

# **AGE-RELATED CHANGES IN SKELETAL MUSCLE: Strength Development Through the Lifespan**



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# AIM

- Skeletal Muscle Development: structure and function
- Changes During Lifespan
- Strength Development Phases
- Physiological Limiting Factors
- Aging Muscle: sarcopenia, dynapenia
- Rehabilitation: oxidative capacity, myofibrillar apparatus

# INTRODUCTION

Human being born vulnerable and leave from this world frail;

Neonates and aged have muscle weakness;

Why?



# Muscle Development

First muscular activity was recorded in 8 week old embryo

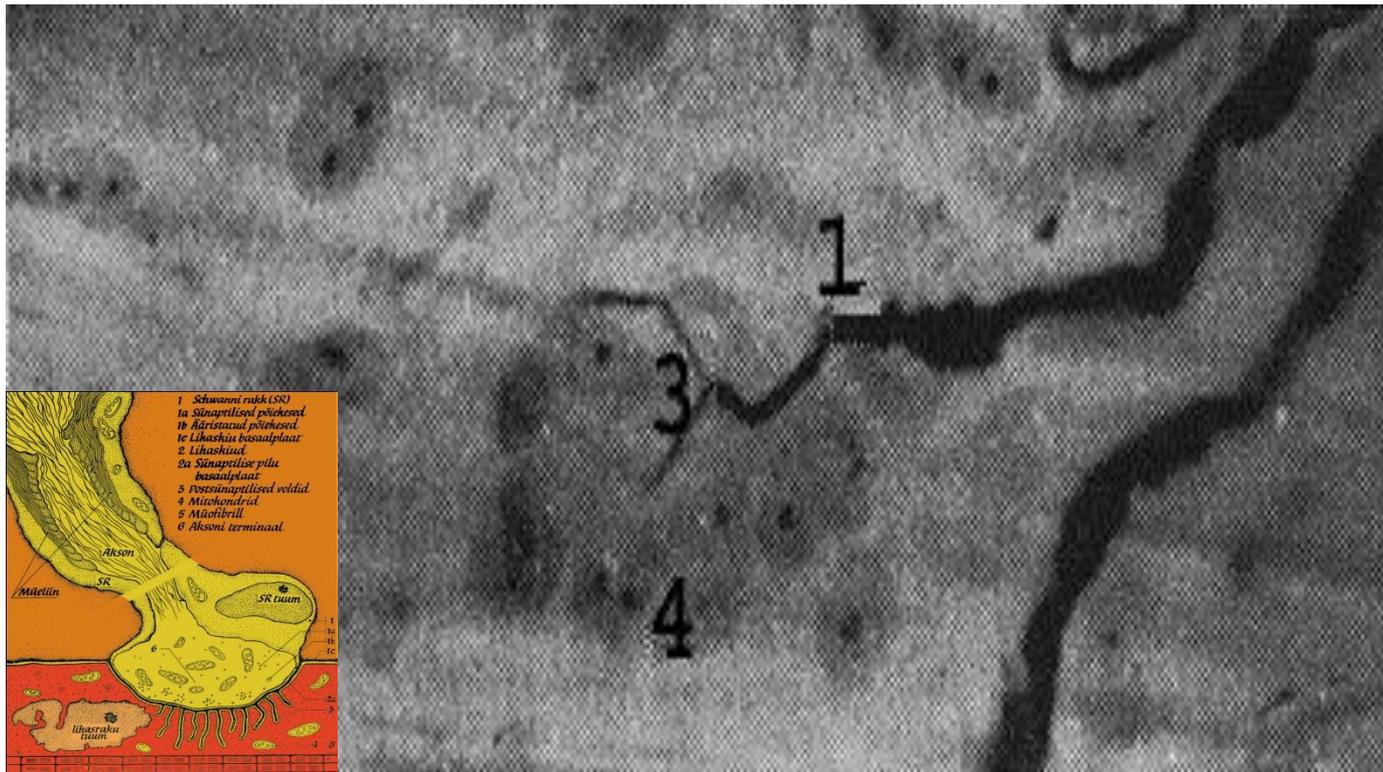


Recognizable muscle contractions was registered in  
16-18 fetal week

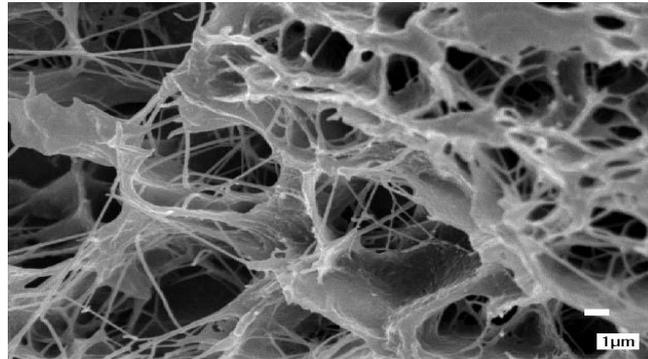


During 16-18 fetal week develops:

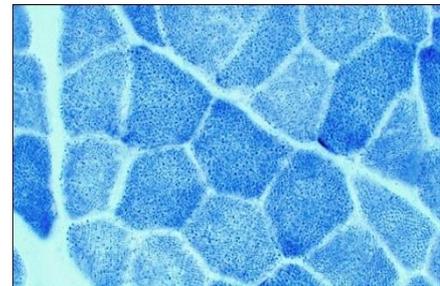
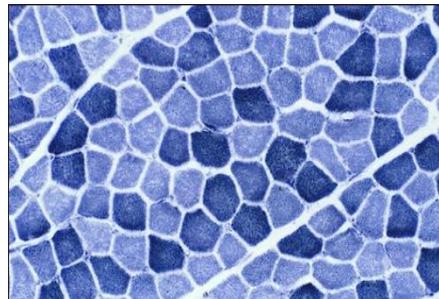
- Nerve muscle contact
- Neurotransmission apparatus (Ach/AChE)



- 29-33 week of gestation amount of endomysial connective tissue decreases



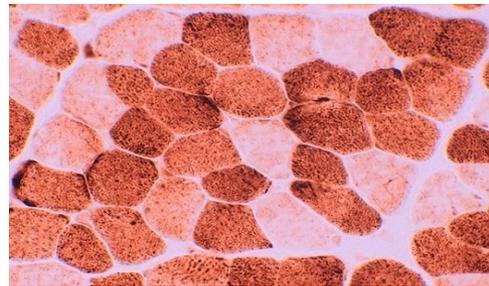
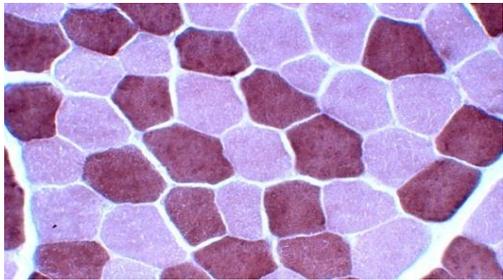
- Increase in number of smaller muscle fibers starts after 34th week of gestation



One month after birth : ~ **40% small size( type I) fibers;**

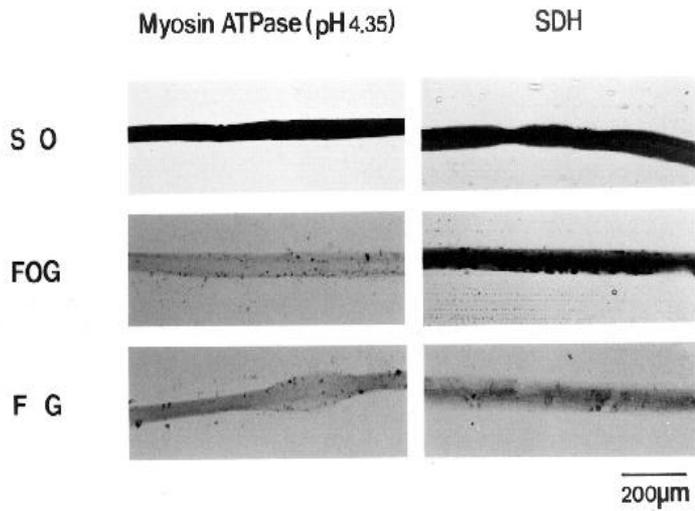
within 2 postnatal years: ~ **60% type I fibers ;**

**CSA of type II fibers** increase **30-fold** before age 20;



At birth all limb muscles have **same contraction velocity**;

