

Disciplina Bioquímica da Atv. Motora

Fibra e Metabolismo Muscular Esquelético: Efeitos do Exercício Físico

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Cronograma do Curso

✓ Fibras e Metabolismo Muscular:

- *Estrutura e função das fibras musculares;*
- *Metodologias utilizadas para determinação do tipo fibra;*
- *Efeito do treinamento físico;*
- *Proteínas determinantes para mudança do perfil de fibras e metabolismo;*
- *Treinamento físico e DCV (HA, IC, obesidade e envelhecimento).*



Qual a importância de se estudar o tecido muscular esquelético?



Músculo esquelético

Corpo humano possui cerca de
660 músculos

Constituem cerca de 45% da massa
corporal



Regulação da Massa e Manutenção da Saúde

Hipertrófico



Eutrófico



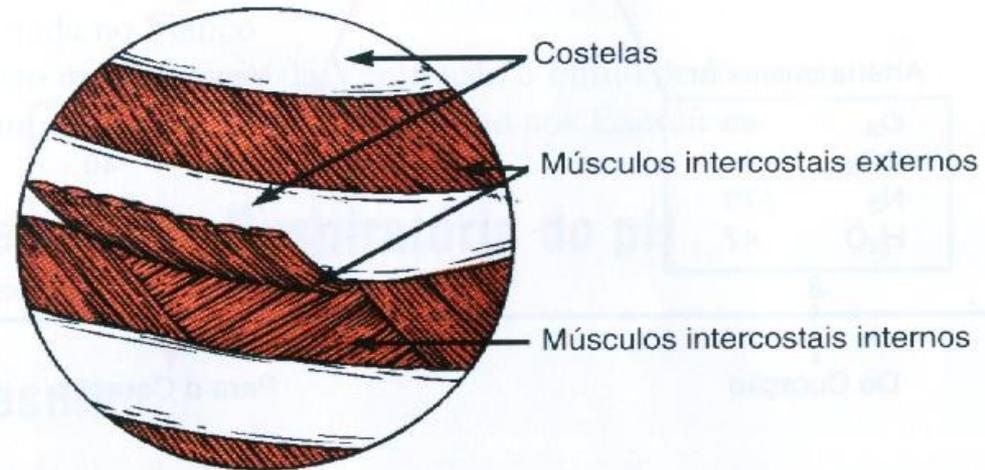
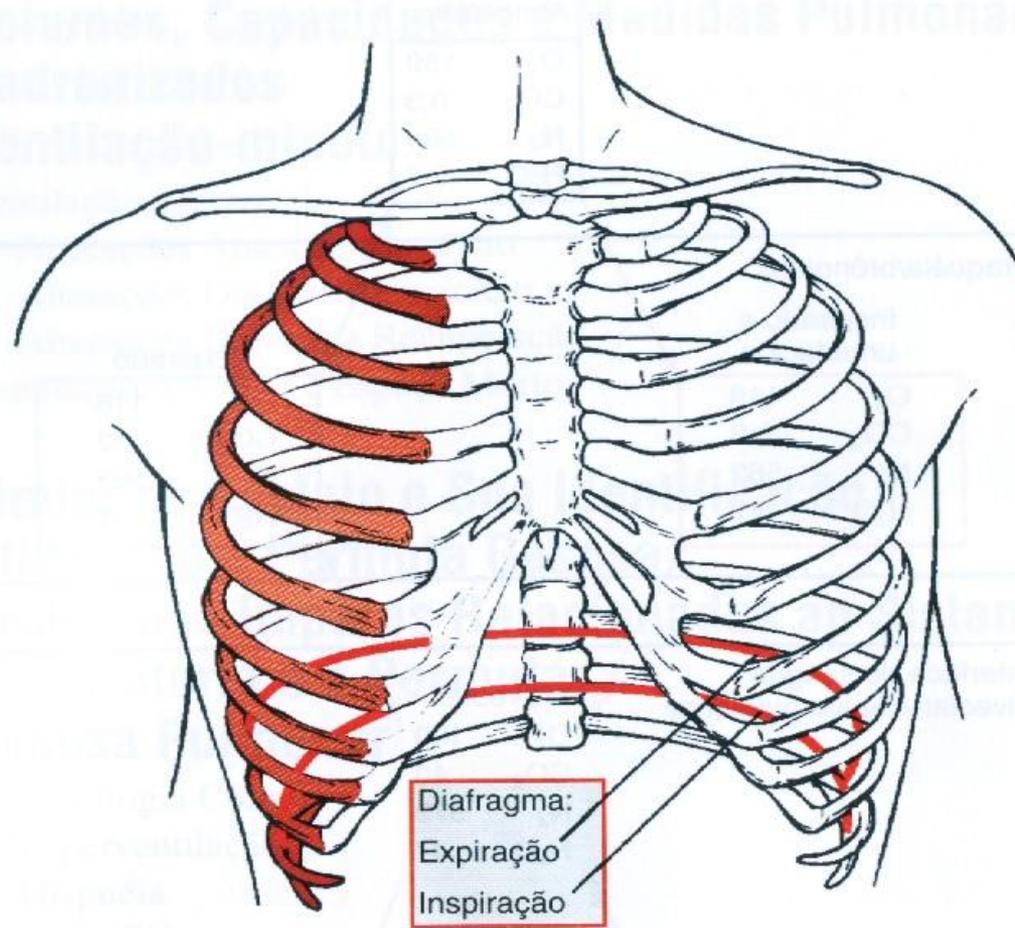
Hipotrófico



Músculo esquelético

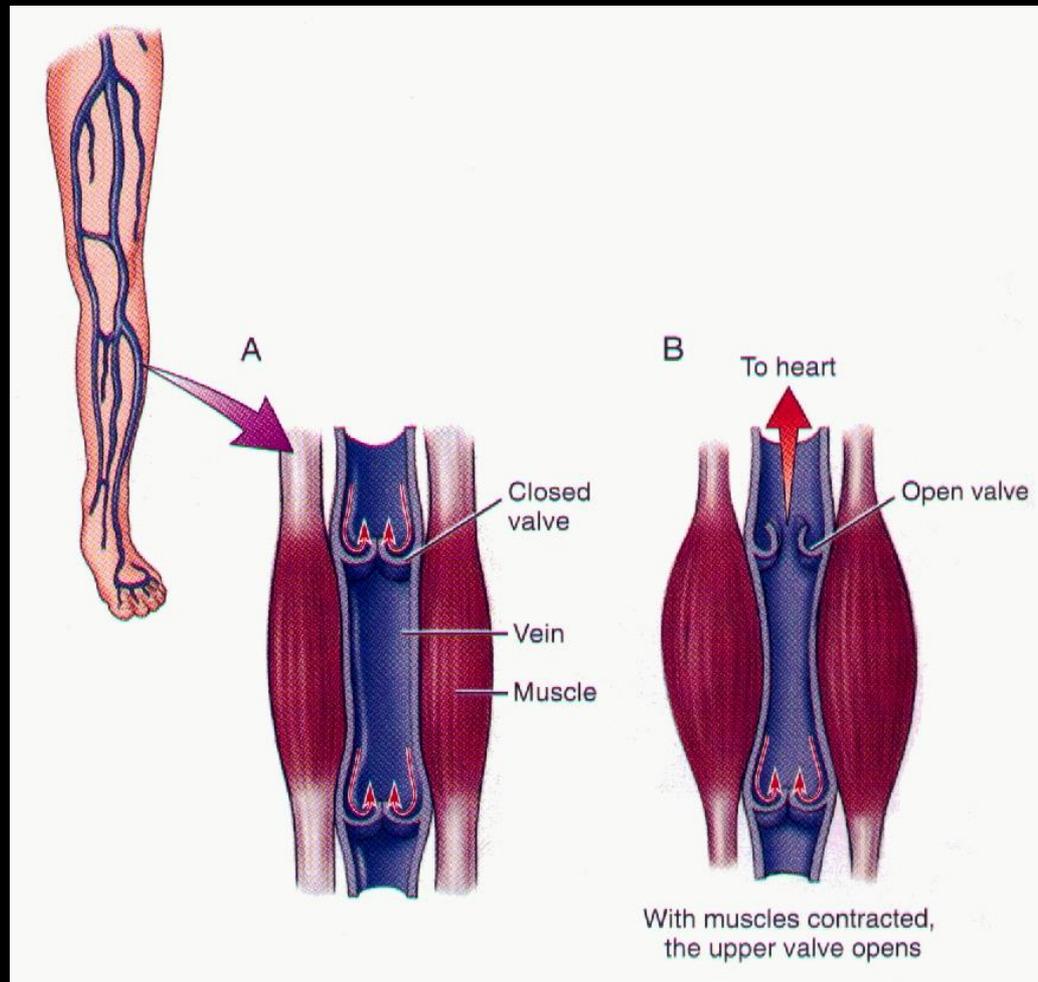
- Funções do Músculo Esquelético
 - Movimentação e estabilidade articular
 - Manutenção da postura
 - Produção de energia química em mecânica
 - Produção de calor
 - Reservatório de proteínas

