery. It places very little stress on your body and helps clear waste products from the muscle
Zone 2	This zone is well below your anaerobic threshold and is used to build aerobic capacity. Can also be used for recovery during high intensity training
Zone 3	This zone is considered sub-threshold and is at or just below your race pace. You should not be able to hold this intensity for > 45 min.
Zone 4	This zone is slightly higher than your time trial pace and places heavy stress on the aerobic system as it an intensity that results in accumulation of lactate.
Zone 5	This zone is at an intensity that directly targets your maximal aerobic power and you should not be able to maintain this intensity for > 5 min. Use this intensity for intervals lasting 2-5 minutes

Aerobic

Continuous Training

Work phase	10 - 45 min
Rest phase	n/a
Work : rest ratio	n/a
Intensity (% max effort)	<70%
Repetitions (number)	Continuous
Sets (number)	n/a
Rest between sets	n/a

Guidelines: engage in
1. Continuous Physical Activity

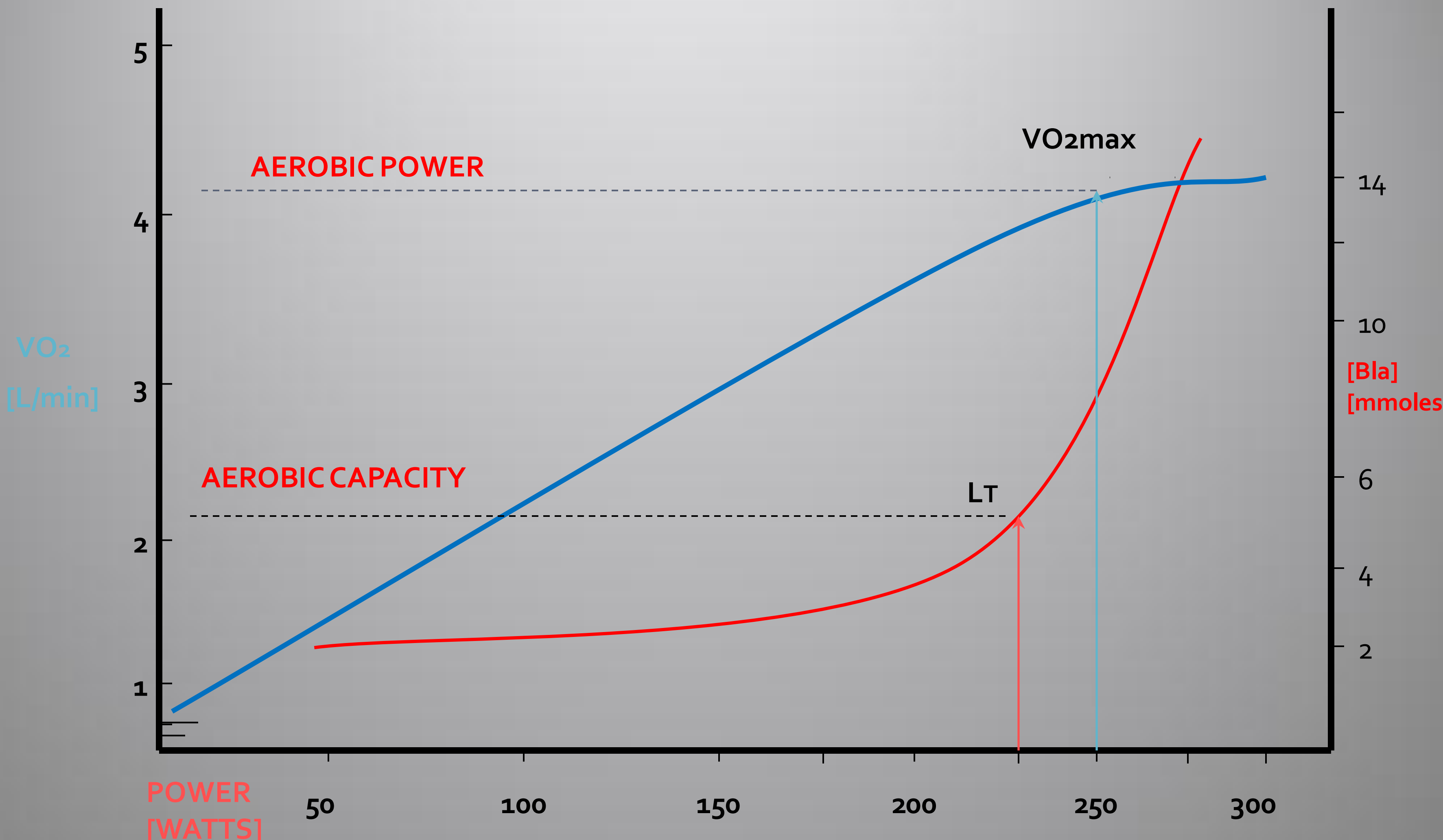
- 30 min of moderate physical activity per day for 5-6 days per week
- 20 min of vigorous physical activity 3 days per week
- 10 min of moderate physical activity 3 times per day for 5-6 days per week
- 10,000 steps a day
- Continuous physical activity (training)

Aerobic (VO2max) *Interval Training*

Work phase	3-10 min
Rest phase	3-10 min (active)
Work : rest ratio	1:1
Intensity (% max effort)	90 – 95% of max HR – 95 – 105% of VO2max pace
Repetitions (number)	Accumulate 12 – 25 min
Sets (number)	1-10
Rest between sets	10-15 min (active)