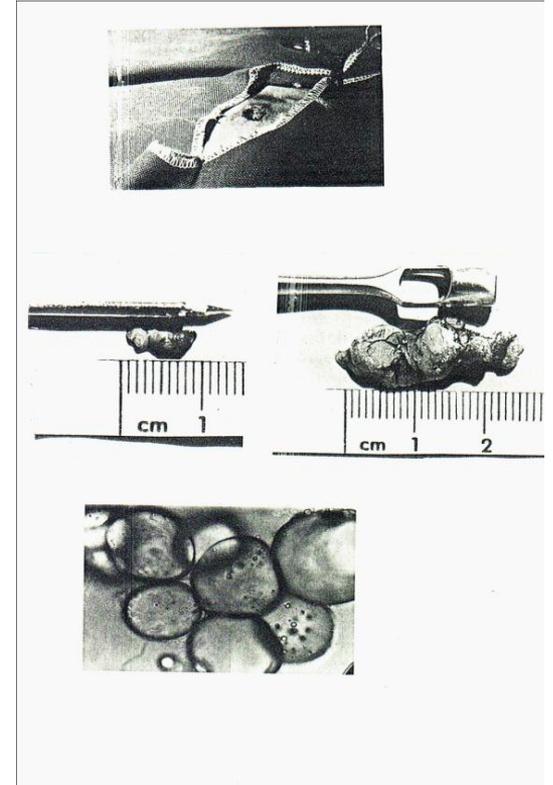
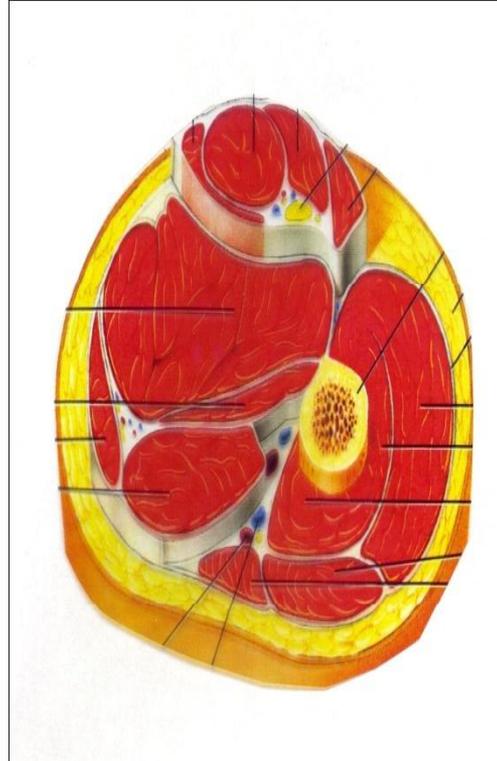
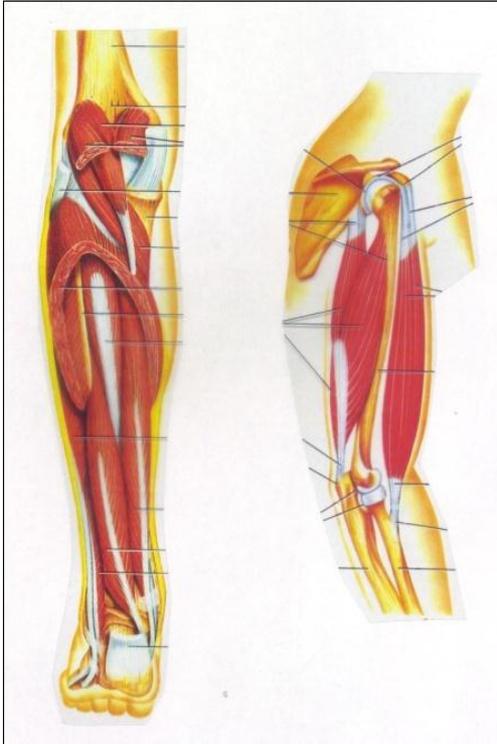
Differentiation into Fast to Slow starts after birth;

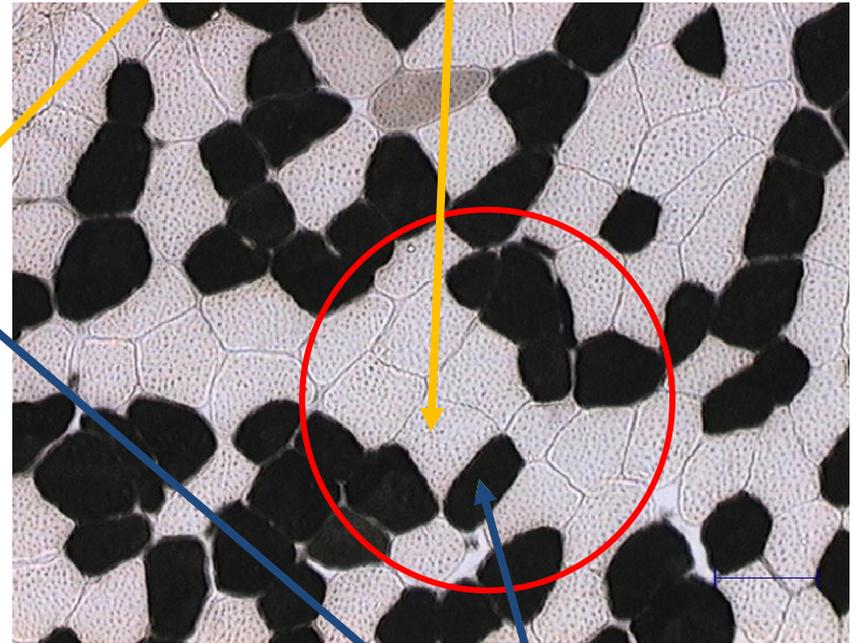
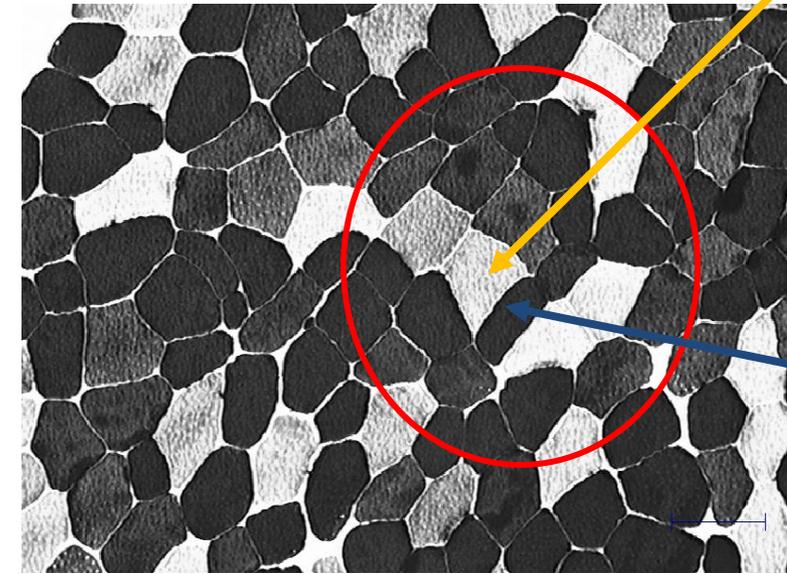
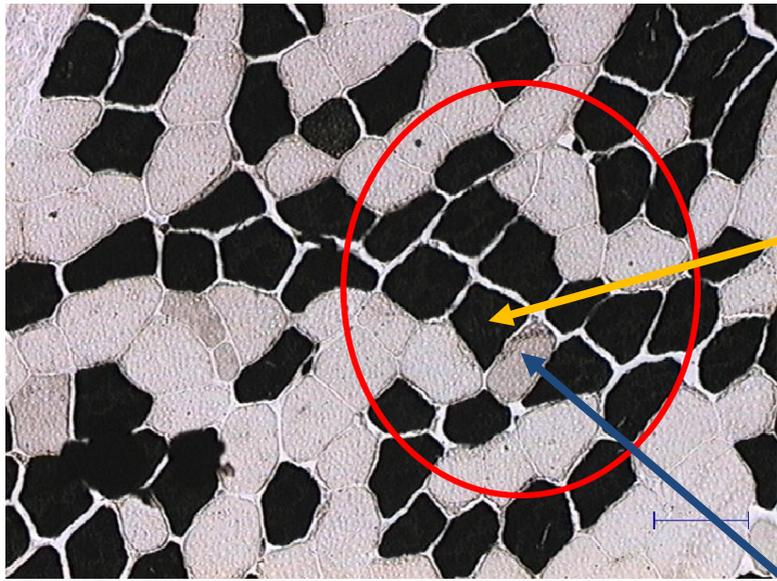


## **Growth of skeletal muscle:**

- The rate of growth is higher during **neonatal** period than any other stage of postnatal development:
  - Protein **synthesis rate** is higher than protein **degradation rate**
    - Factors that play role in it: **insulin, growth hormone, glucagon, IGF-I, leucine**

# Skeletal Muscle Structure





IIA  
IIX

I

# Muscle fibre:

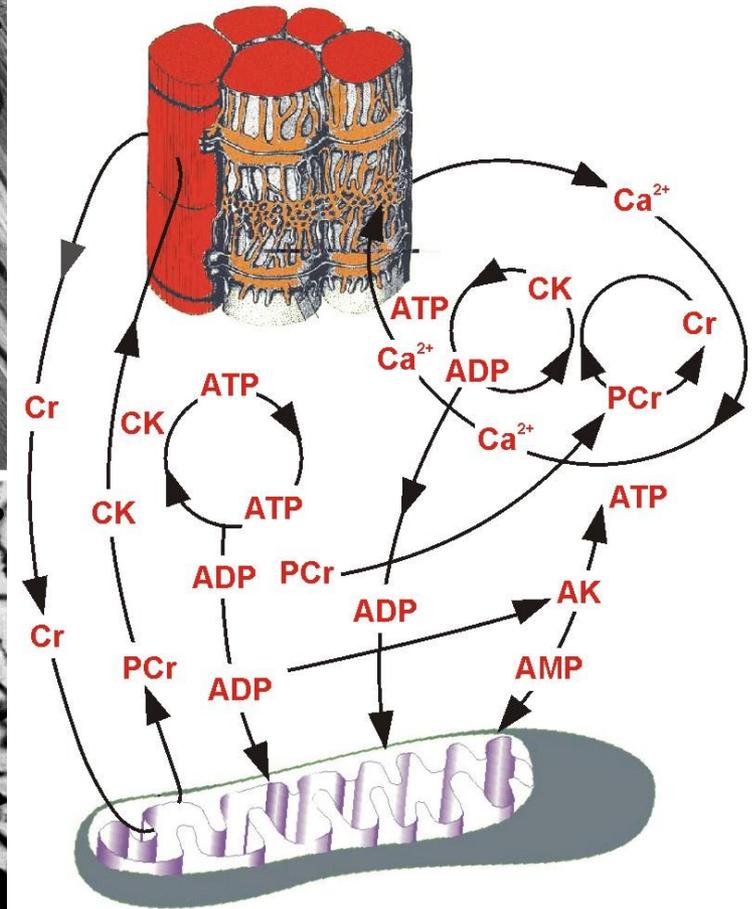
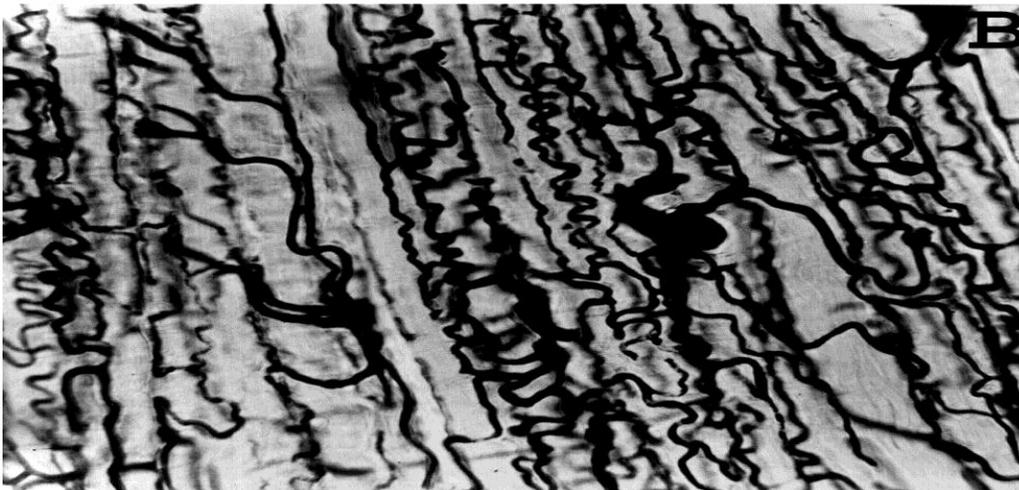
## CSA