Sistema Respiratório

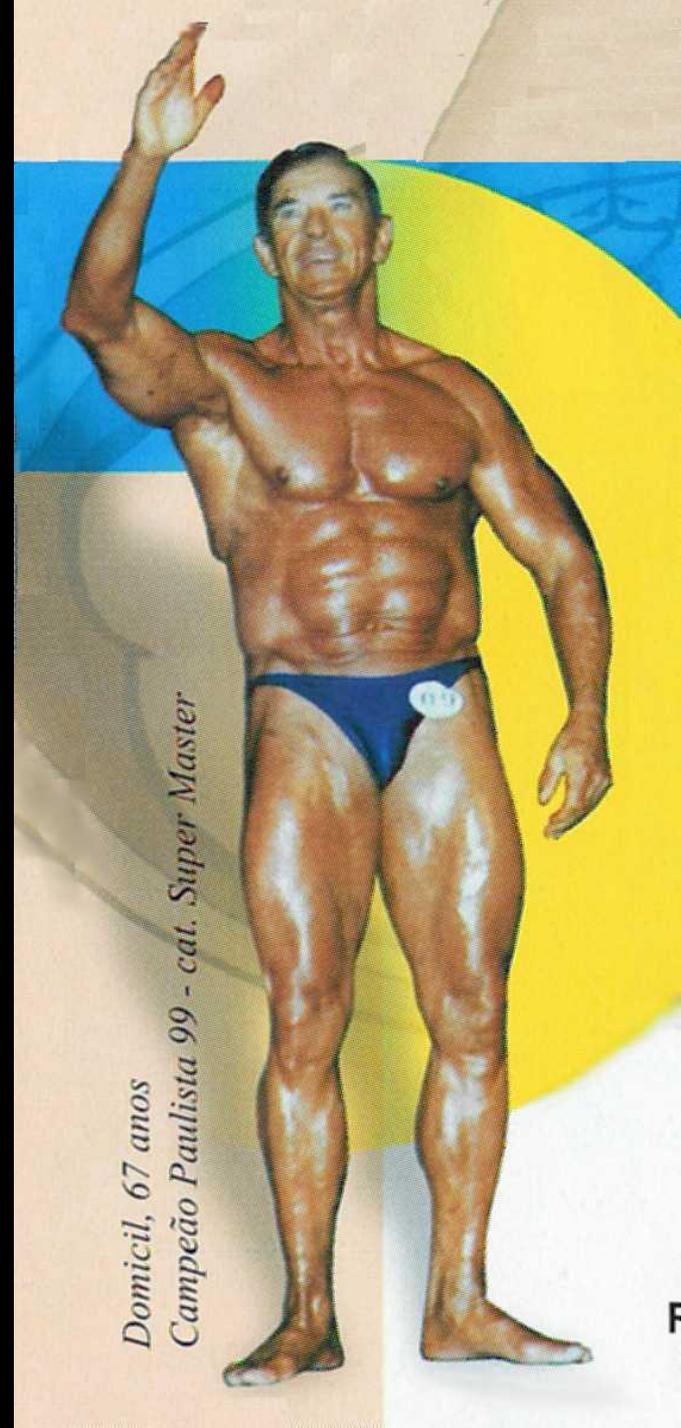


Sistema Cardiovascular

- Auxílio no Retorno Venoso “2º coração”



Envelhecimento



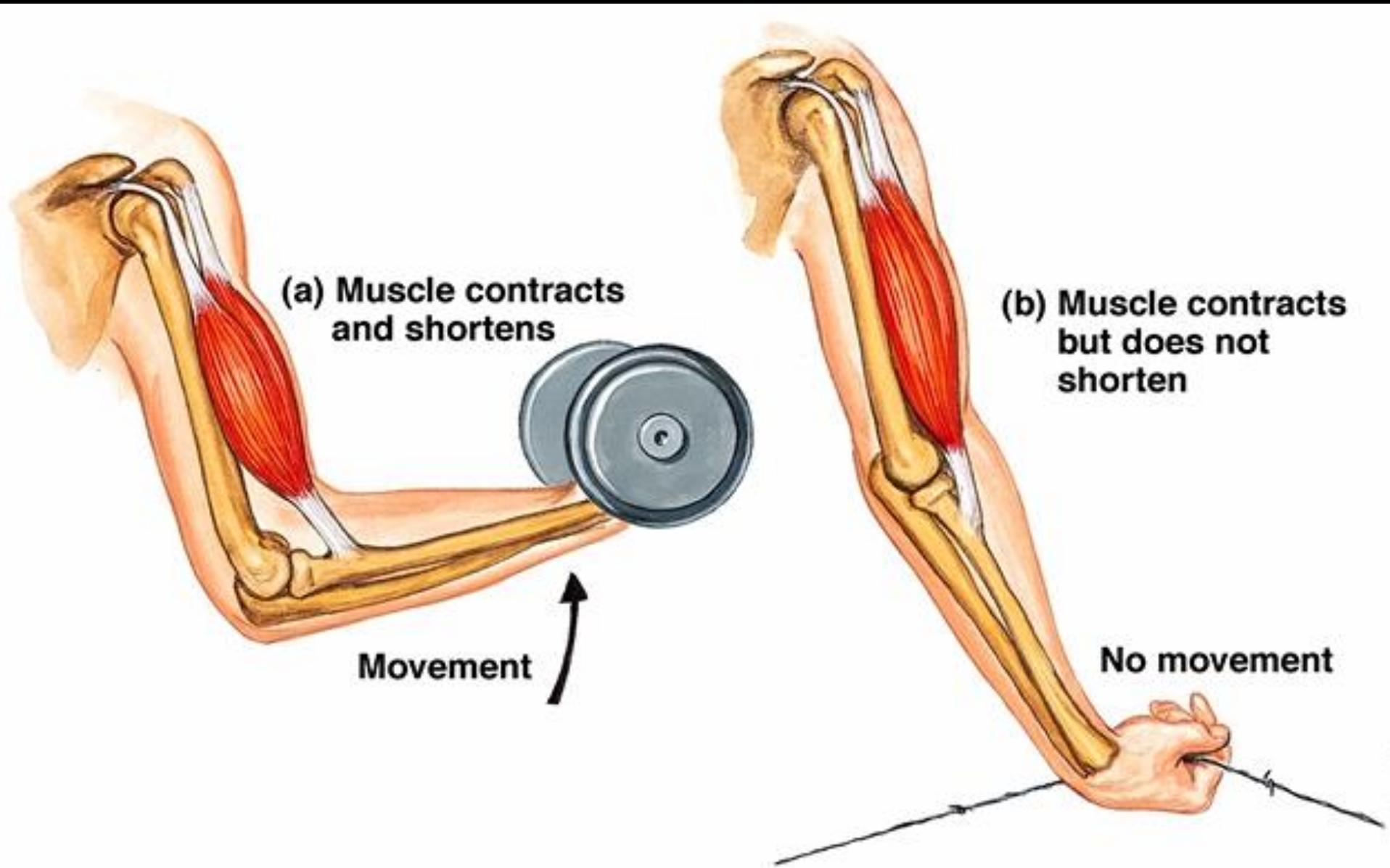
*Domicil, 67 anos
Campeão Paulista 99 - cat. Super Master*

Contração Muscular:

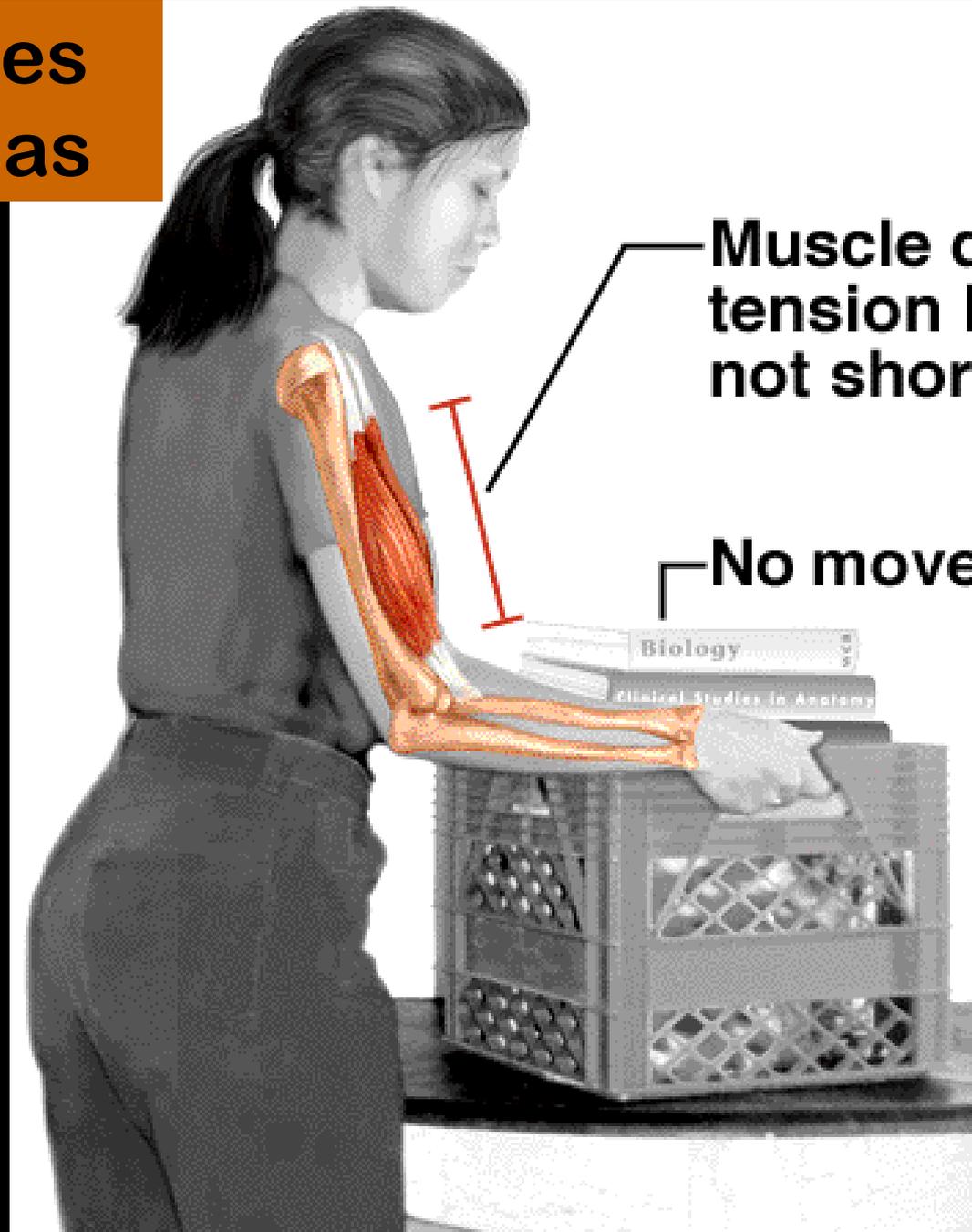


“ É a ativação das fibras musculares, com tendência à encurtamento.”