- **Discussion - Group Management**

DETERMINING AEROBIC POWER AND CAPACITY IN RELATION TO VO_2 AND BLa



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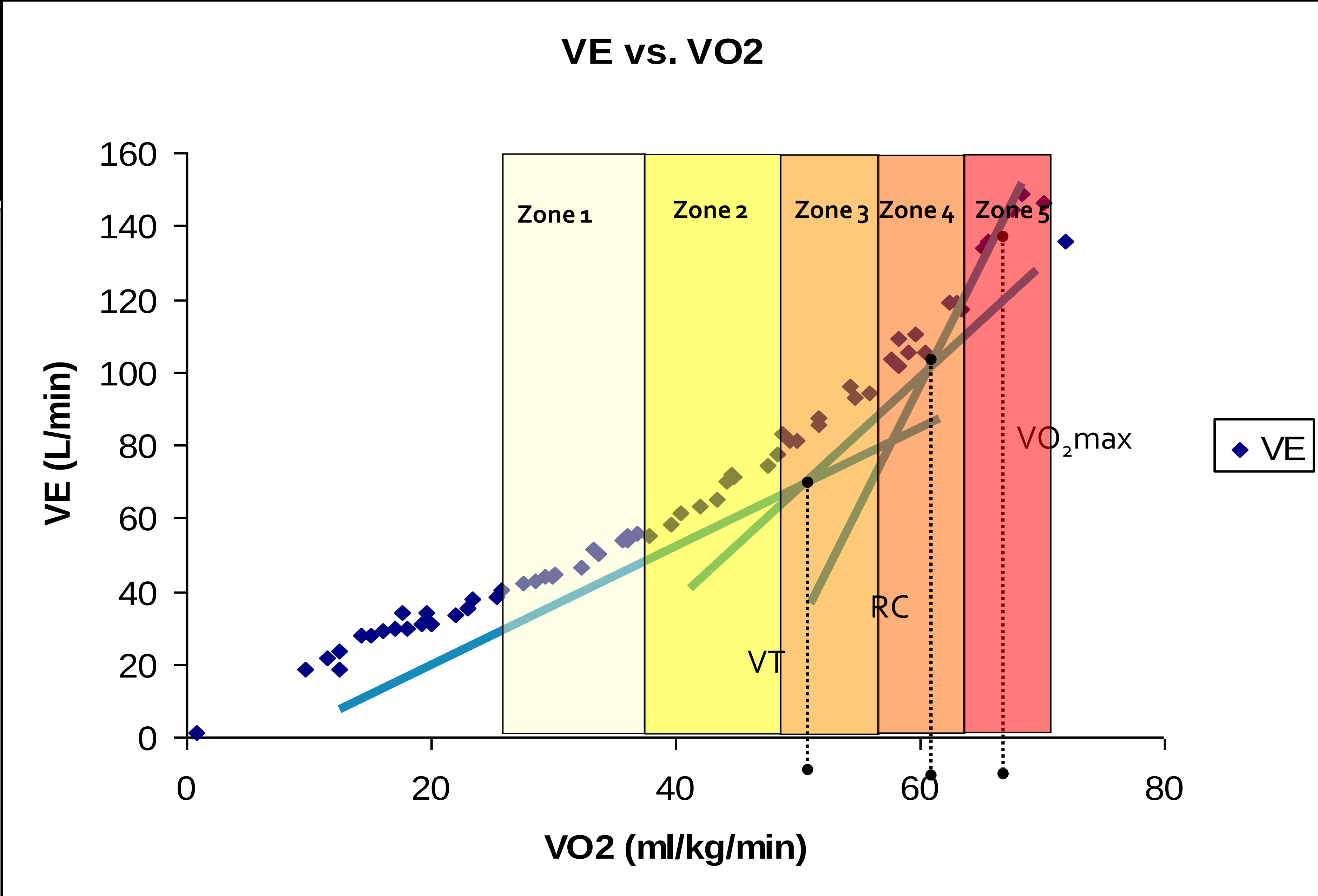

VE vs. VO2
VE (L/min)
160
140
120
100
80
60
40
20
0
VO2 (ml/kg/min)
0
20
40
60
80
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
VT
RC
VO2max
VE

2. Aerobic interval training

- Interval training involves a period of high intensity effort (30s-3min) followed by and equal or greater time of active rest (30s-3min) repeated 5-10 times
- Suggested it targets the oxidative mechanisms in muscle by making the muscle hypoxic (increases oxidative enzymes and number of mitochondria). Also considered to offset some of the effects of aging (*from Cell Metabolism, 2017*)

Astrand ,Rodahl, Dahl, & Stromme, 2003, Bell & Wenger, 1986. Gaiga & Docherty, 1995. Rhodas et al., 2000, MacDougall et al., 1998.

Original aerobic interval training guidelines.

- 1:1 work to recovery ratios
- 1-3 min work intervals
- Active recovery (60% VO_2 max)
- Number of work intervals (6-10)
- Optimal 30-35 min at or close to VO_2 max.

Astrand ,Rodahl, Dahl, & Stromme, 2003, Bell and Wenger, 1986

More recent approaches
(high intensity interval training:HIIT)

- What is HITT?
- High intensity efforts with short recovery periods

  10 maximum efforts of 60s work with 60s active recovery (total time=20 min)

  4-6 maximum efforts of 30s work with 4 min active recovery (total time=20-27 min)

  ***8 maximum efforts of 20s work with 10s active recovery (total time=4 min!)**

  3 maximum efforts of 20s work with 2 min active recovery (total time=2 min!)

*McMaster Group, *Tabata group.*

Tabata Intervals

- 20 sec full out effort
- 10 sec active rest
- Repeat 8 times
- Total training time = 4 min

- Found to produce 7 mL (11%) increase in VO_2 max (52-59 mL) and 28% in anaerobic performance!!