- Type I 5000  $\mu\text{m}^2$
- Type IIA 7000  $\mu\text{m}^2$
- Type IIX 8400  $\mu\text{m}^2$

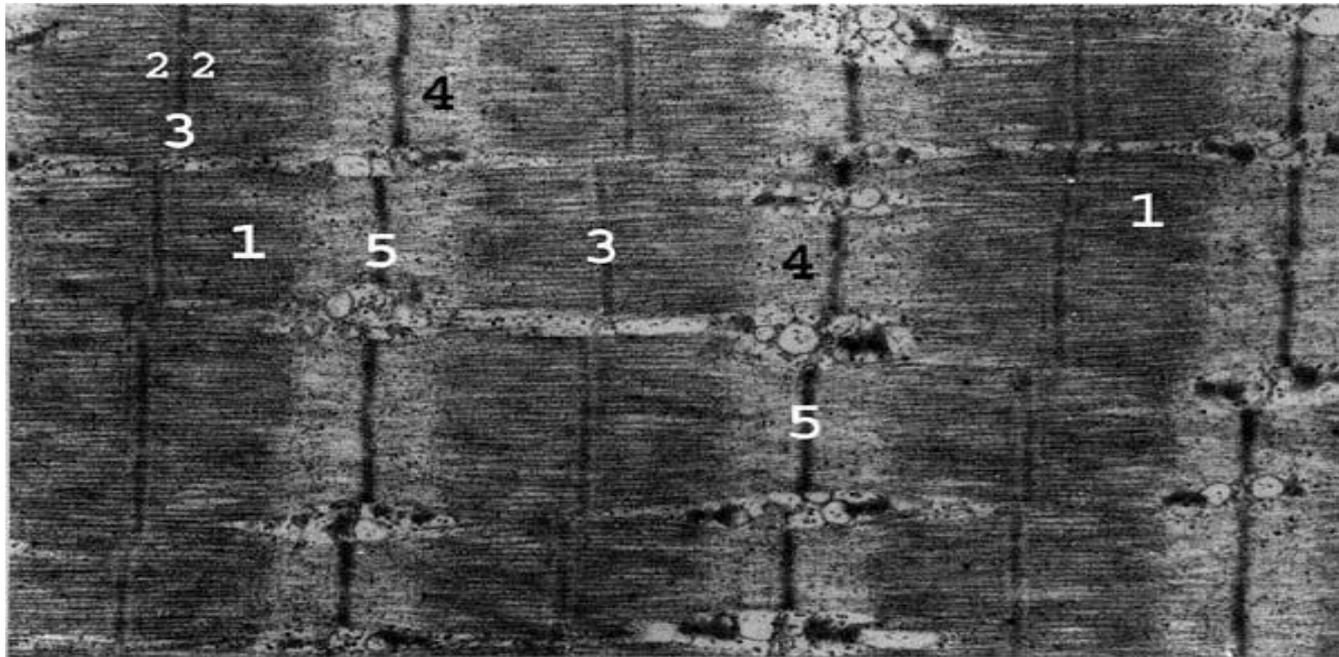
## Myonuclear Density

- Type I 40 per nl spl
- Type IIA 40 per nl spl
- Type IIX 20 per nl spl

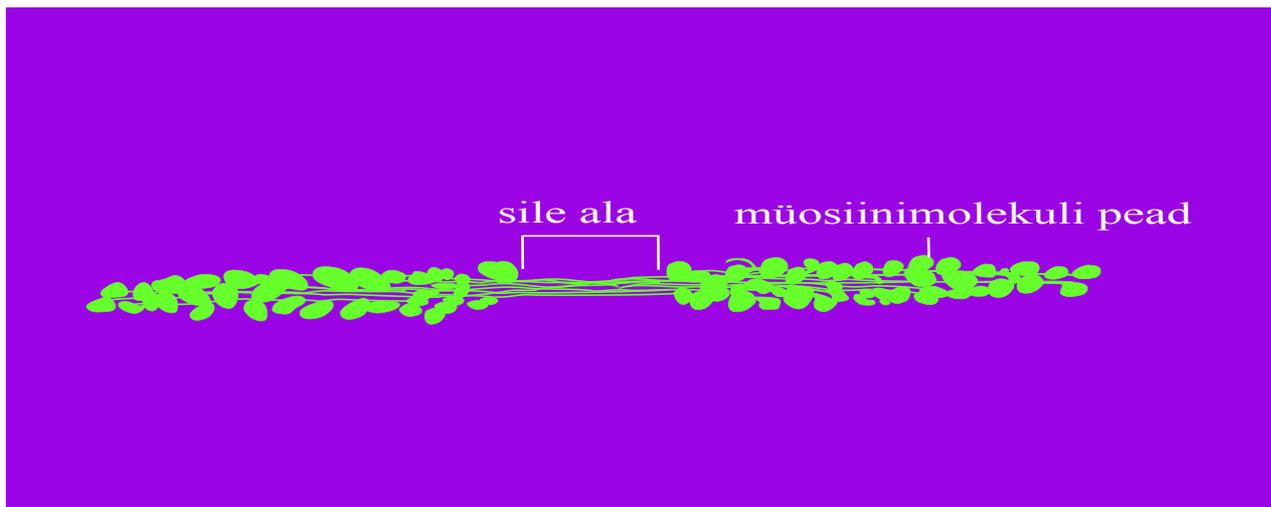
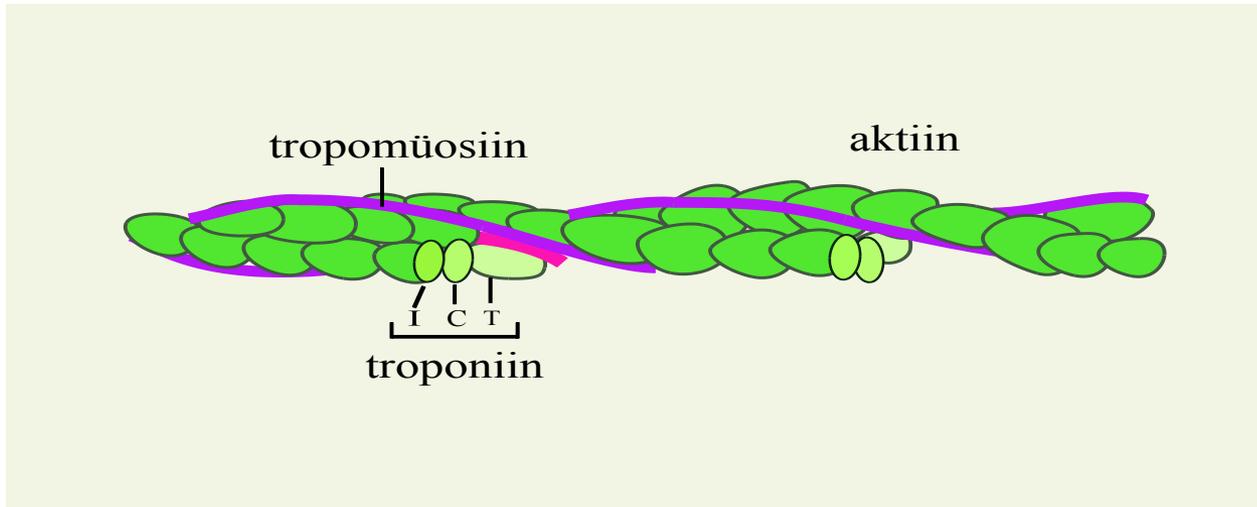
# Oxidative capacity of muscle fibers