Tipos de contração muscular



Contrações isométricas



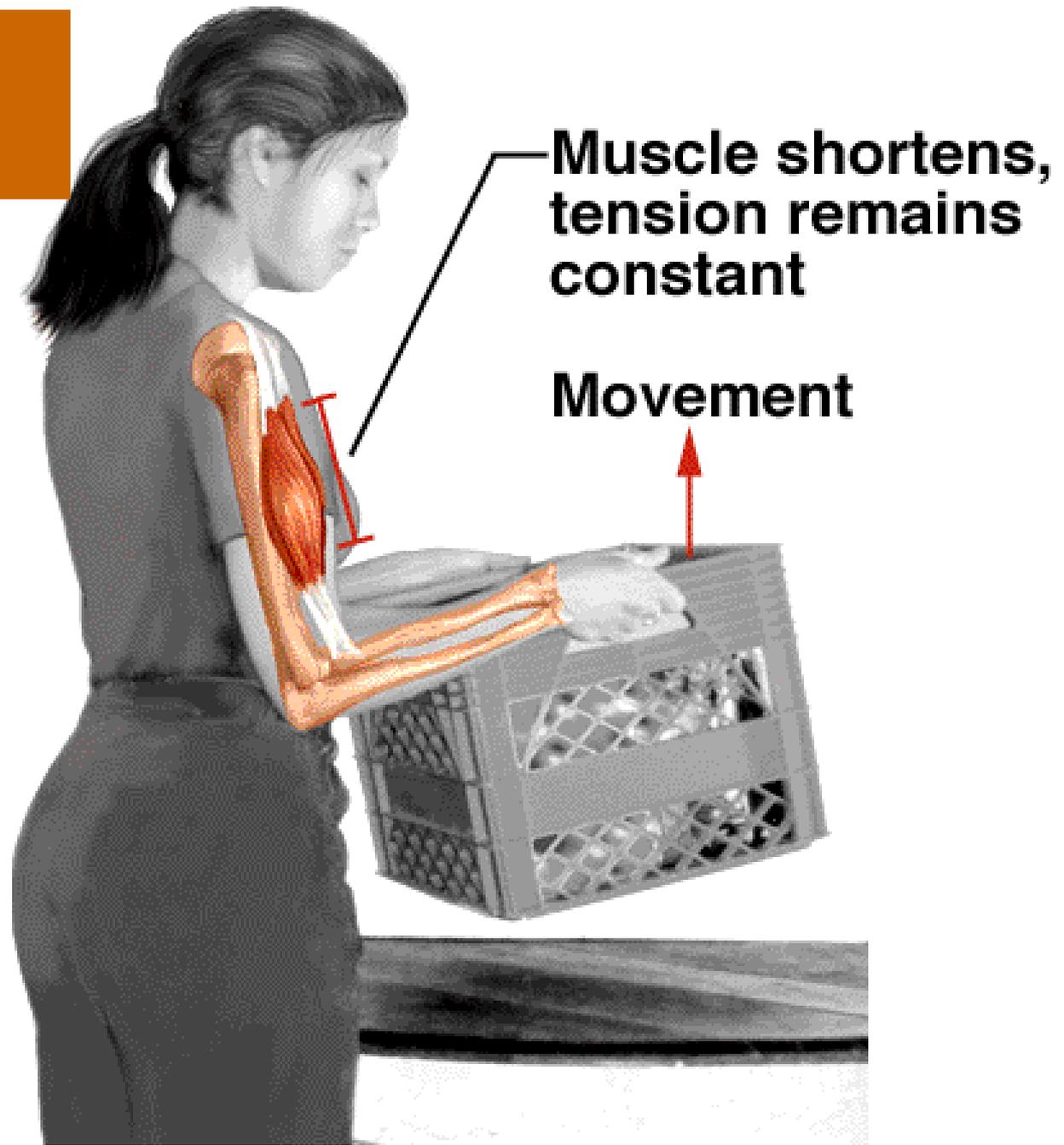
Muscle develops tension but does not shorten

No movement

Contrações dinâmicas:

Concêntricas

Excêntricas



Organização Hierárquica da musculatura esquelética

Músculo



Feixe



Fibras



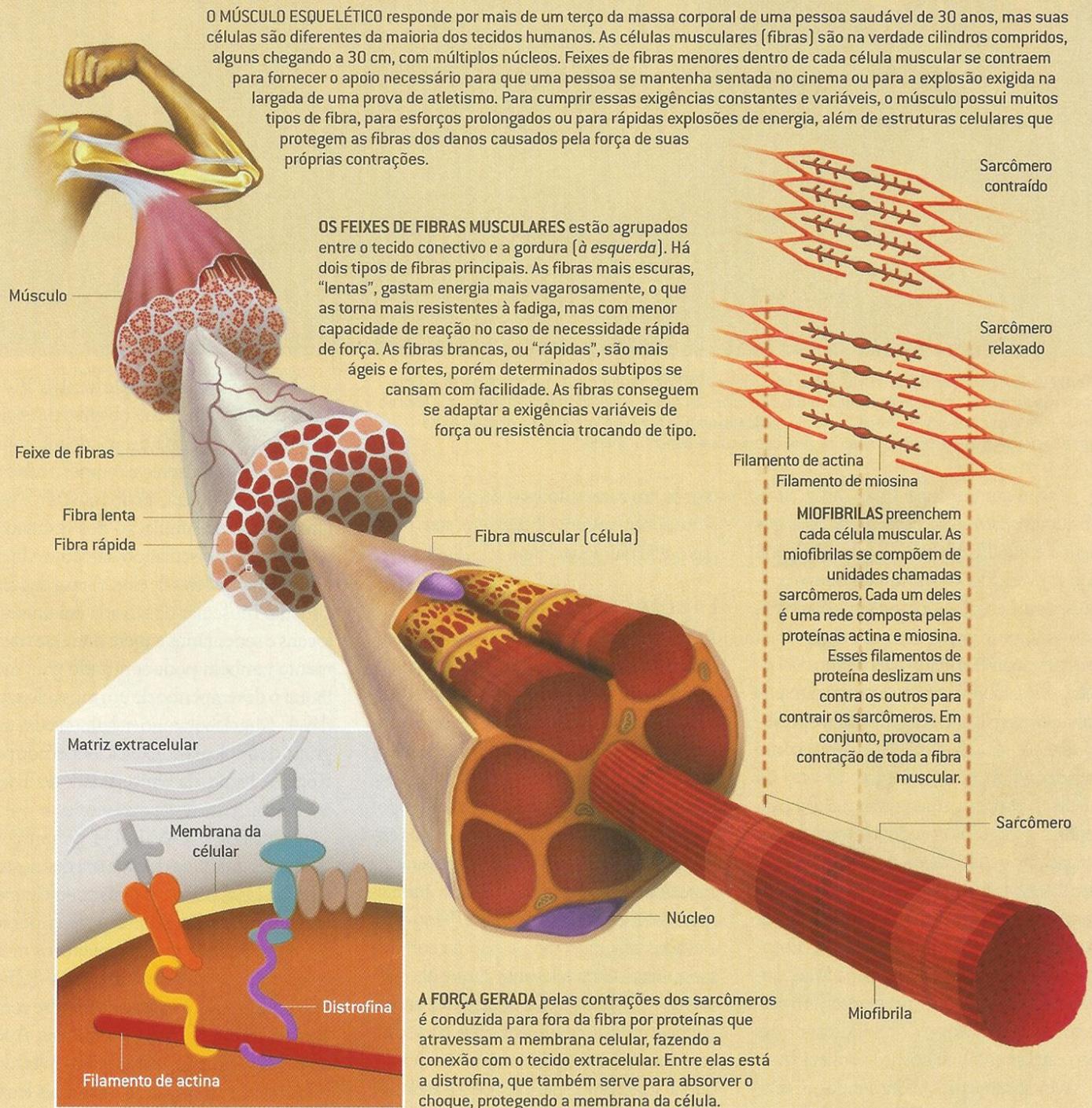
Miofibrilas



Sarcômeros



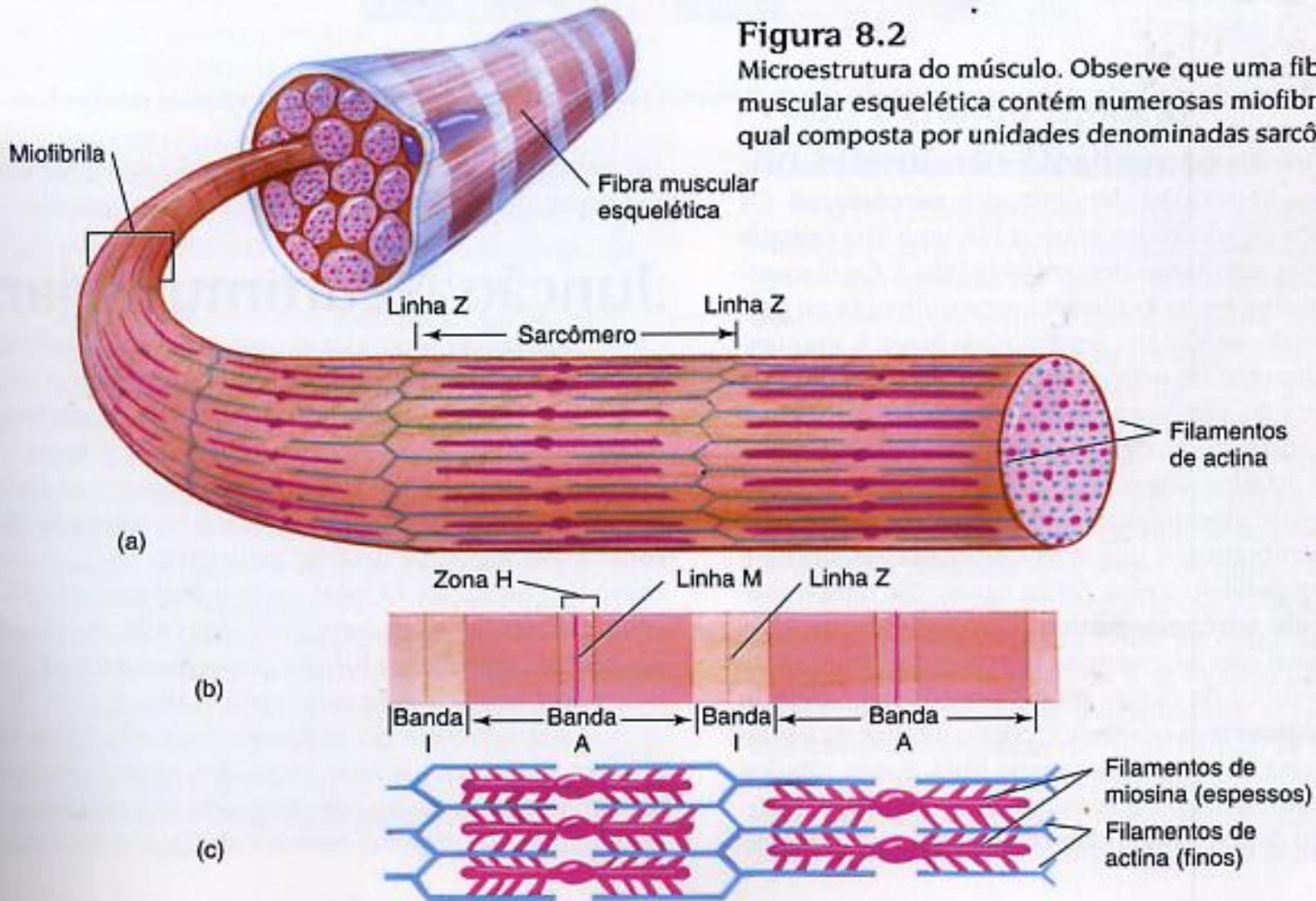
Miofilamentos

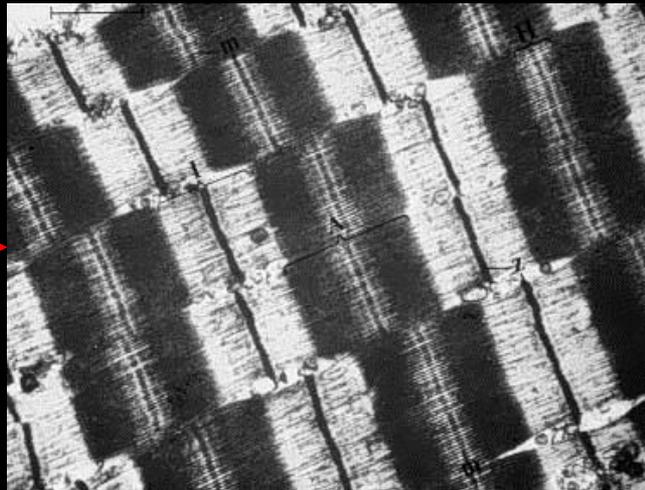
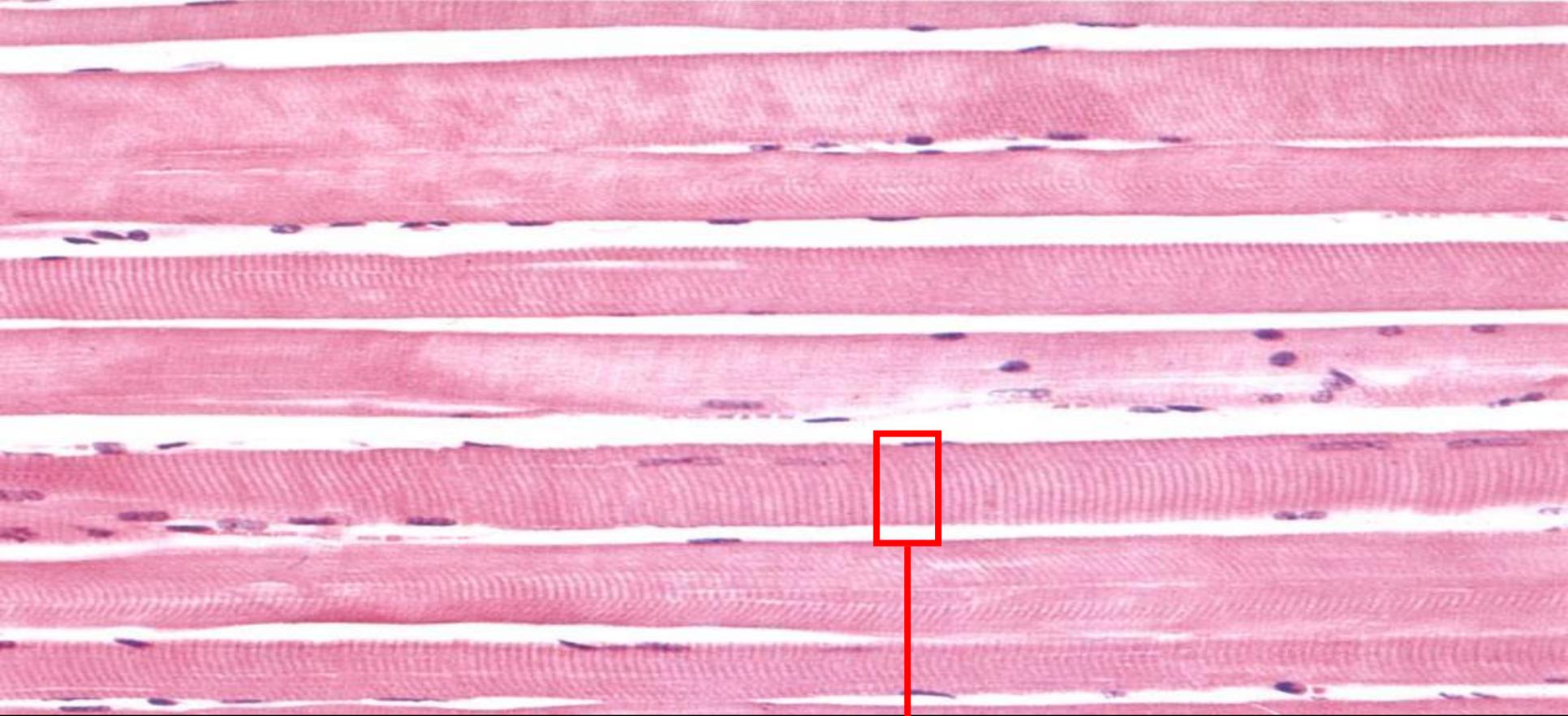


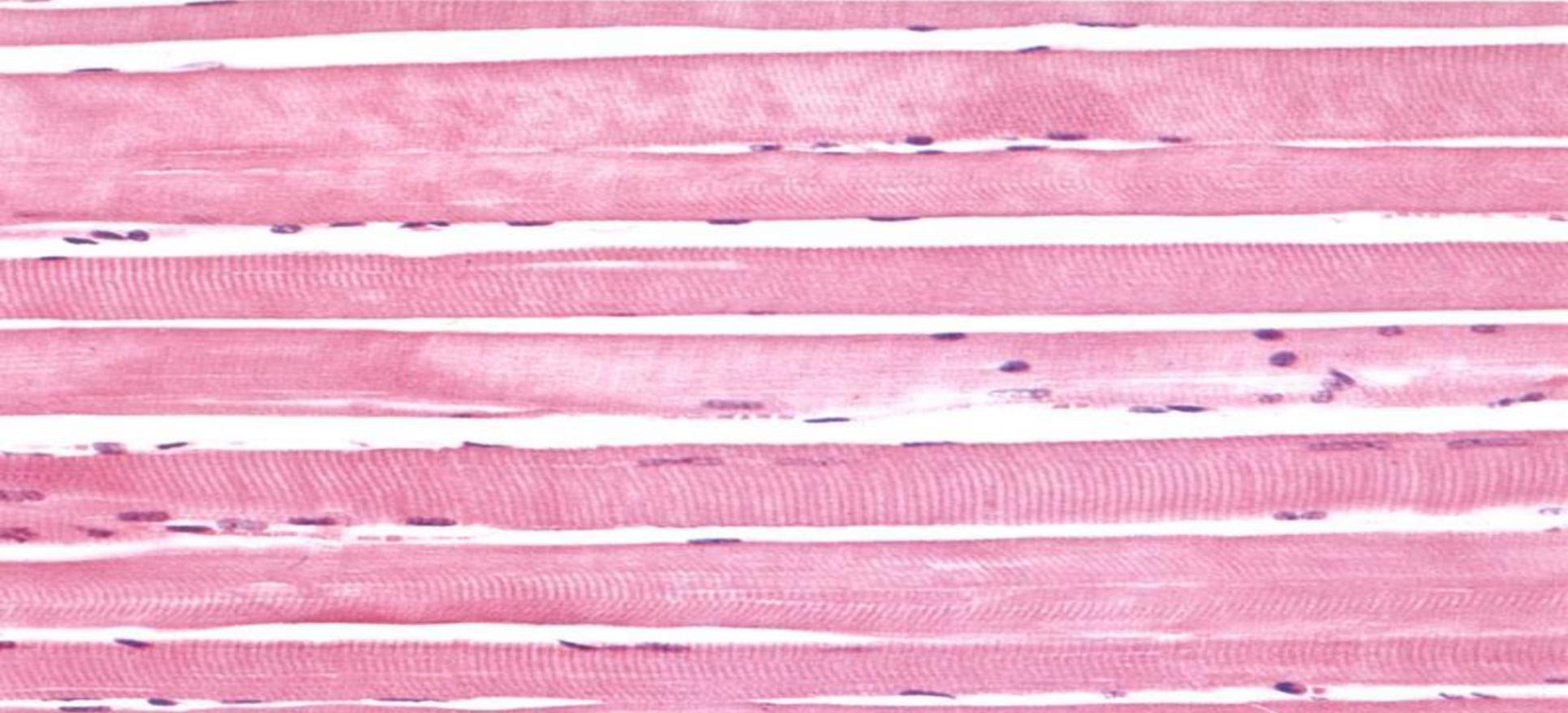
Microestrutura da Musculatura Esquelética

Figura 8.2

Microestrutura do músculo. Observe que uma fibra muscular esquelética contém numerosas miofibrilas, cada qual composta por unidades denominadas sarcômeros.