Tabata et al., 1996

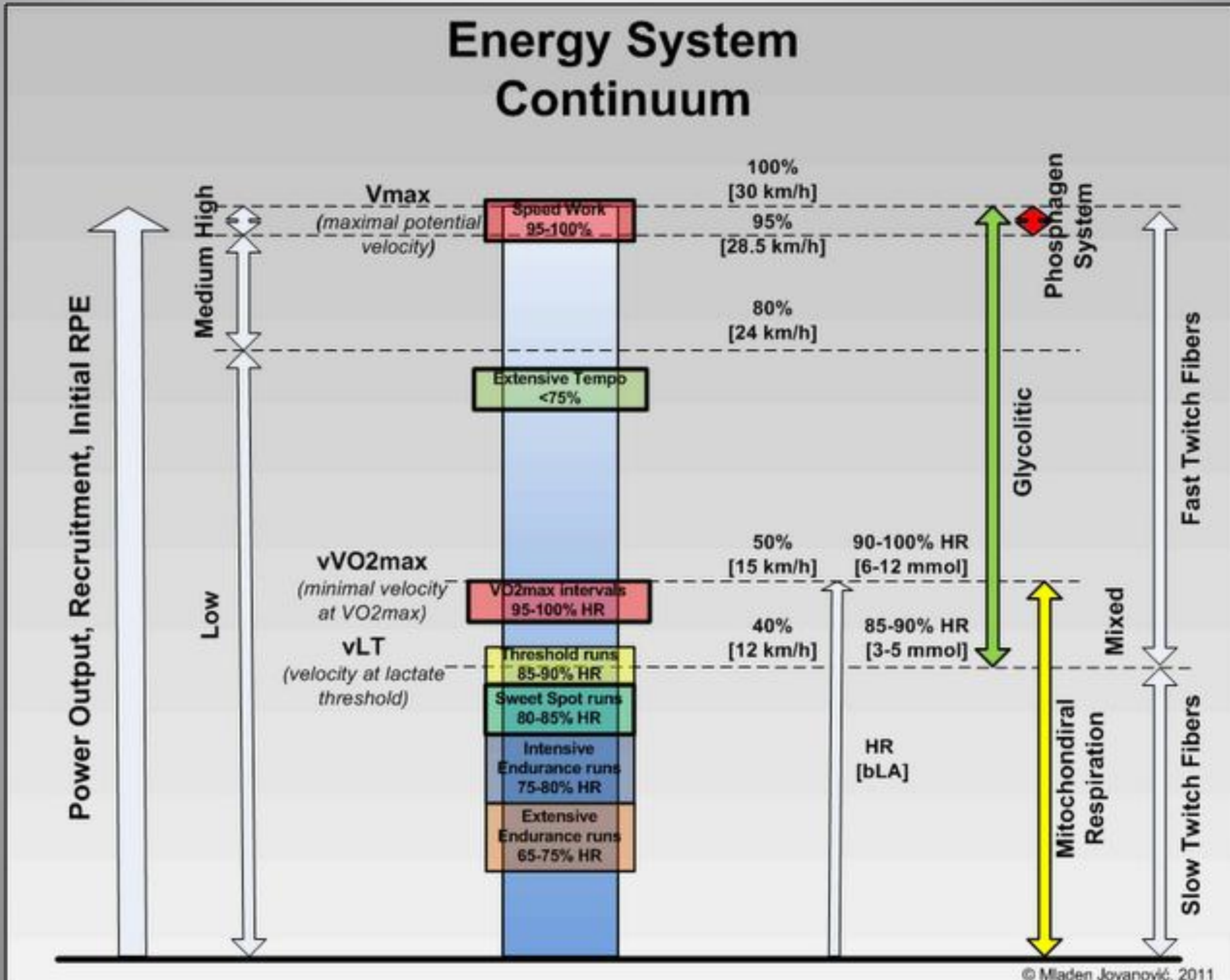
- Used with many different populations including those with CHD and other chronic conditions (diabetes, obesity)
- Produces equal or better fitness and health outcomes compared to long duration endurance training (e.g. 30-60 min at lower intensity)

Little et al., 1985, Currie et al., 2013, Gibala & Jones, 2013, Gillan et al., 2013, Currie et al., 2012, Kessler et al., 2012

Mode of activity

- Cycling ergometer (stationary bike!)
- Running (treadmill or track)
- Whole body activity (e.g. burpees, jumping jacks, push ups etc.)
- Resistance exercise (e.g. body weight squats)