# Skeletal Muscle Ultrastructure

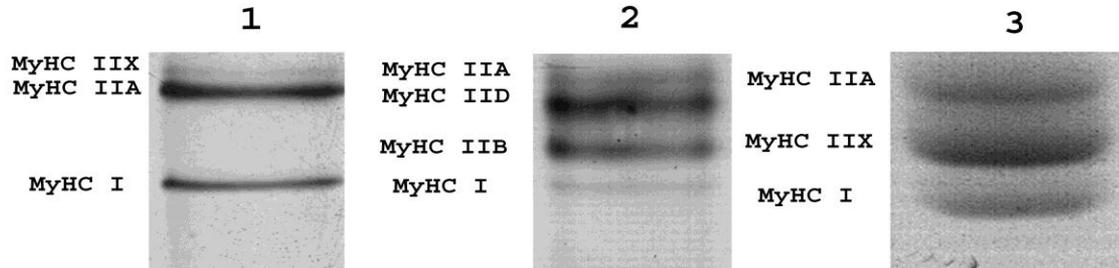


# Molecular structure

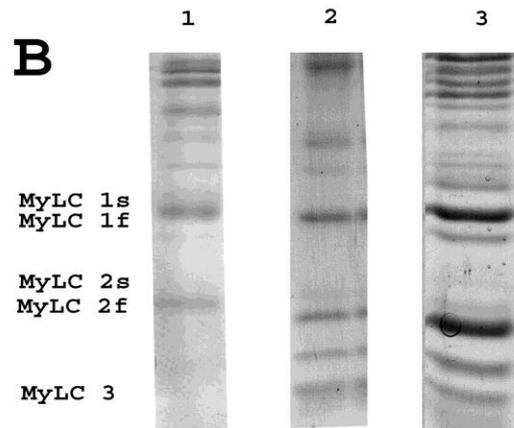


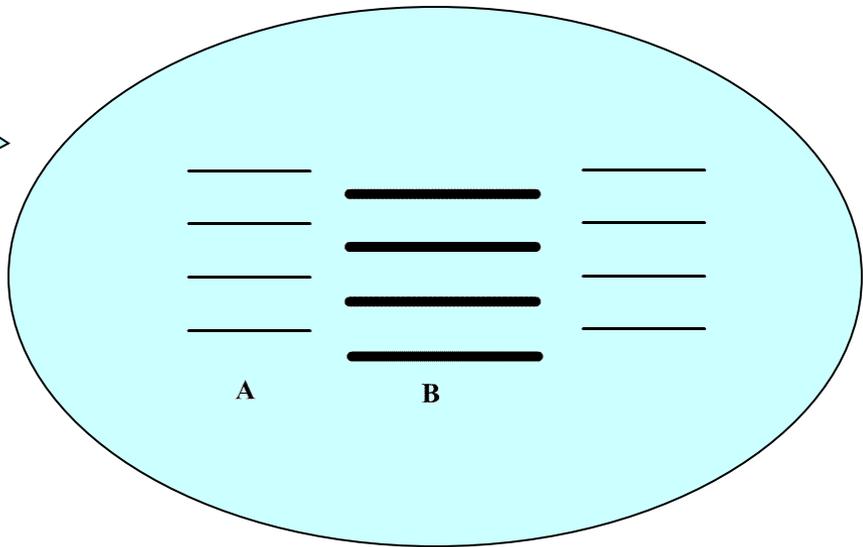
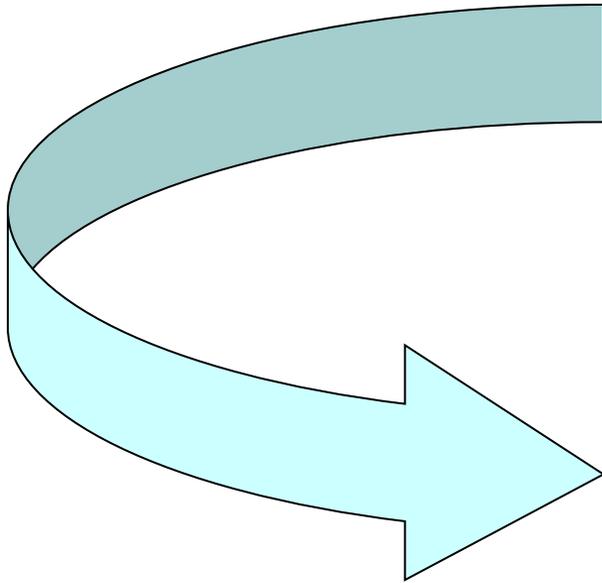
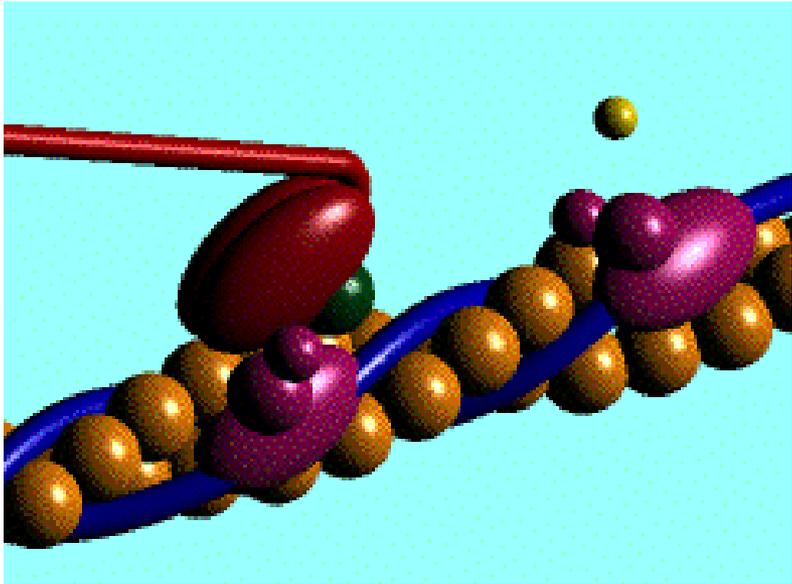
# Myosin isoforms:

## A

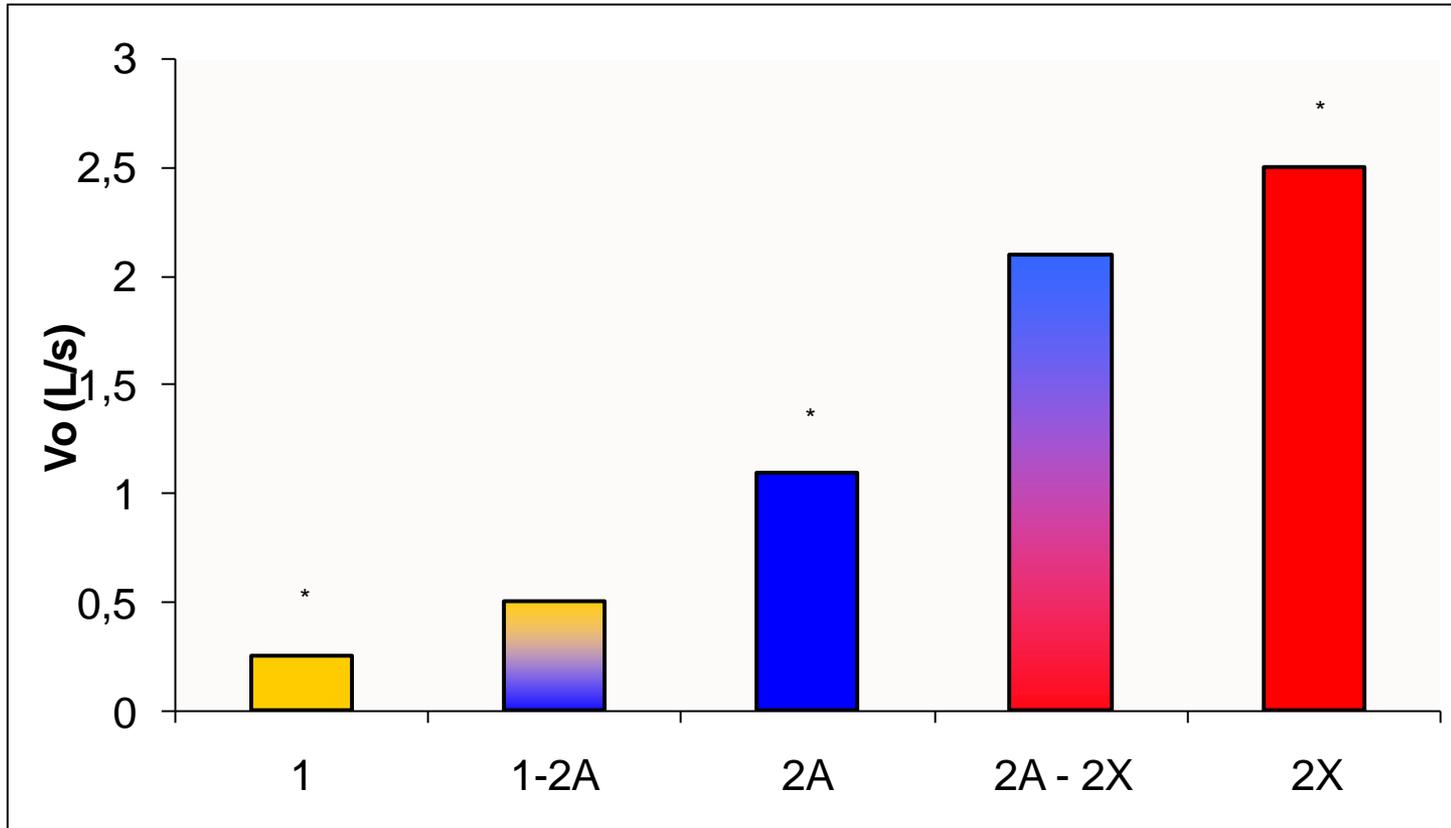


## B





# Actin filament sliding velocity



**T-system**

**DHPR**

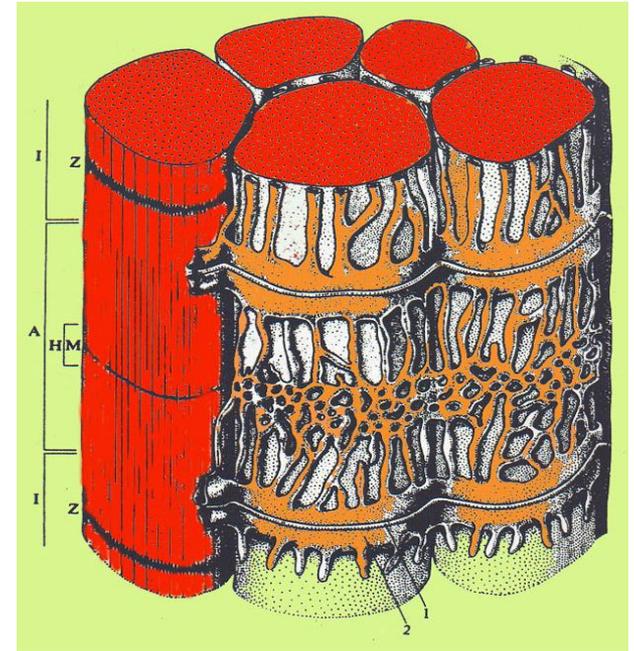
**SR**

**RyR**

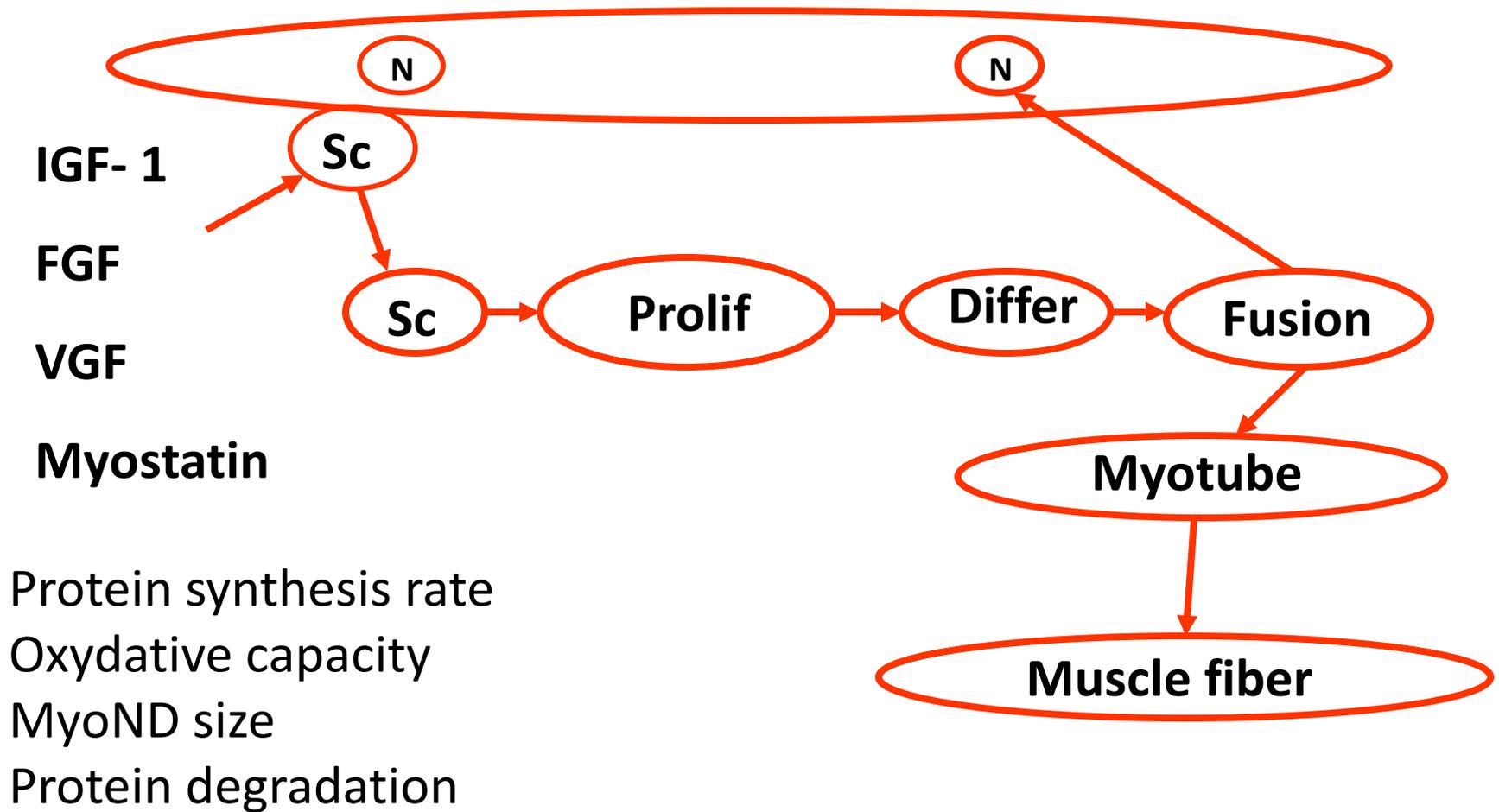
**SERCA  
1,2**

**Ca<sup>2+</sup>**

**mitochondria**



# Muscle fiber type/size paradox



Human organism is ready for strength development from late puberty



## Strength capacity changes through the life-span:

During first 5 months > ~ 300%

15-20 y > ~ 180% (25-35%/y)

20-30 y > ~ 15% (1.5-2.5%/y)

30-40 y < ~ 7% (0.3-0.8%/y)

50-70 y < ~ 30% (1.0-1.8%/y)

70-80 y < ~30% (2.5-3.5%/y)

# Neonates Strength Development



## Changes in the force moment of neck muscles during first five months:

1st month 0.64 N x m

4th month 1.73 N x m

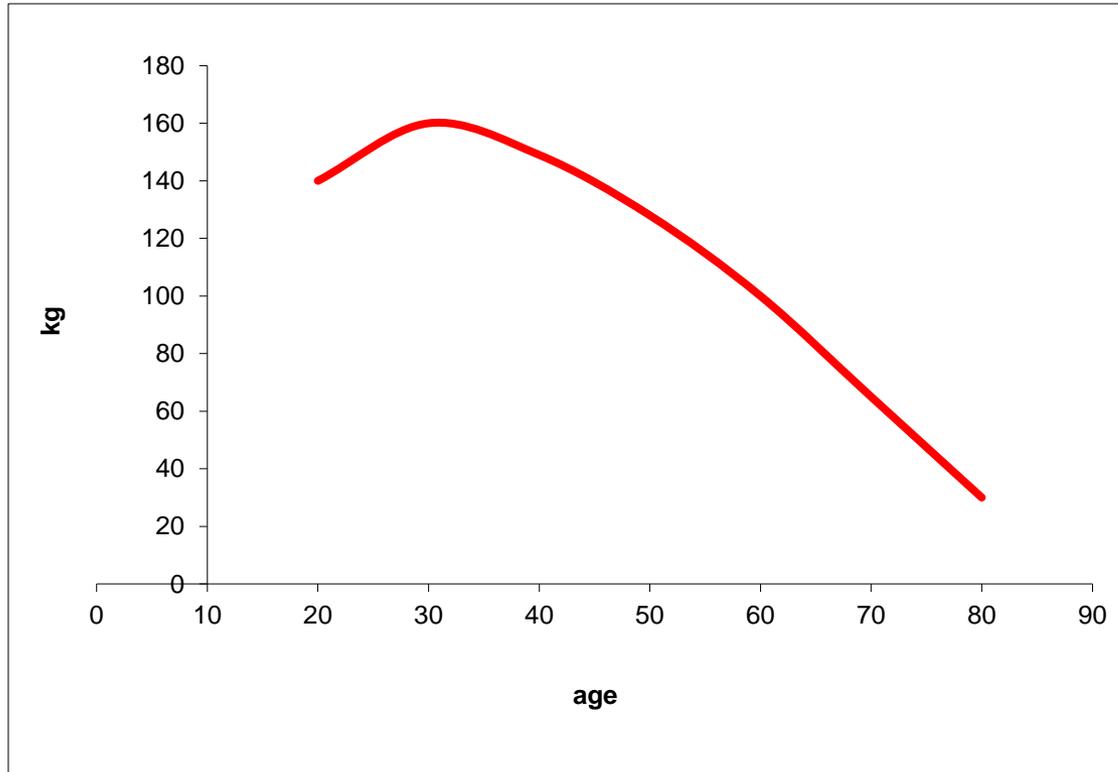
5th month 1.89 N x m

## During the first year

- Busy developing coordination
- Muscle strength



# Age related changes in muscle strength:





Changes in skeletal muscle at age 30 years (% per decade)

VO2max	mass	Muscle strength
3-8%	5-8%	3-8%

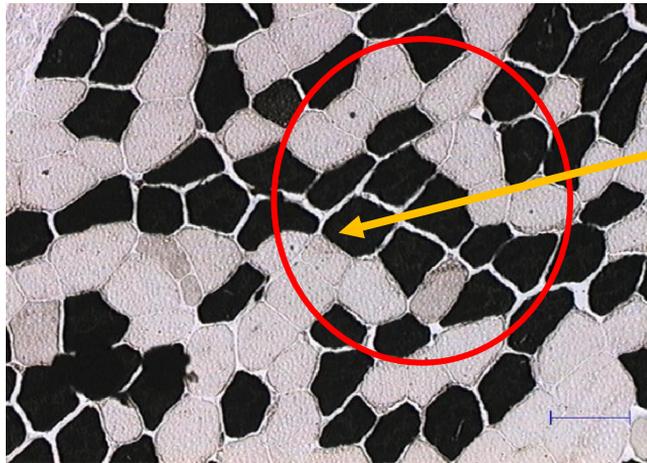
## Aging Tends to Reduce:

- Strength
- Endurance
- Agility
- Flexibility
- Balance

## Aging related functional /social limitations:

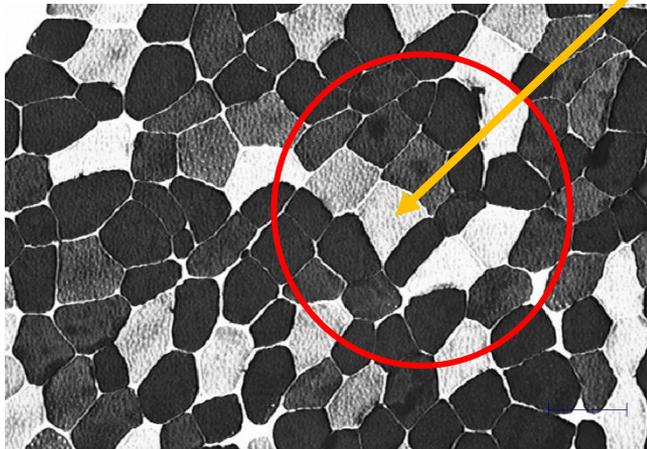
- Difficulties in walking;
- Climbing stairs;
- Lifting heavy objects;
- 60% of 65+ (w+m) cannot lift 5 kg;
- 5% weight loss cause 2x increase in risk of disability;
- Loss of independency;

Age-related decline in muscle mass results from type II fiber atrophy and loss of number of these fibers