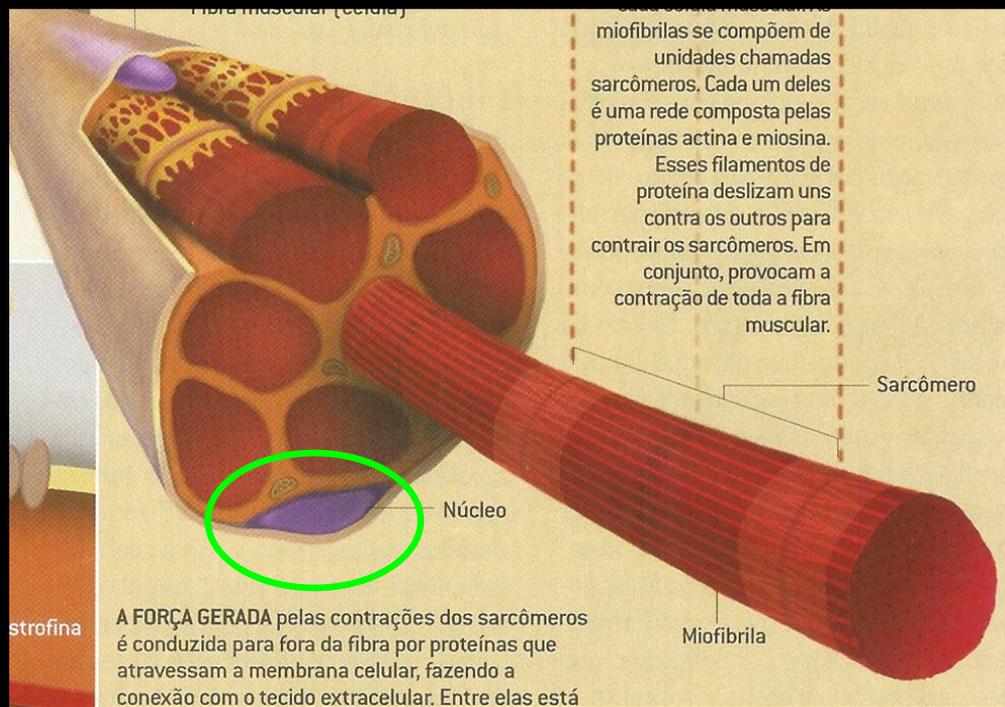


~ 200-300 mionúcleos por mm de fibra

Músculo	Comprimento do músculo	Comprimento das fibras musculares
Gastrocnêmio medial	25 cm	3,5 mm
Sartório	50 cm	45 cm

Fibra muscular (cardíaca)

As miofibrilas se compõem de unidades chamadas sarcômeros. Cada um deles é uma rede composta pelas proteínas actina e miosina. Esses filamentos de proteína deslizam uns contra os outros para contrair os sarcômeros. Em conjunto, provocam a contração de toda a fibra muscular.



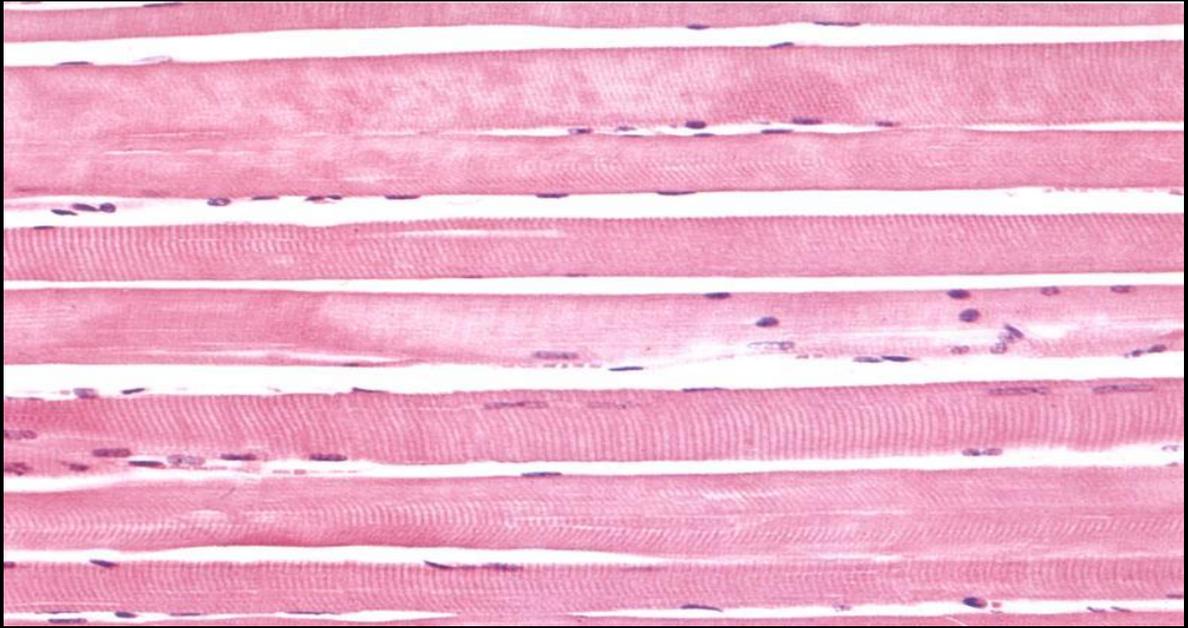
Sarcômero

Núcleo

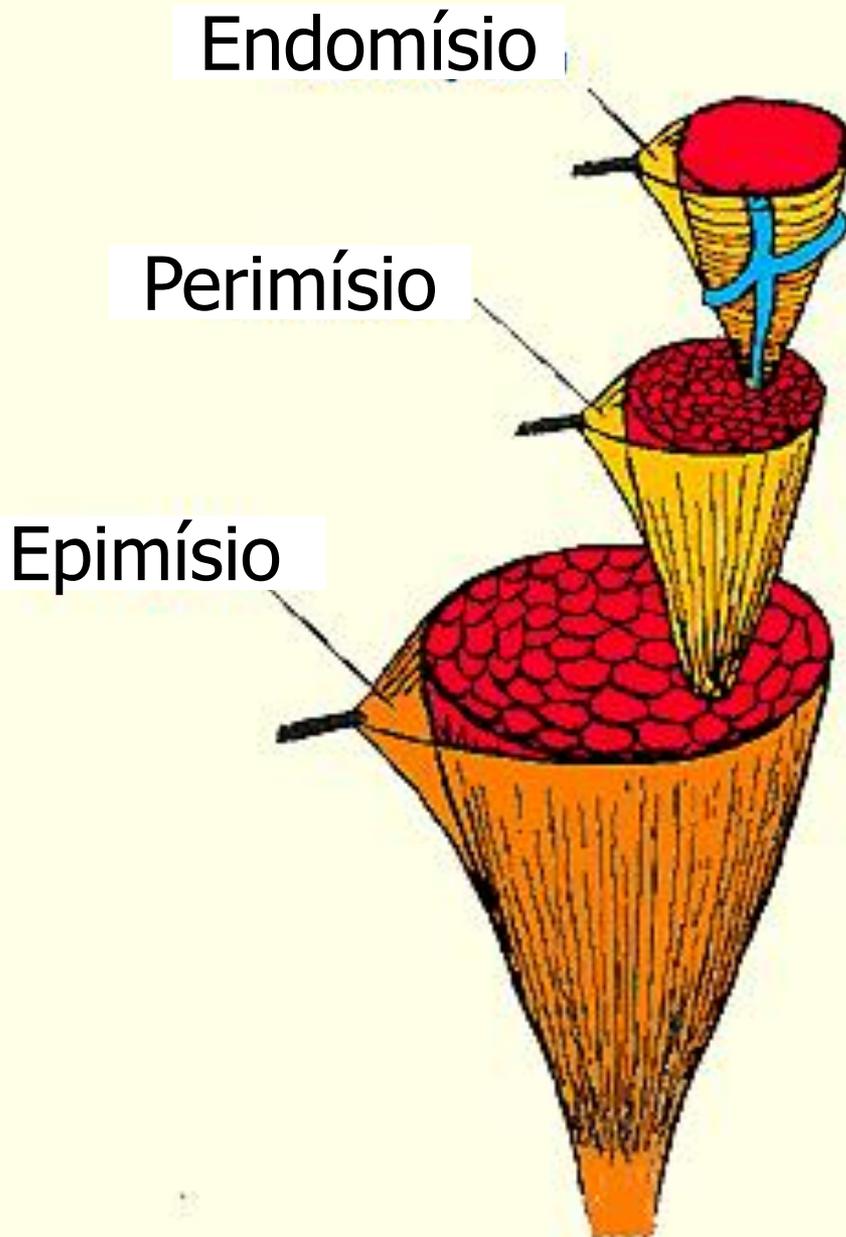
Miofibrila

trofina

A FORÇA GERADA pelas contrações dos sarcômeros é conduzida para fora da fibra por proteínas que atravessam a membrana celular, fazendo a conexão com o tecido extracelular. Entre elas está