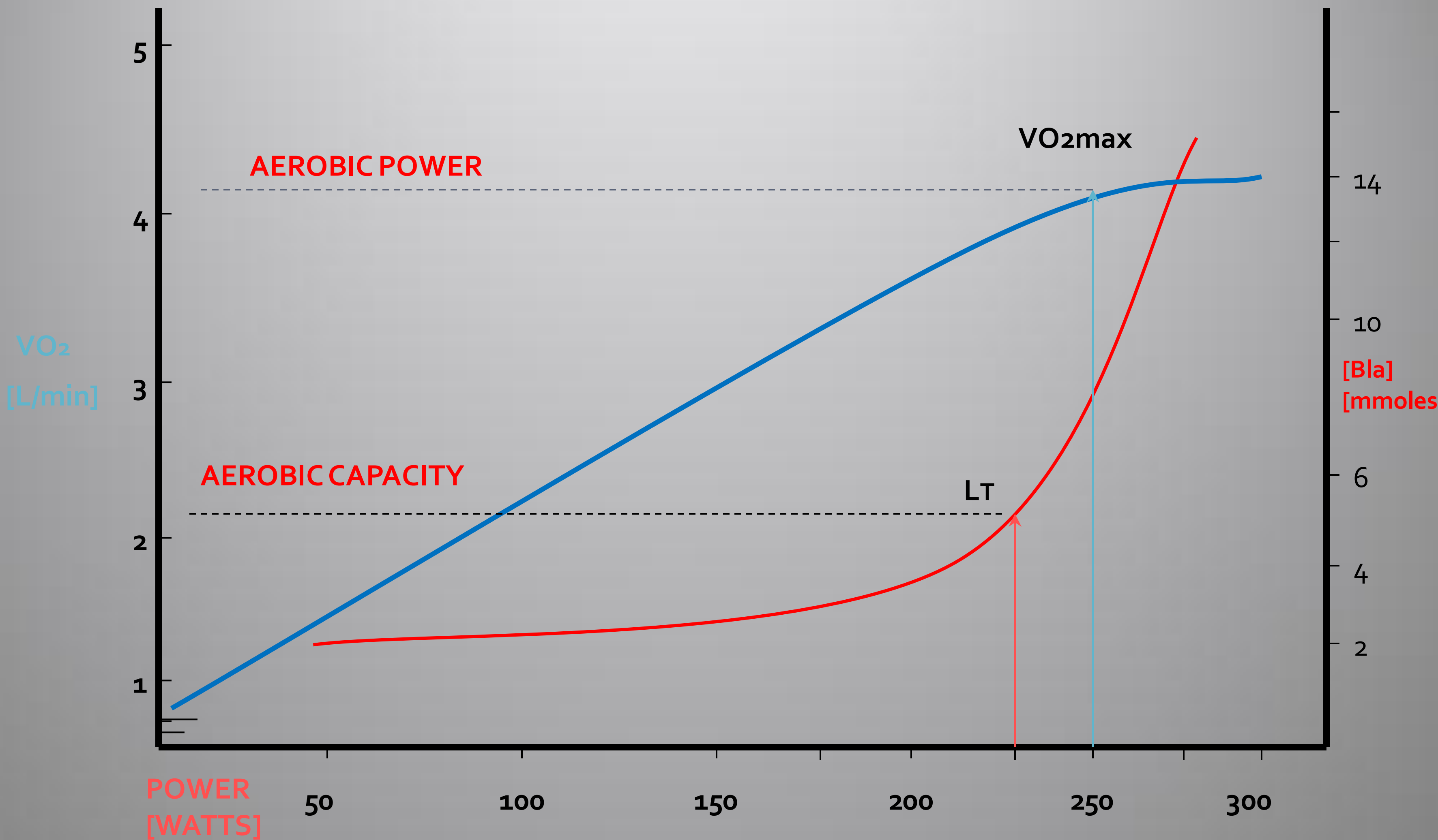
Tabata, 1996, Gillan, , Gabala, McCrae et al., 2012, Rozenek et al., 2007, and Kates, 2014



Energy System Continuum
Vmax
(maximal potential velocity)
Speed Work 95-100%
100% [30 km/h]
95% [28.5 km/h]
80% [24 km/h]
Extensive Tempo <75%
vVO2max
(minimal velocity at VO2max)
VO2max intervals 95-100% HR
50% [15 km/h]
90-100% HR [6-12 mmol]
40% [12 km/h]
85-90% HR [3-5 mmol]
vLT
(velocity at lactate threshold)
Threshold runs 85-90% HR
Sweet Spot runs 80-85% HR
Intensive Endurance runs 75-80% HR
Extensive Endurance runs 65-75% HR
HR [bLA]
Power Output, Recruitment, Initial RPE
High
Medium
Low
Phosphagen System
Glycolitic
Mixed
Mitochondiral Respiration
Fast Twitch Fibers
Slow Twitch Fibers
© Mladen Jovanović, 2011

hwenger11

DETERMINING AEROBIC POWER AND CAPACITY IN RELATION TO VO_2 AND BLa



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Aerobic (Anaerobic Threshold)

Work phase	4-15 min
Rest phase	Dependent on work interval
Work : rest ratio	2:1 – 5:1 (active)
Intensity (% max effort)	Anaerobic threshold –5% to +10%
Repetitions (number)	3-10
Sets (number)	1-3
Rest between sets	Variable – active rest

Dave`s workouts

- Monday:
  - 3-5 min warm up. 30 min steady state cycling
  - Chins, bar dips, and knee raises and lowers (abs)
  - Stretch 5 min
- Tuesday:
  - 3-5 min warm up. 3min:3min; 2min:2min; 1min:1min work:recovery (twice)
  - Inclined bench, seated rows, side arm raises
  - Stretch 5 min
- Wednesday:
  - 3-5 min warm up. 1min:1min work:recovery (10 times)
  - Arm curls, arm push downs, upright row
  - Stretch 5 min

- Thursday:
  - 3-5 min warm up. 1min:1min;2min:2min work:recovery (5 times)
  - Pec deck (chest), lat pull downs, shoulder shrugs
  - Stretch 5 min
- Friday:
  - 3-5 min warm up. 20sec:2 min work:recovery (3 times); Tabata intervals 20sec:10sec work:recovery (8 times); 1min:1min work:recovery (5 times)
  - Stretch 5 min
  - Standing bench press and upright row, ab workout (100 ab exercises and 30 leg raises and lowers (twice)

- You can also come up with your own variations
- Usually plan on 30 min of some form of aerobic work and about 20 min of strength exercises
- Workout generally takes 45-50 min and then 5 min cool down and stretch

- Questions?