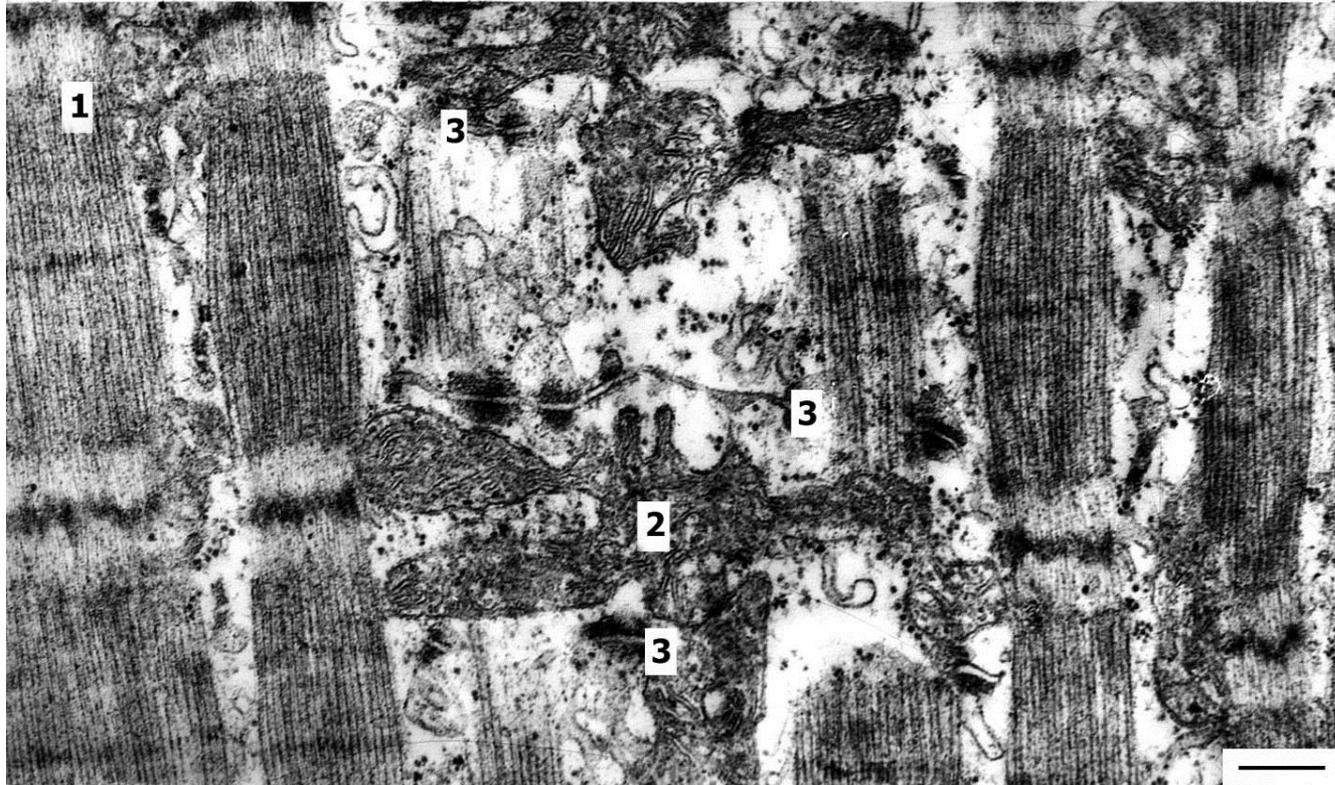
9.6

IIB  
IIX

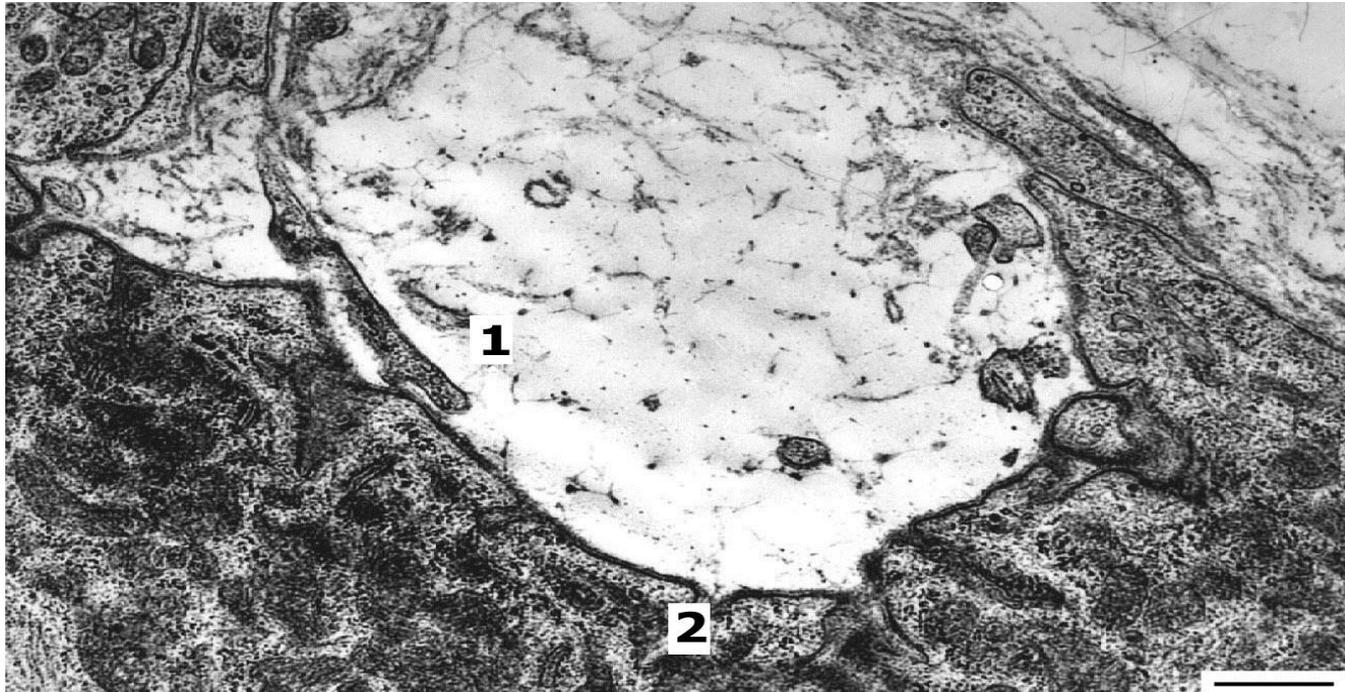


4.5

# Destruction of myofibrills



# Destruction of neuromuscular junction



## Age- related decrease of muscle mass:

- Increases the risk of developing glucose intolerance and diabetes
- Muscle tissue is the primary site of glucose disposal

# Sarcopenia:

- Changes in hormonal anseble;
- Anabolic/catabolic processis in muscle;
- Alterations in immune function;
- Redduction in total motor unit number;
- Structural changes in muscle fibres;
- Chronic inflammation;
- Decrease in physical activity.

## Percentage of sarcopenic person

Age (yrs)	Men	Women
<70	14%	25%
70-74	20%	33%
75-80	27%	33%
>80	53%	43%

## Dynapenia:

- Impairment of neural activation;
- Excitation-contraction uncoupling;
- Fibre type transformation;
- Infiltration of adipocytes into muscle fibres;
- Deterioration of capillary blood supply;
- Reduction in muscle contractile quality;
- Reduction in functional reserve;
- Decrease in vital capacity.



Predicted organ mass change from 20 to 80 yrs of age  
(adapted by Manini, 2009)

**Muscle weakness** is the main factor in the dysfunction of motor activity and balance during life



## Physical risk factors for falls of children and aging persons:

- Muscle weakness;
- Reduced walking speed;
- Inability to maintain balance.



## Successful Aging – is it real?

“Exercise is low–cost and low–tech, accessible to nearly everyone, and thus highly suited for potentially widespread participation”

(Kramer & Erickson, 2007)

## Adaptation to exercise training/therapy

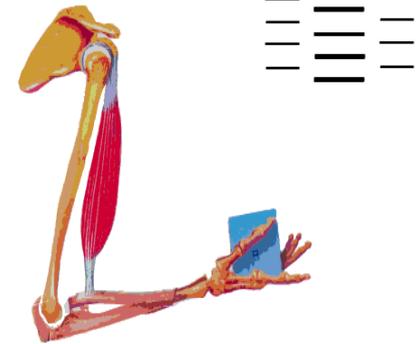
Training session provokes both an increase in fitness and an increase in fatigue

Training session suppress performance ability, the recovery period allow for improved performance because residual fatigue resulting from training fades more rapidly than the residual fitness resulting from training

$$\text{performance ability} = \frac{\text{increase in fitness}}{\text{fatigue from last training session}}$$

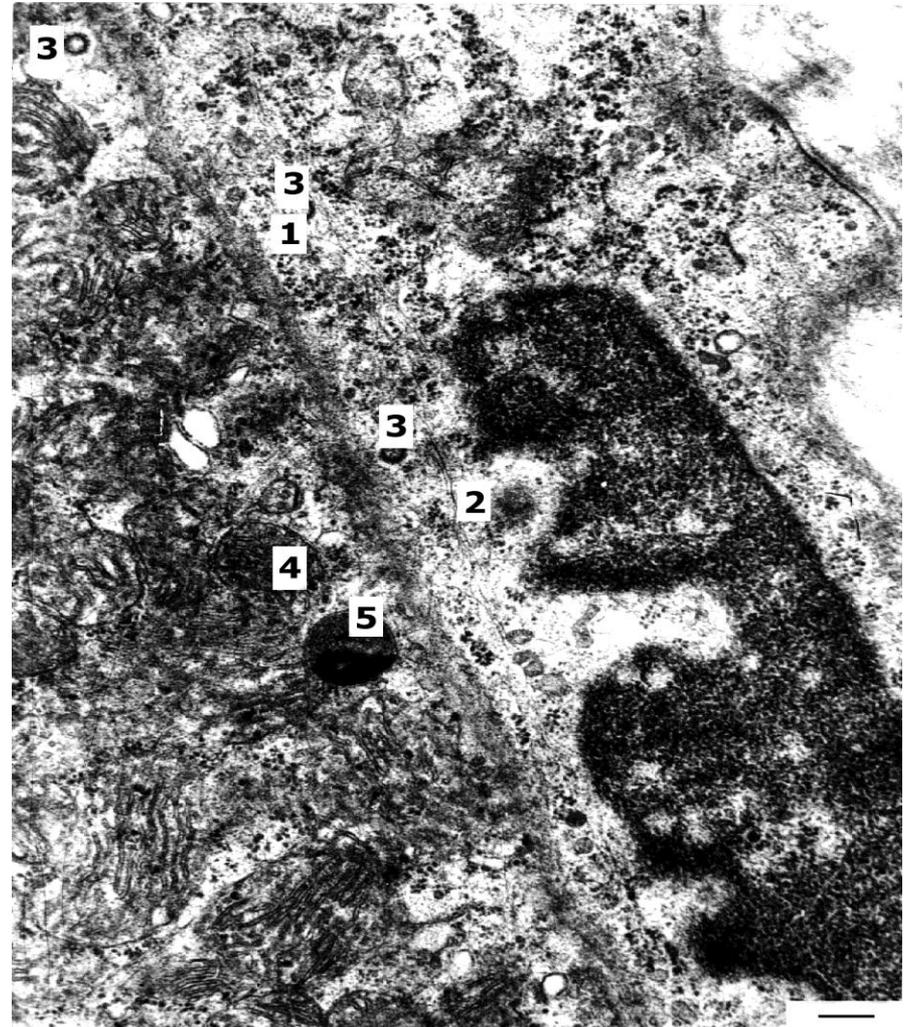
# Resistance Training:

- Increase muscle strength;
- Hypertrophy of FT fibres;
- Anabolic and anticatabolic effect on muscle;
- Structural rearrangement in FT fibres;
- Increase in the turnover rate of myofibrillar proteins;
- Improvement in neuromuscular junctions;
- Qualitative remodelling of skeletal muscle.