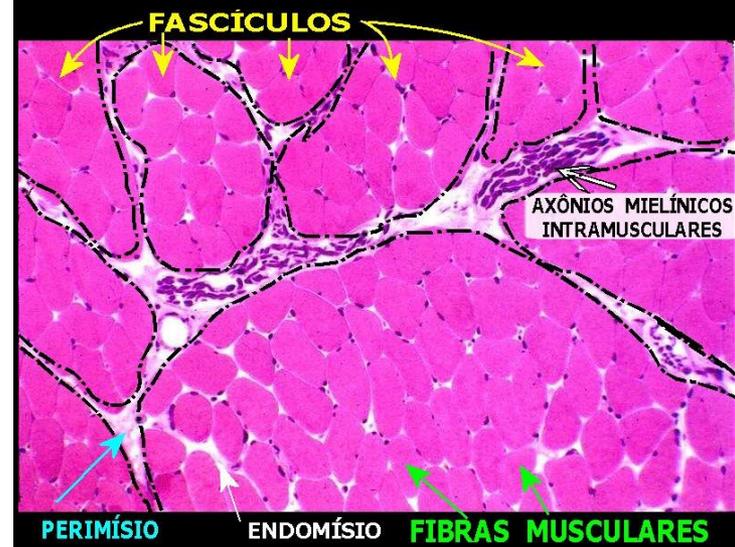
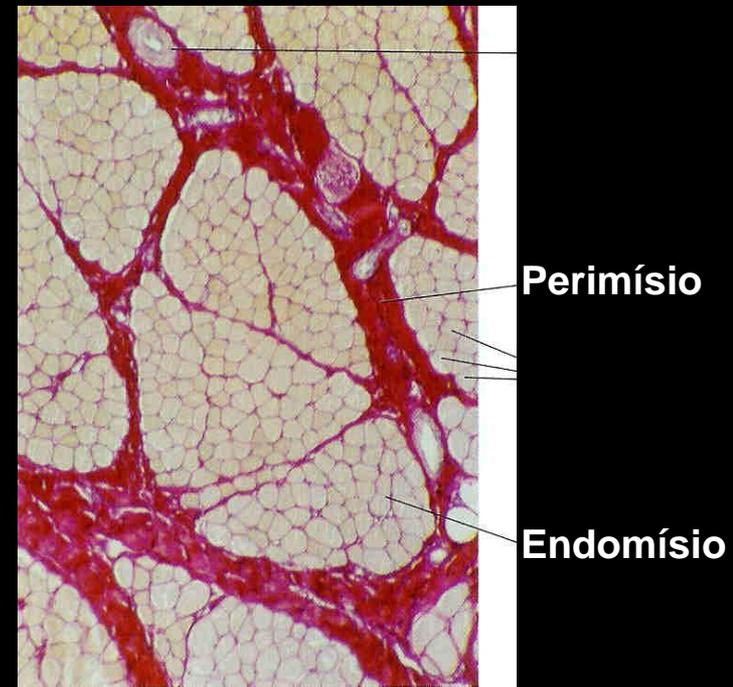
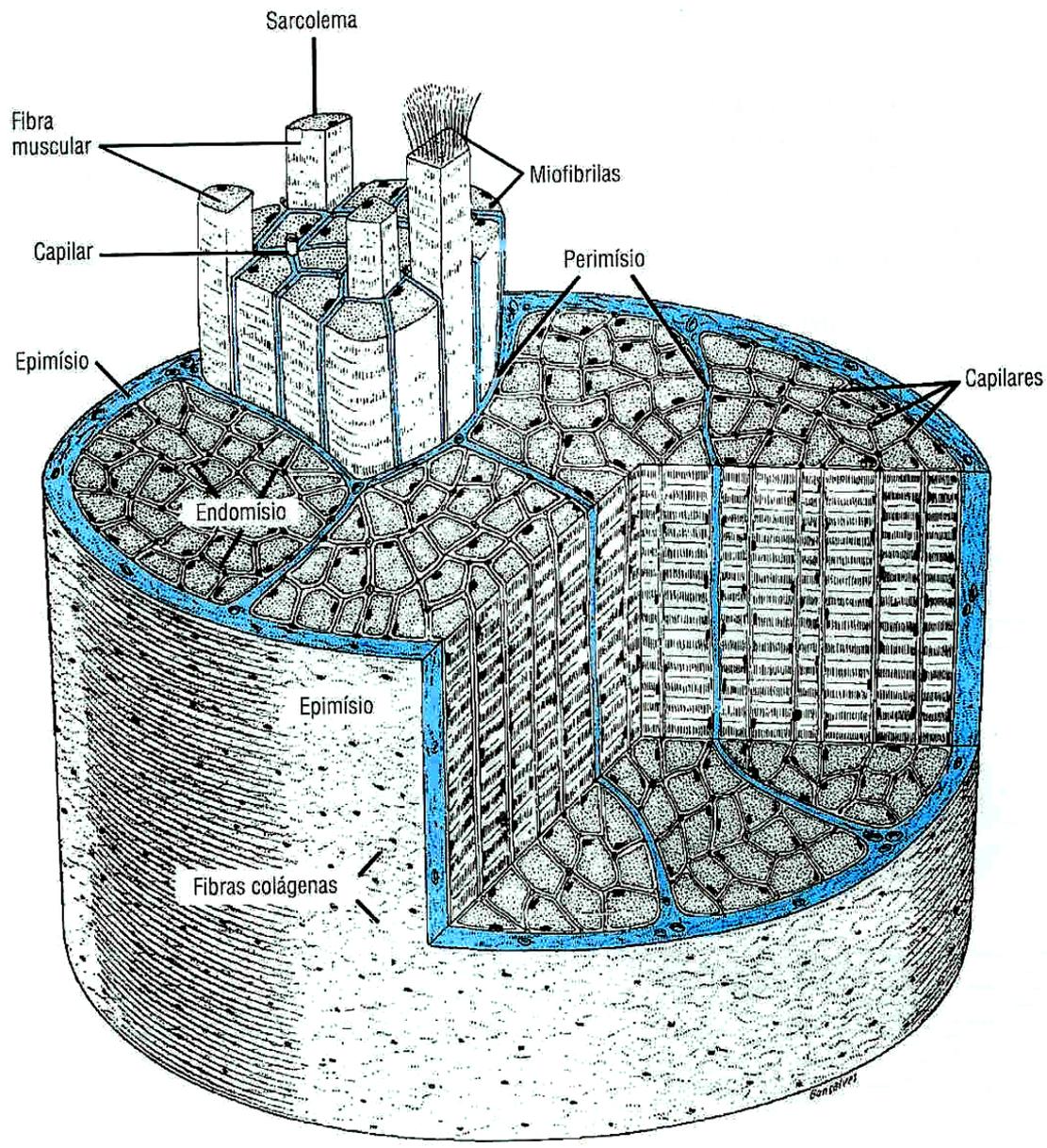
Organização muscular esquelética

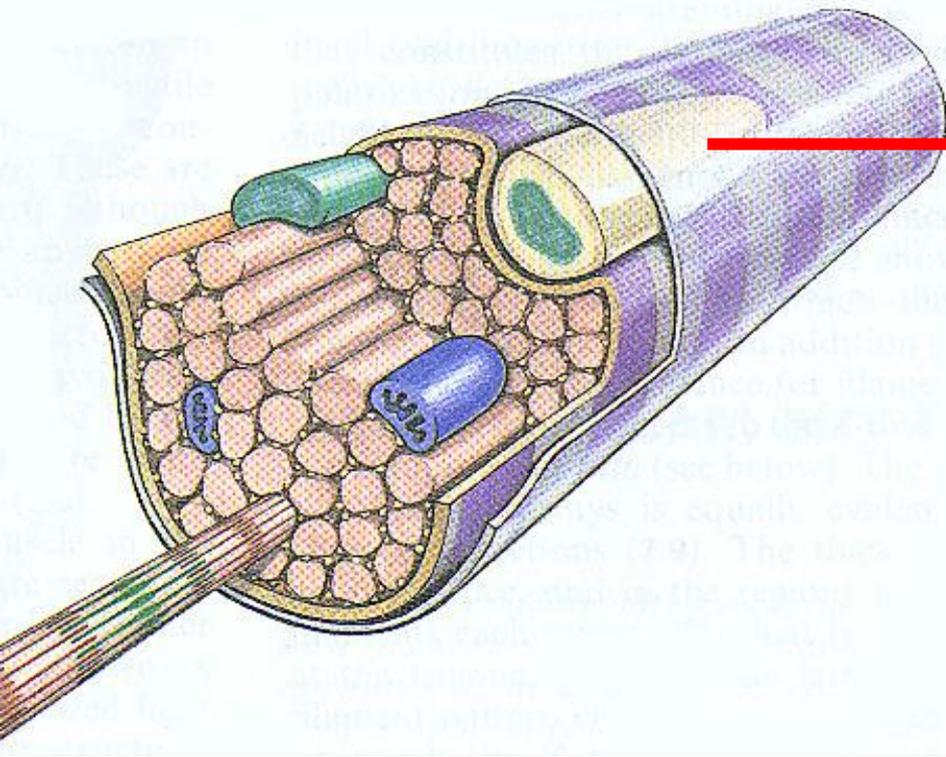


Músculo
Epimísio

Fascículo de fibras
Perimísio

Fibras
Endomísio





**CÉLULA
SATÉLITE**

**Em microscópio
eletrônico observa-se
cerca de 85-95% dos
núcleos estão dentro
da fibras.**



Célula Satélite



Mionúcleo



Em microscopia óptica, não é possível individualizar as células satélites. Seus núcleos parecem idênticos aos mionúcleos ou seja, os núcleos da própria fibra muscular. Em microscopia eletrônica a diferença fica clara porque a célula satélite tem membrana e citoplasma próprios, e os mionúcleos estão situados no citoplasma da fibra muscular.

Quando há necrose da fibra muscular adjacente, a célula satélite sai de seu estado de repouso e passa a apresentar mitoses, constituindo os mioblastos. Nestes, há abundante retículo endoplasmático rugoso, que sintetiza actina e miosina para formar miofibrilas. Os mioblastos tornam-se fusiformes (chamados agora miotubos) e eventualmente se fundem, formando uma célula única, que será a fibra muscular regenerada.

Junção músculo-tendínea



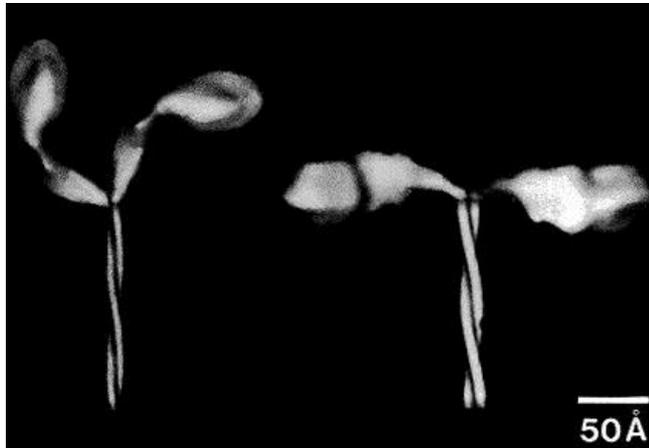
Composição do Músculo esquelético

- 75% água
- 5% sal inorgânico, subst.
- 20% proteínas

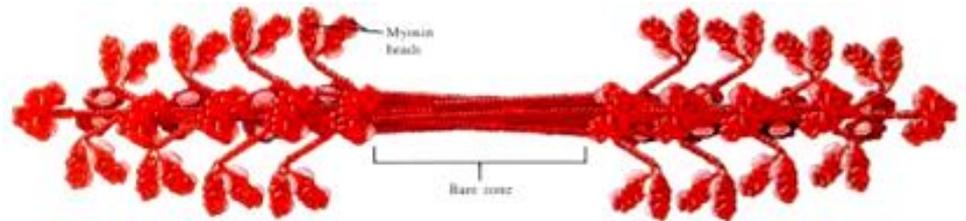


Filamento de miosina

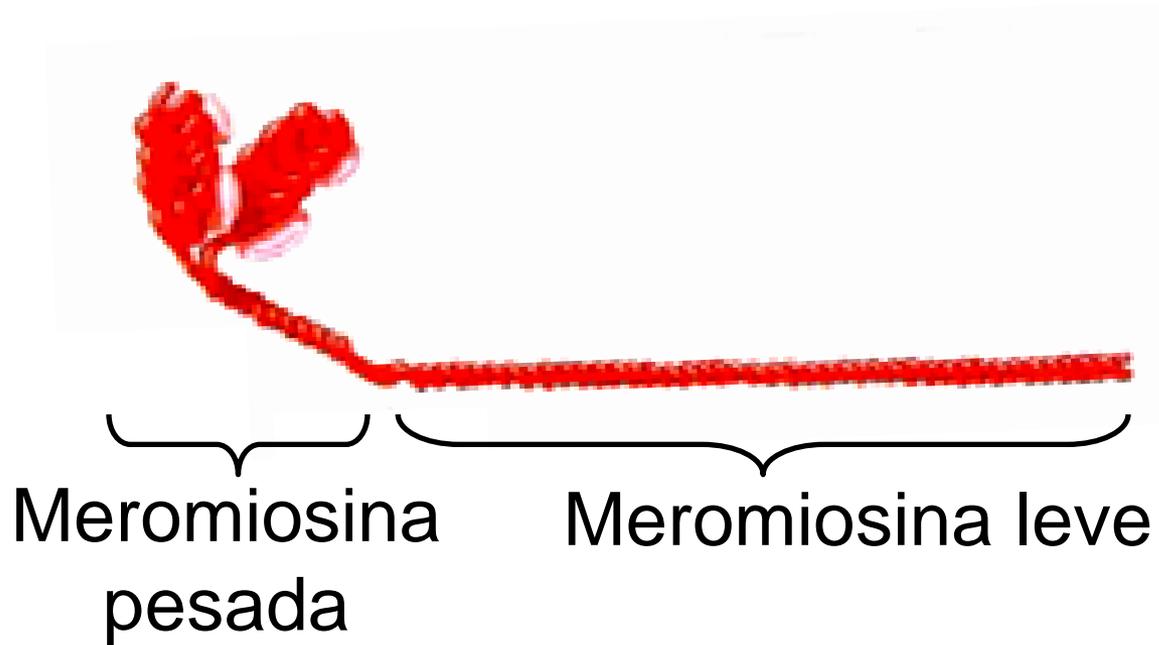
Molécula Hexamérica: 2 MHC (200 kDa)
4 MLC (16-28 kDa)