Scheduling of training

Need to consider the following:

- Objectives of training phase
- Recovery time of energy system
  - Fuel supply
  - Metabolic clearance rates
- Requirement for skill and/or technical precision
- Minimum training loads for adaptation
- Reliance on other energy systems for enhanced development

General training principles for the energy systems

- When training the anaerobic systems (alactic and lactic)
  - First train for power and then for capacity
- When training the aerobic system
  - First train for capacity and then train for power

Scheduling of training

DURATION	*INTENSITY*	*1/2 AND FULL RECOVERY*	*ENERGY SYSTEM*
3 - 10 MINS	**70-75%ME** **95-100% max HR** **95-100% VO2 max**	**20-30 MIN** **1-2 HOURS** **[For lactic Acid]** **5 -24 hours** **[For Glycogen]**	**AEROBIC POWER**
10 min +	**50-60% ME** **70-80% AT;VT;LT**	**10 hours** **48 hours** **[for Glycogen]**	**AEROBIC CAPACITY**

Breakout Activity

- Identify the key energy systems require by your sport including:
  - characteristics of the sport/event,
  - the intensity at which the athlete must compete,
  - the duration of the effort,
  - the duration and frequency of recovery periods,
  - and the chosen tactics/strategy.

Energy System Assessment

- Validity
  - Does the test really measure what its supposed to measure?
- Reliability
  - How reproducible are the results (test to test and between testers)?
- Meaningful difference
  - How sensitive is the test to a change in performance?

For all energy system tests consider

- ease of conducting test
- cost of equipment to conduct test
- ease of obtaining accurate results
- validity of test for determining power / capacity for the specific energy system
- population / sport the test is suited to
- availability of normative data

Anaerobic components

- Anaerobic alactic (ATP-PC)
  - Power
  - Capacity
- Anaerobic lactic (anaerobic glycolysis)
  - Power
  - Capacity
- However……………………..

A practical framework

- Anaerobic peak power (highest value)
- Short term anaerobic capacity (<10s)
- Intermediate anaerobic capacity (20-30s)
- Long term anaerobic capacity (60-90s)

(Bouchard et al.,1991)

Anaerobic Tests

Performance Tests:

1. Anaerobic Speed Test (AST)
2. Wingate Test
3. Vertical jump or repeated jumps
4. Repeated sprint tests
5. "Claude Bouchard" time frame (0-120s)

Physiological additions:

- blood lactate measures following maximal effort (e.g. AST or Wingate)
- greater [lactate] → higher anaerobic capacity
  - e.g. 17 mmol/L vs. 14 mmol/L

Aerobic Tests

- Performance measures (e.g. 12 min run, 10km, Beep)
- VO_2max test (sport specific)
- Submaximal economy tests
- Threshold tests (VT;LT)

Units of measurement

- $L \cdot min^{-1}$ (absolute aerobic power)
- $mL \cdot kg^{-1} \cdot min^{-1}$ (relative aerobic power)
- Other recommendations
  - $mL \cdot kg^{-.69} \cdot min^{-1}$
  - $mL \cdot kg^{-.75} \cdot min^{-1}$
  - $mL \cdot ht^{2} \cdot min^{-1}$

Maximal aerobic capacity

- Anaerobic threshold
  - Definition: ***The critical intensity at which energy production is no longer supplied primarily by aerobic (oxidative) metabolism***

Measuring anaerobic threshold

- Lactate threshold (LT)
  - Definition: ***The critical intensity at which the blood lactate shows sudden non-linear increase (onset of blood lactate accumulation, OBLA).*** It is measured as the work increment that immediately precedes the first 1 mmol•L rise in blood lactate
  - Some researchers use critical level

  (e.g. 4 mmol•L of blood lactate)

Measuring anaerobic threshold

- Ventilatory threshold (VT)
  - Definition: ***The point of non-linear increases in ventilation (Ve) related to VO_2.*** Reflects the changes in Ve, VO_2, and CO_2.
  - Non-invasive technique

Training Intensity	Energy System *	Type of Training	Optimal Time	Work: Recovery Ratio	%Max Effort	%HR Max	HR Range**(b/min)	Lactate Range(m mol/L)	Characteristics
Anaerobic I(AN1)	ATP-PC	All out sprint	10 - 30 sec	Complete recovery	95-100	95-100	180-190	Small amount	Preferential energy fuels are stored PC and ATP in muscle; muscle fiber recruitment always begins with Type I (slow twitch) followed quickly by Type IIa (fast oxidative) and Type IIb (fast nonoxidative) with emphasis on Type II fibers
Anaerobic II (AN2)	LA	Short interval	30 - 90 sec	1:3	90-95	90-95	170-180	Maximum values (10-30)	Highest rate of anaerobic glycolysis; blood glucose and some muscle glycogen are preferred energy sources; recruitment pattern of muscle fiber types is same as AN1 and increases occur in muscle anaerobic enzymes and there is improved buffering power of muscles and blood
Transportation(TN)	ATP-PC LA O2	Moderate interval	90 sec - 5 min	1:2	85-90	85-90	165-170	6-10	Slightly lower exercise intensity than AN2; utilizes primarily glycogen from muscle and liver for shorter work bout and incorporates more O2 as work time is extended; excellent stimulation of cardiovascular delivery apparatus and improves VO2 max; all muscle fiber types will be used if intensity and exercise duration are increased
Anaerobic Threshold (AT)	LA O	Long interval	5 – 20 min	1:1	80-85	80-85	155-160	4-6	This is very hard work and probably cannot be sustained much longer than 20 min without onset of fatigue; cellular O2 transport becomes a problem; major source of energy is glucose and glycogen with some fatty acid metabolism during longer work bouts; emphasizes use of fiber types I and IIa
Utilization 1 (U1)	O2 LA	Continuous work or Long interval	10 – 30 min	1:0.5 or 1:0.25	75-80	75-80	145-155	2-4	Primary objective of this intensity is to cause muscle to use oxygen more efficiently; should make up bulk of total training; Types I and IIa muscle fibers are used preferentially;although glycogen is used for energy, use of fatty acids becomes more important
Utilization 2(U2)	O	Continuous	30 – 60 min	Continuous	65-75	65-75	125-145	2 or less	Uses continuous or interrupted exercise of long duration; major energy source is free fatty acids with some glycogen use; emphasizes Type I muscle fibers; often referred to as conversational pace
Utilization 3 (U3)	O	Continuous	60 - 120 min	Continuous	50-65	50-65	95-125	Very small amounts	Lowest level of aerobic stimuli; recommended for non-competitive recreational athletes; can maintain minimal fitness requirements; energy source is primarily free fatty acids; uses Type I and some IIa fibers