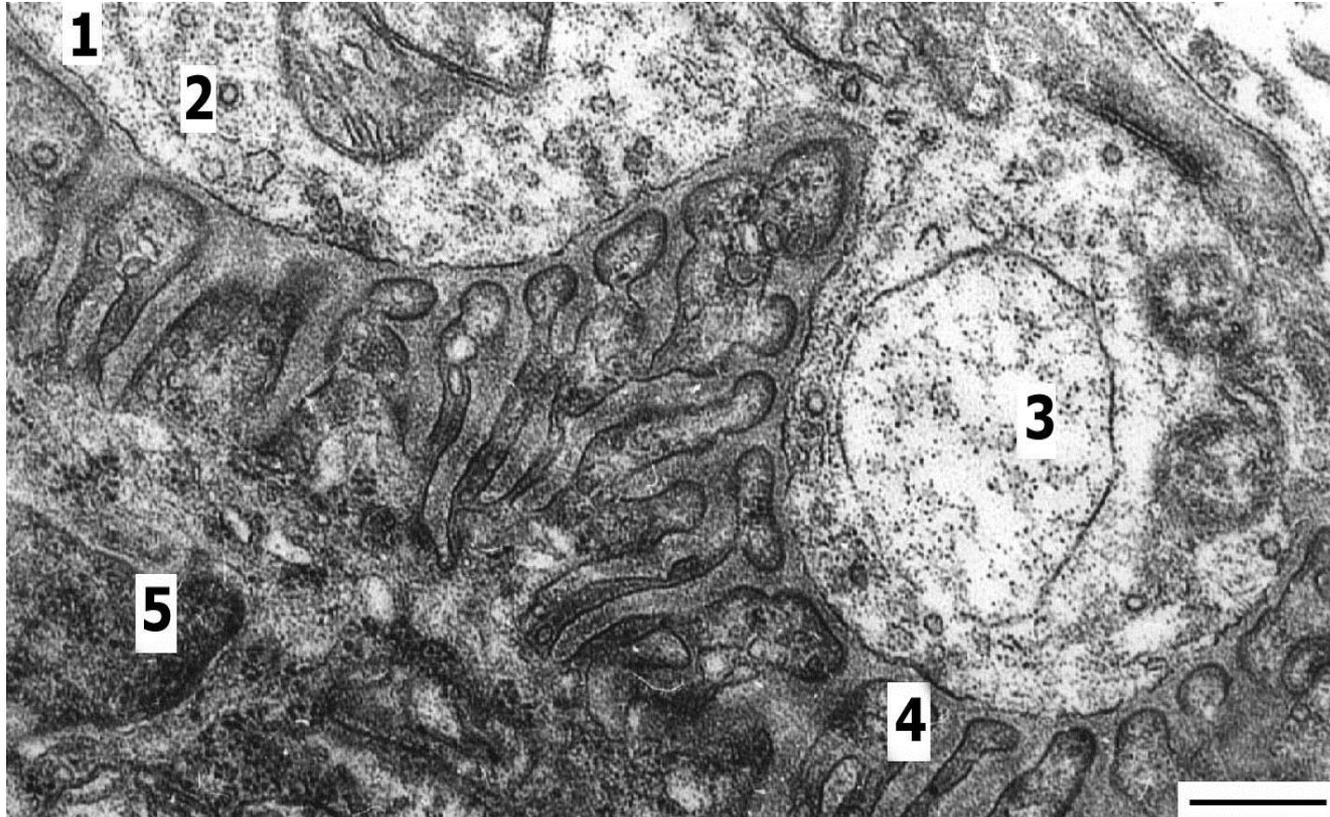


## Resistance training response is quick:

- 4 h after training FSR of muscle proteins increases;
- In type II fibers hypertrophy is faster than in type I



# Increase of postsynaptic folds



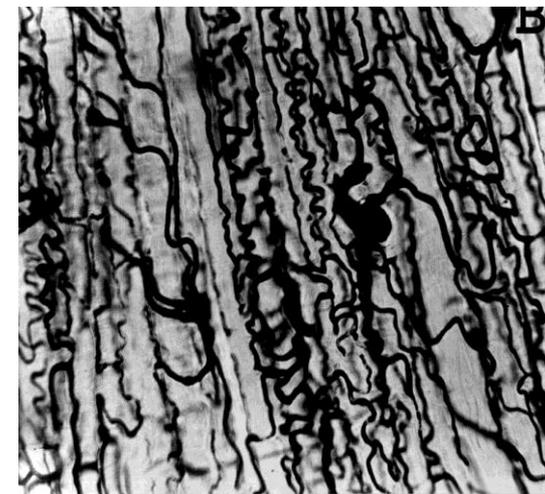
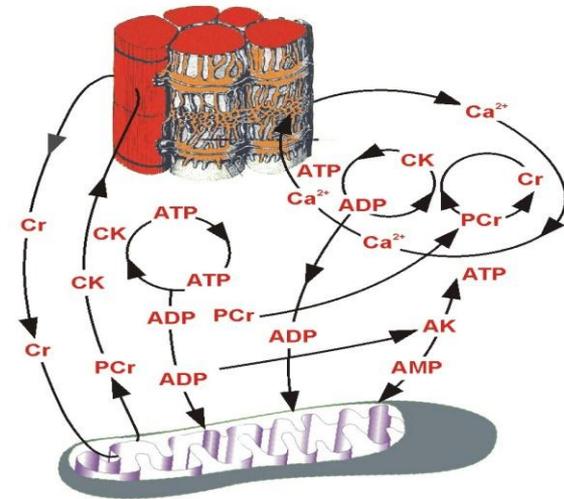
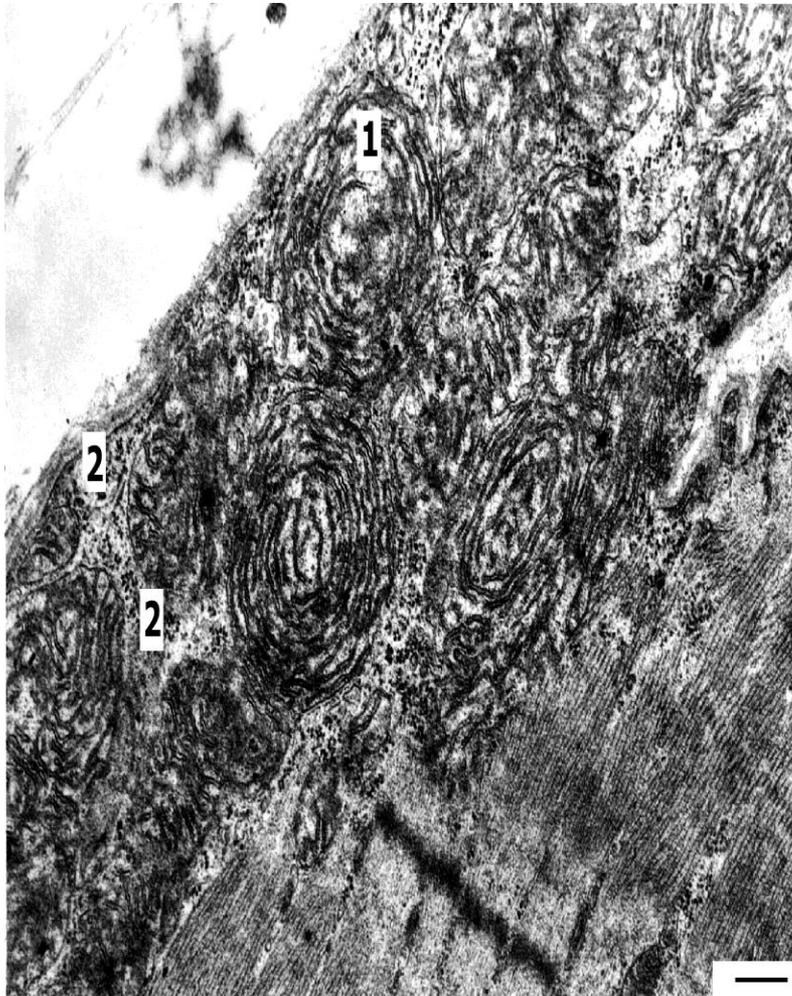
- Relative intensity (% of maximal strength - % 1 RM)
- Too low relative intensity (< 40% 1RM)
  - IIX fibers do not recruit
  - IIX fibers stay in “reserve”
  - IIA fibers are recruited
  - no transformation occurs from IIX → IIA fibers

**Endurance** – the ability to maintain or repeat a given force or power output



# Endurance training

results in increased mitochondrial density, capillary supply, changes in key metabolic enzymes and increased maximal oxygen uptake