Em um filamento grosso tem ~
300 moléculas de miosina

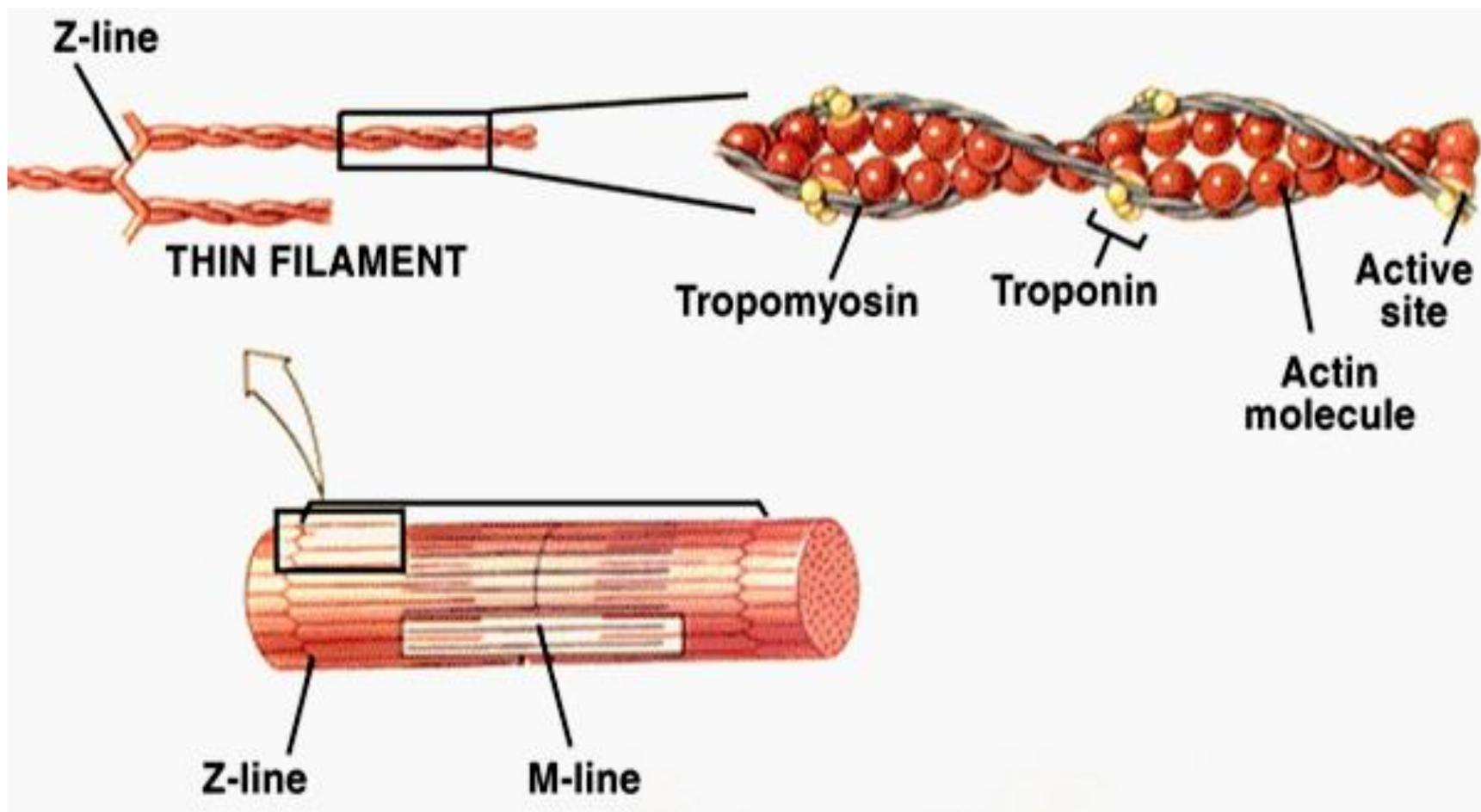


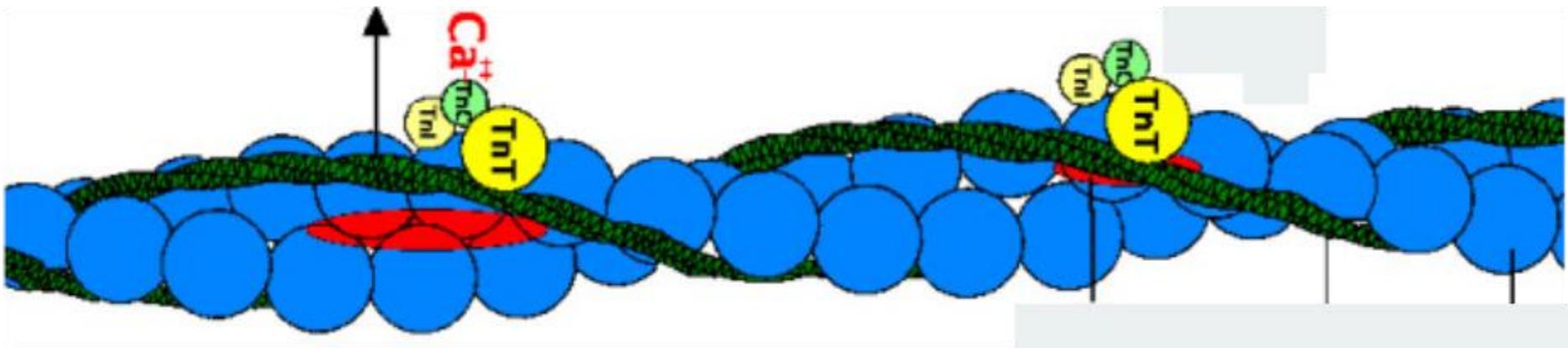
Filamento de miosina

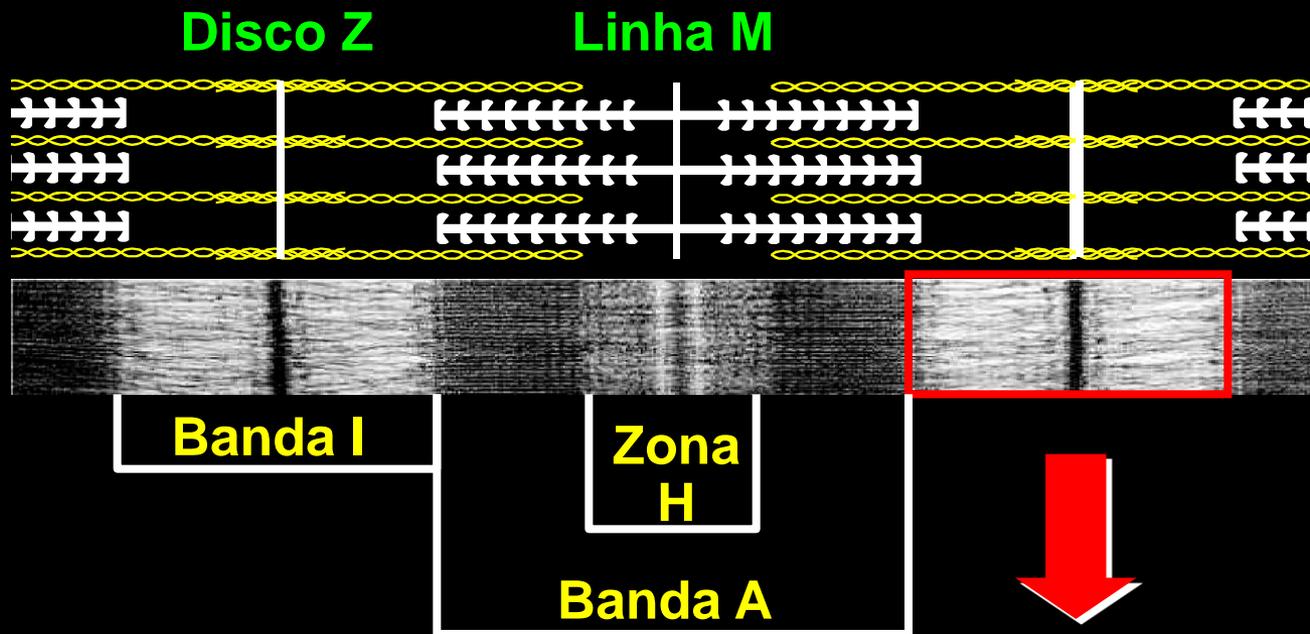


Filamento de actina

- ✓ Dupla hélice
- ✓ 42 kDa
- ✓ 90% do ADP do músculo está ligado à actina

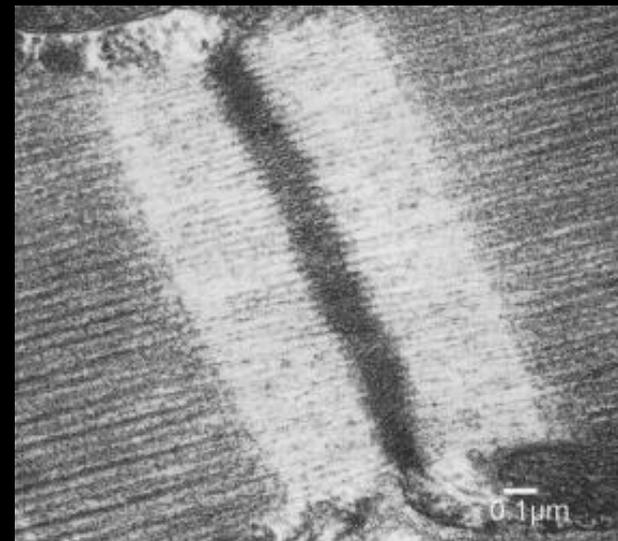




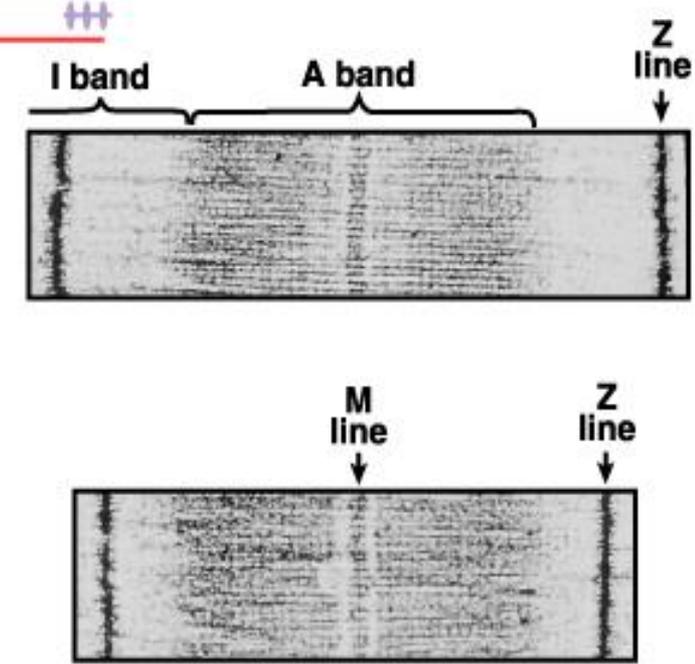
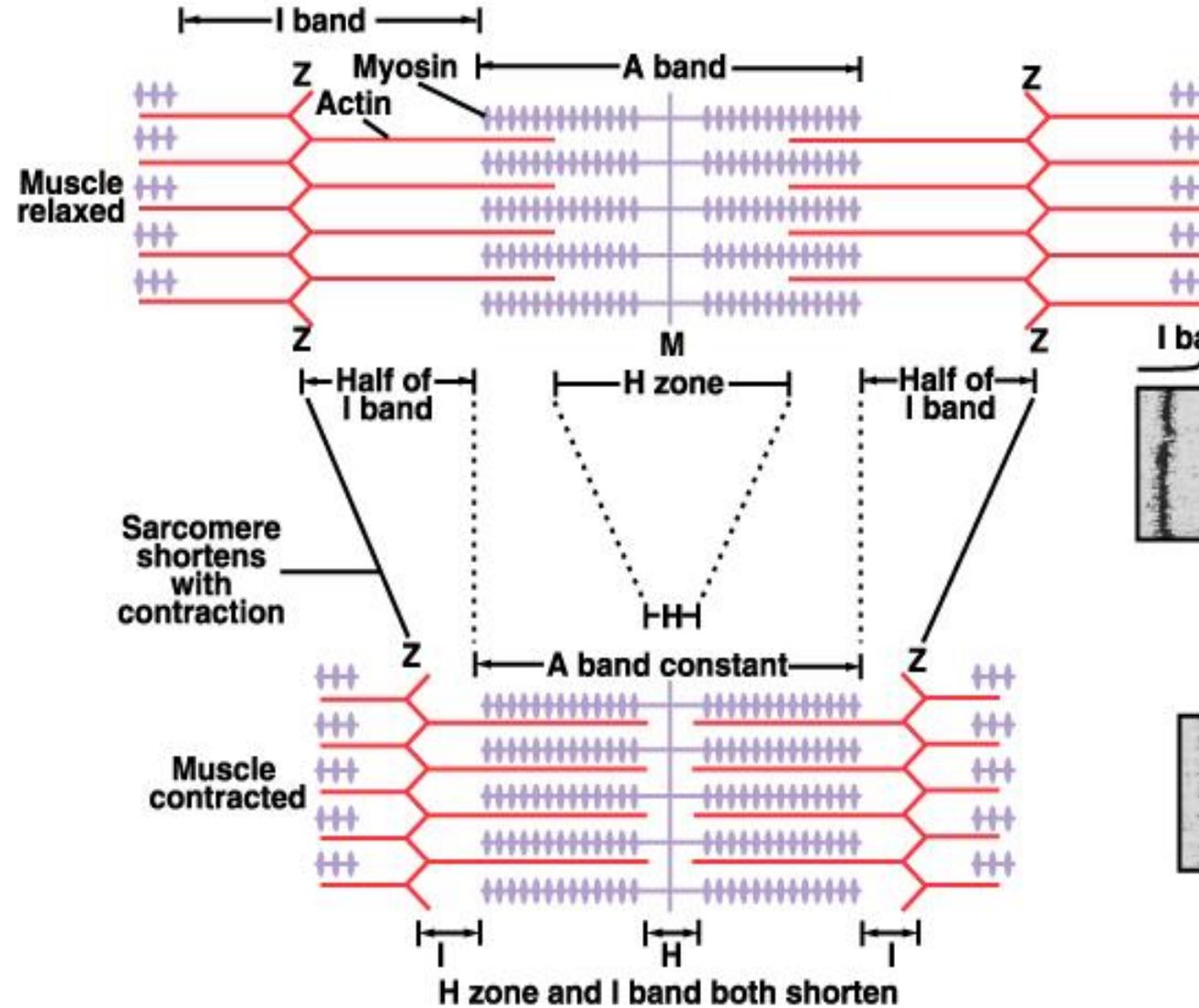