FH

Expressions of anaerobic threshold (AT)

- As a percentage of VO_2 max
- As a measure of VO_2 at AT
- As a heart rate at AT
- As a pace (running velocity, cycling, stoke rate etc.)

VO2 max Norms

Sport	Age	Male	Female
Baseball	18-32	48-56	52-57
Basketball	18-30	40-60	43-60
Cycling	18-26	62-74	47-57
Canoeing	22-28	55-67	48-52
Football (USA)	20-36	42-60	
Gymnastics	18-22	52-58	35-50
Ice Hockey	10-30	50-63	
Orienteering	20-60	47-53	46-60
Rowing	20-35	60-72	58-65
Skiing alpine	18-30	57-68	50-55
Skiing nordic	20-28	65-94	60-75
Soccer	22-28	54-64	50-60
Speed skating	18-24	56-73	44-55
Swimming	10-25	50-70	40-60
Track & Field - Discus	22-30	42-55	
Track & Field - Running	18-39	60-85	50-75
Track & Field - Running	40-75	40-60	35-60
Track & Field - Shot	22-30	40-46	
Volleyball	18-22		40-56

Courtesy of www.brianmac.co.uk

TABLE 4.5 Equivalent Performances for Various Distances

$\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$)	Performance Time for Various Distances (hours:minutes:seconds)				
	1.5 km	1 mile	5 km	10 km	42.2 km
28	13:30	14:46	56:49	2:39:14	31:41:25
31.5	11:27	12:29	47:04	2:02:00	16:35:05
35	9:56	10:49	40:10	1:38:53	11:13:52
38.5	8:46	9:33	35:02	1:23:08	8:29:26
42	7:51	8:33	31:04	1:11:43	6:49:30
45.5	7:07	7:44	27:54	1:03:03	5:42:21
49	6:30	7:03	25:20	0:56:15	4:54:07
52.5	5:59	6:29	23:11	0:50:47	4:17:48
56	5:32	6:01	21:23	0:46:17	3:49:28
59.5	5:09	5:36	19:50	0:42:30	3:26:44
63	4:50	5:14	18:30	0:39:33	3:08:06
66.5	4:32	4:55	17:20	0:36:33	2:52:34
70	4:17	4:38	16:18	0:34:10	2:39:23
73.5	4:03	4:23	15:23	0:32:12	2:28:05
77	3:50	4:09	14:34	0:30:12	2:18:16
80.5	3:39	3:57	13:50	0:28:33	2:09:41
84	3:29	3:46	13:10	0:27:04	2:02:06
87.5	3:20	3:36	12:34	0:25:44	1:55:21

Training the energy systems

ATP-CP

	Interval
Work phase	1-10 sec
Rest phase	10-100 sec (passive)
Work : rest ratio	1:10
Intensity (% max effort)	98-100%
Repetitions (number)	4-6
Sets (number)	2-4
Rest between sets	5-10 min (light active)

Reps depend on ability to maintain velocity and form
How do you know? Need to time them and watch!!
Get feedback from athletes

Anaerobic Lactic

	Interval
Work phase	30-120s
Rest phase	90-360s (active is best)
Work : rest ratio	1:3
Intensity (% max effort)	80-85%
Repetitions (number)	4-6
Sets (number)	1-4
Rest between sets	5-10 min

1. Accumulate lactic acid in blood and muscle
2. Allow time for complete recovery
3. Shorter recovery results in waste products accumulating over the duration of the set (helpful for training body to tolerate high levels of lactate)