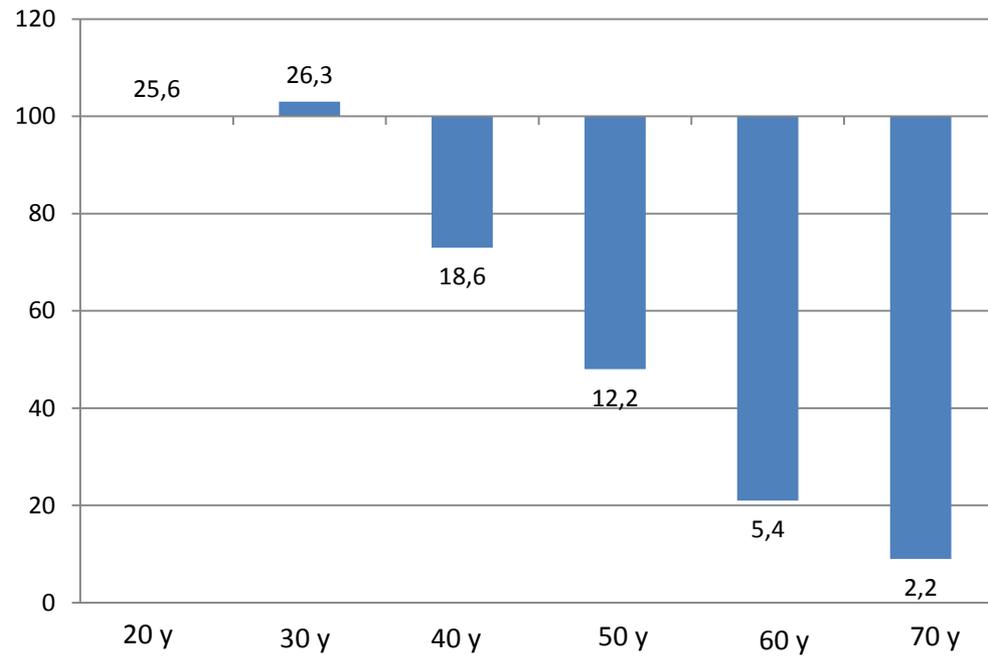


Rowing is an endurance event, but not the classical one

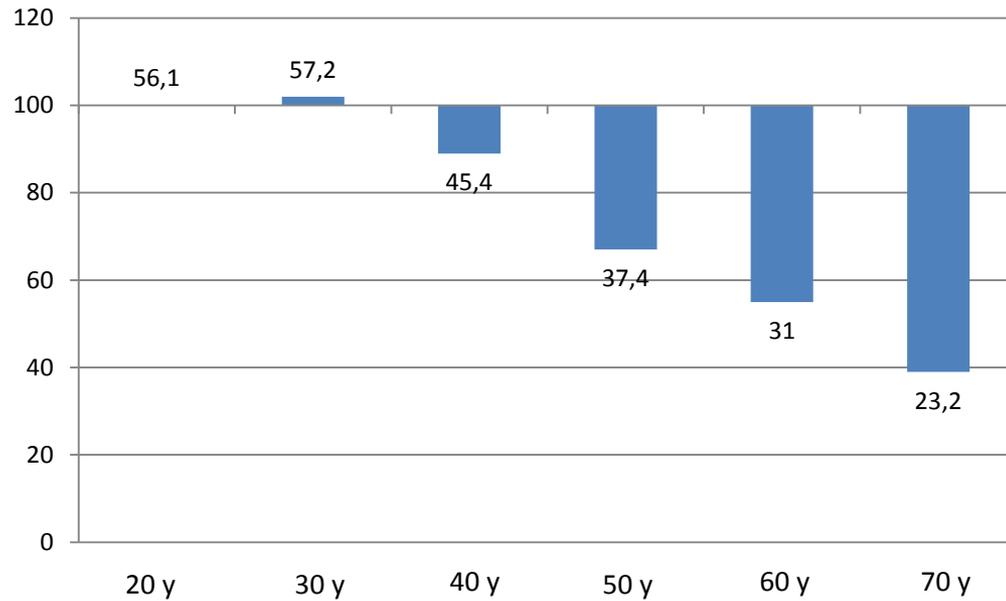


~70% of muscle mass is recruited during the 2000 m race

~65-90% 1 RM (during each stroke)



Age related changes in rowers' pull up capacity (reps/30'')



Age related changes in rowers two footed jump capacity (m/30'')

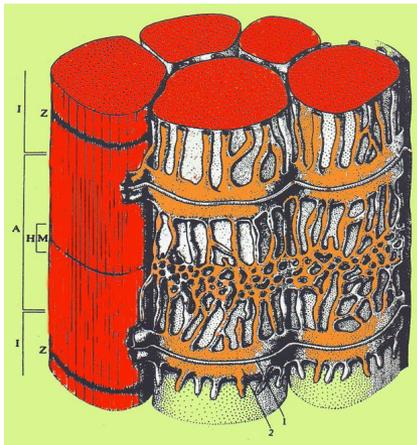
# Resistance and Endurance Training

- are leading to the deceleration of muscle weakness
- the effect of concurrent endurance and strength training among aging persons???



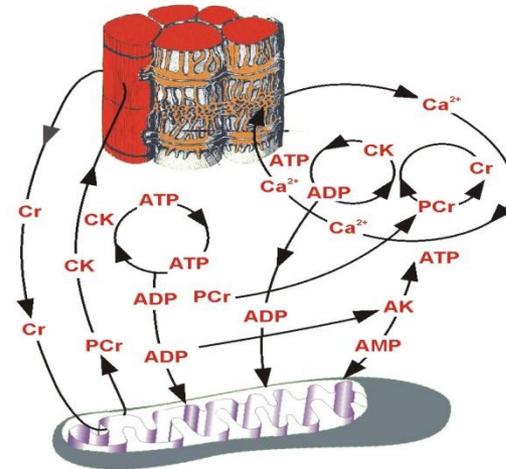
## Strength training

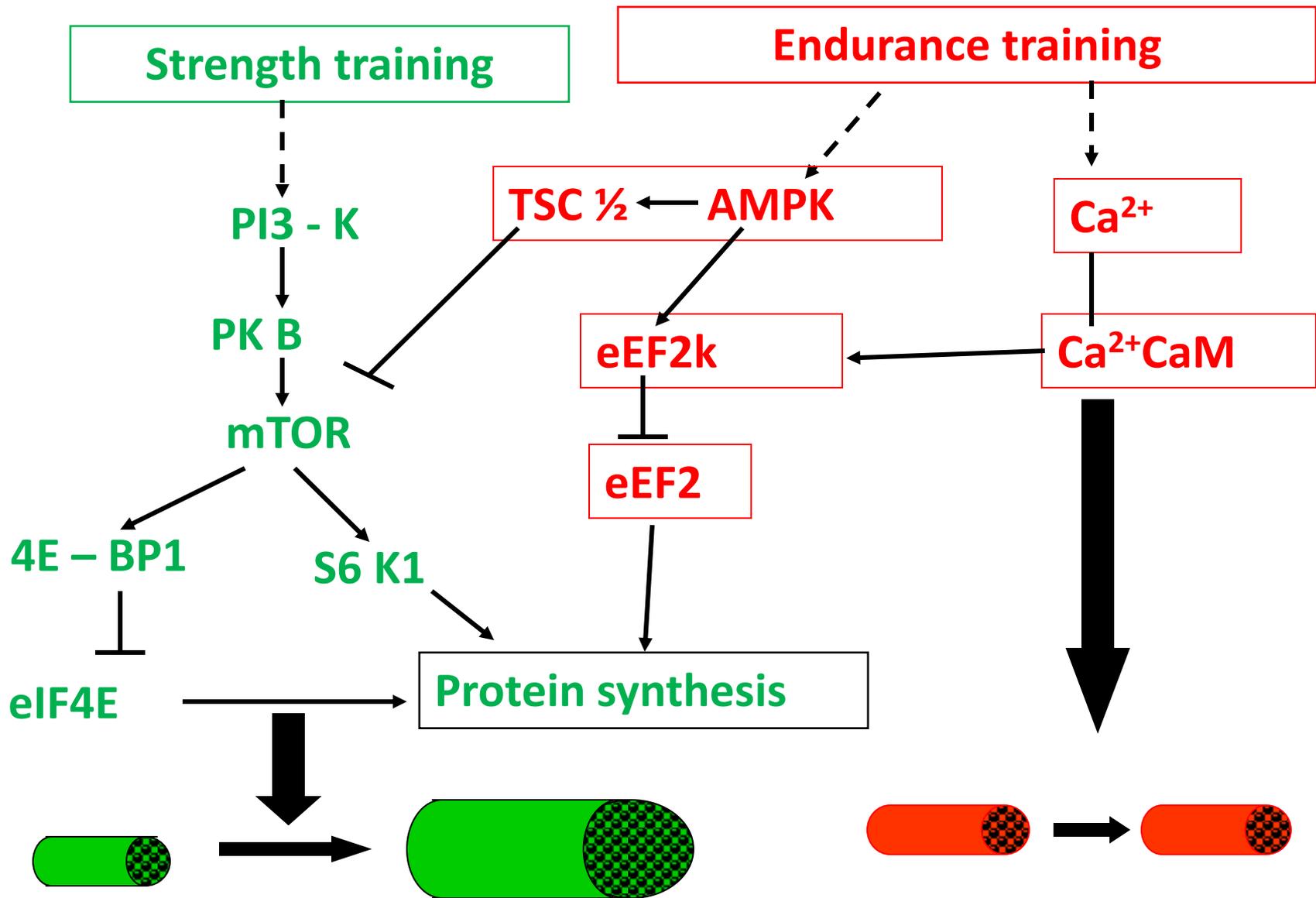
Activates signaling to modulate protein synthesis rate and muscle growth



## Endurance training

Activates signaling involved in metabolic homeostasis





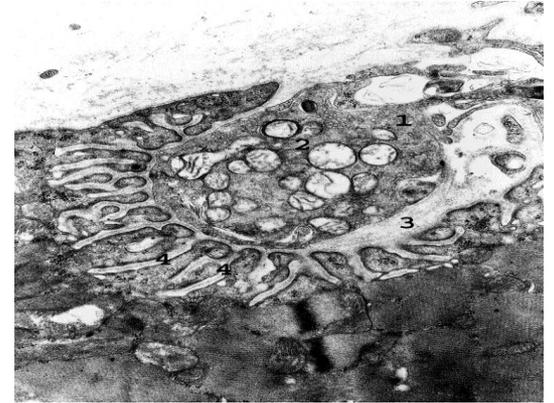
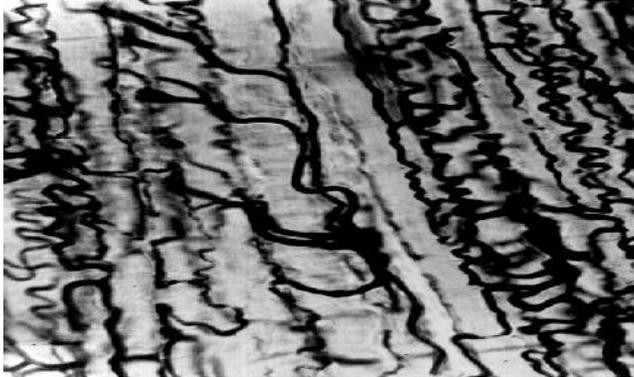
## Exercise caused muscle hypertrophy



Muscle hypertrophy as a result of **myostatin** (GDF-8) gene mutation



# CONCLUSION



Sc ↑

N ↑ (myonuclear domain size do not change)

MyHC IIx ↓ (qualitative remodeling)

The sequence of endurance and strength training is necessary in daily training (anticatabolic effect of resistance training)