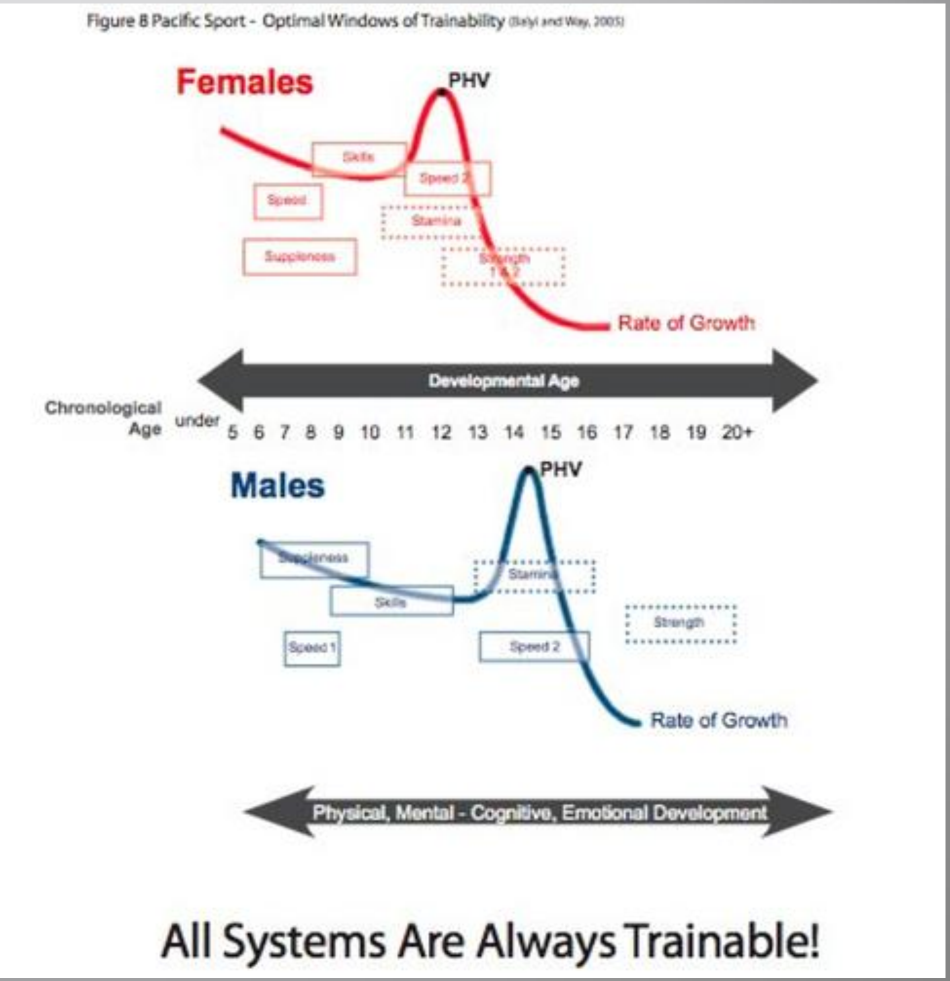
Breakout activity

- Identify two or three fitness tests used in your sport and relate to the energy systems they are measuring
- Evaluate the validity and reliability of the tests

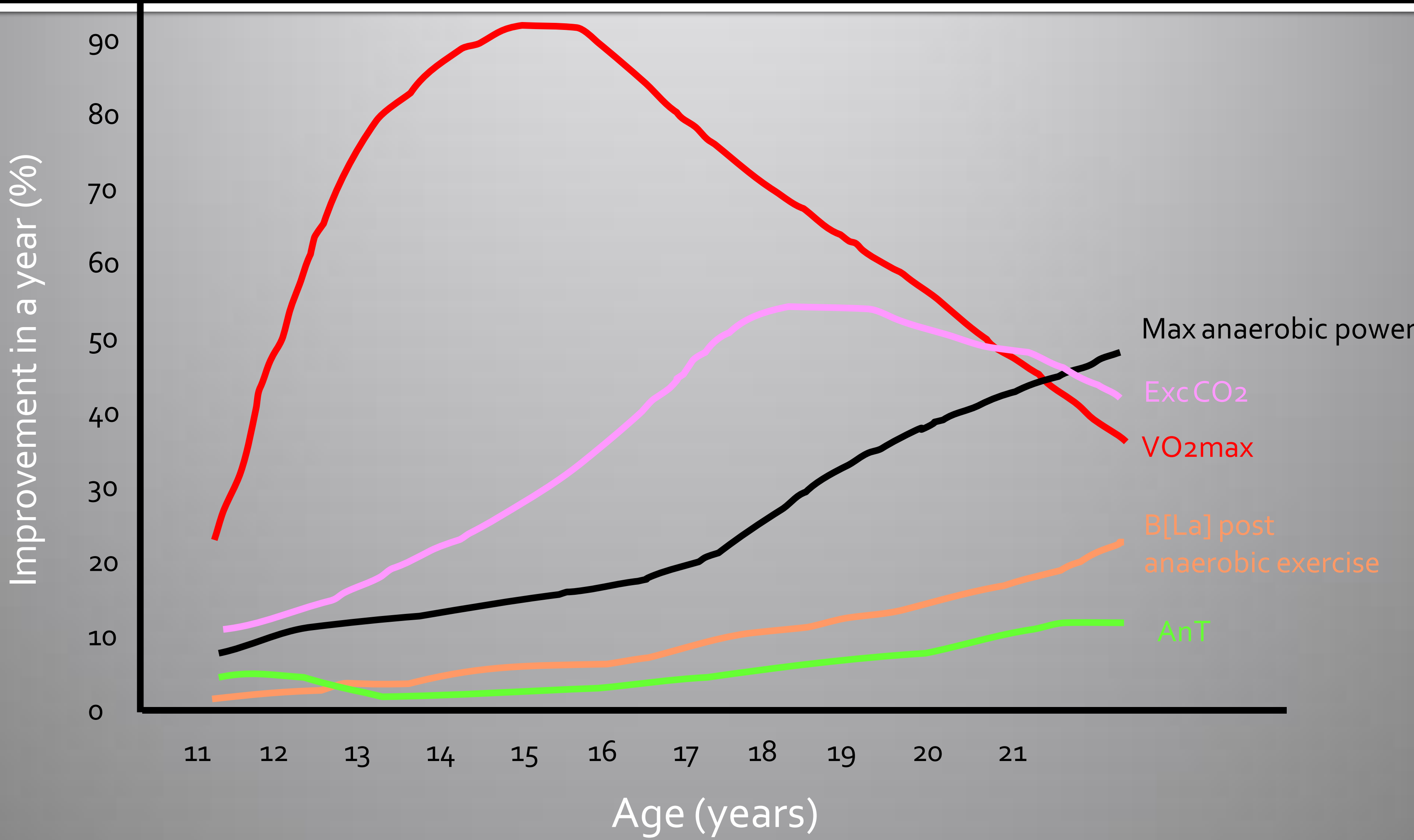
"I thought for a minute I'd lost you there but I guess the old stetho's on the blink."

Trainability?

- Different muscle biochemistry in pre-puberty
- Low levels of enzyme PFK
- Train nervous system for speed
- Balyi and Way 2008 – Speed 1 and 2



Influence of maturation…



Voitenko, 1985

Aerobic Power

$$VO_2 = CO \times (a\text{-}v)O_2 \text{ difference}$$

Aerobic Power

- **Maximal aerobic power:**
  - maximal oxygen uptake, VO2max
  - point @ which oxygen consumption plateaus & shows no further increase (or increases slightly) with an additional workload

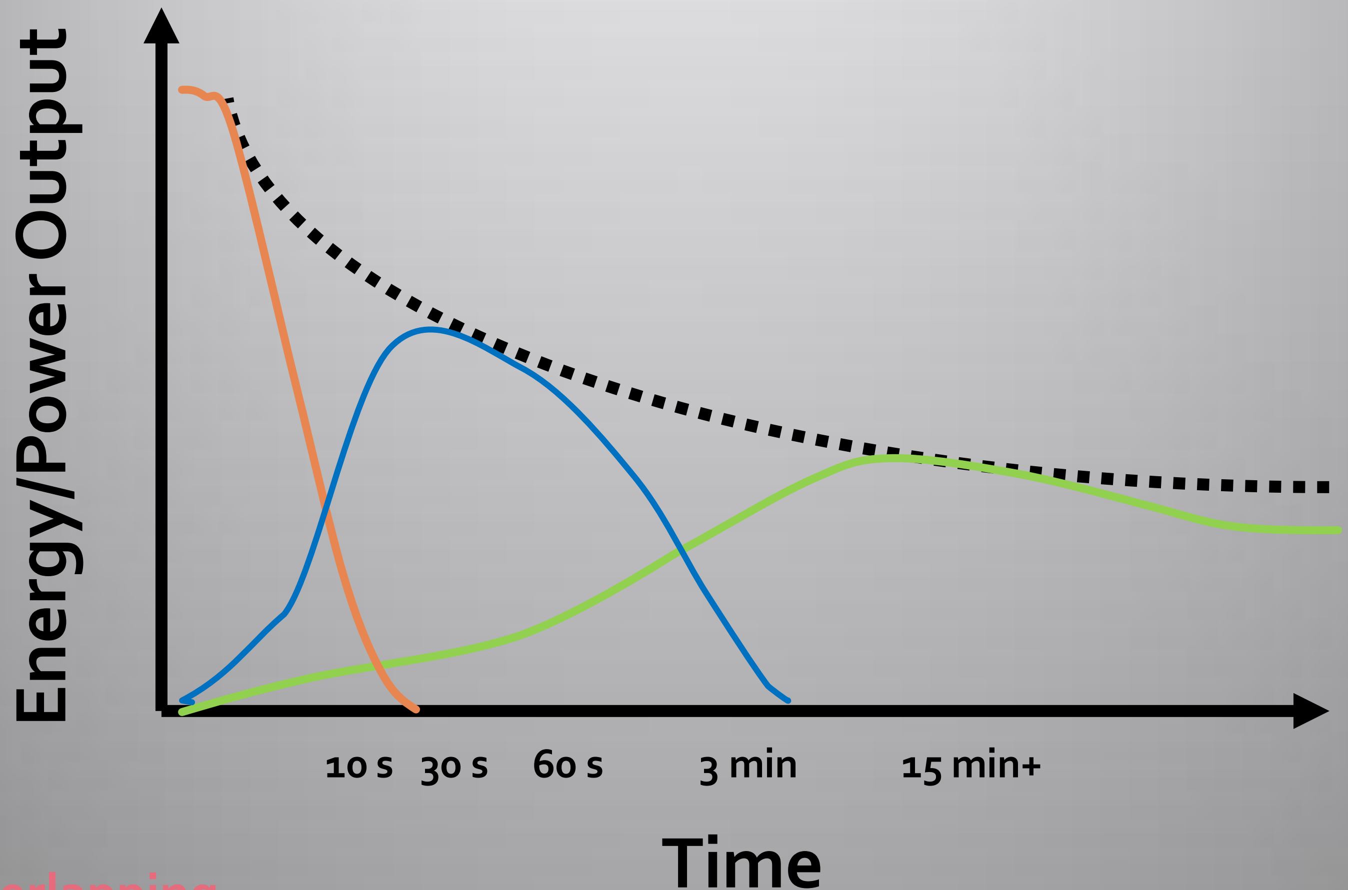
Aerobic Power

- **Maximal aerobic power:**
  - VO2max; good interpreter of endurance performance when studying heterogenous group
  - BUT…relatively poor when examining athletes of similar ability level (homogenous group!)

Factors Affecting Anaerobic Performance

- age
- gender
- rate of ATP production
- initial levels of muscle glycogen
- ability to tolerate low intracellular pH
- efficiency of metabolic pathways
- muscle mass
- heredity
- distribution of fibre type
- state of training - use of substrates/tolerance
- efficiency of aerobic pathways - WHY?

Energy System Continuum



• overlapping
• rarely independent but at times dominant