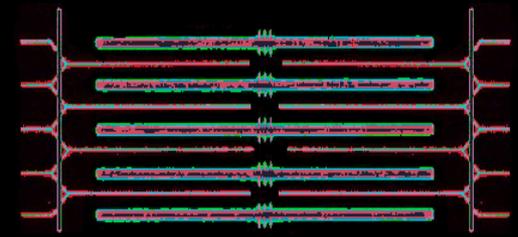


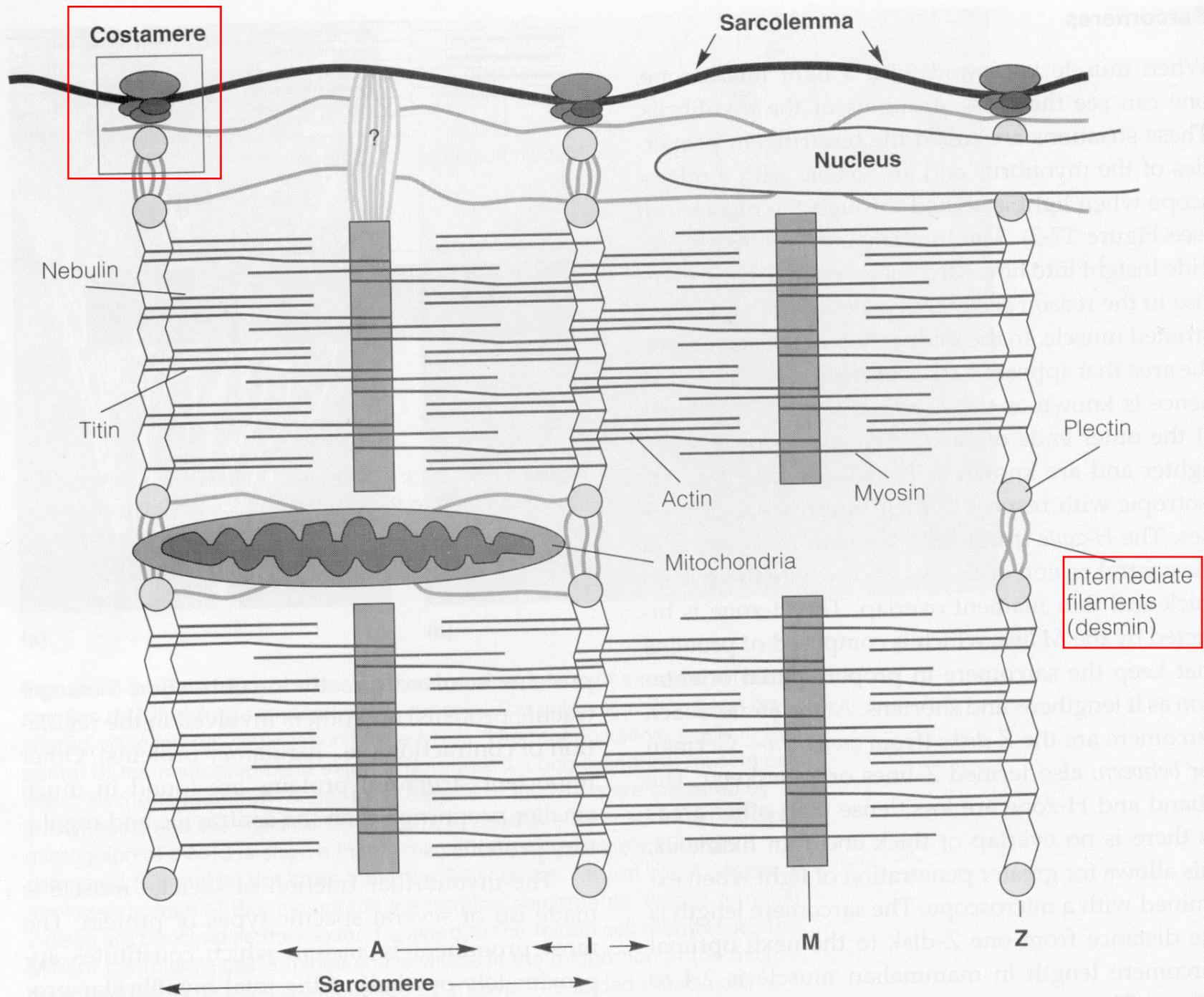
Disco-Z:

- Demarcam o sarcômero;
- ≈ 100 nm de largura;
- Situa-se no centro da banda I;
- Mecanosensor – pela habilidade de mudar seu padrão junto com as alterações dos filamentos de actina e miosina;
- Liga-se transversalmente aos filamentos em uma estrutura tridimensional extremamente organizada.



Sarcômero





Costamere

Sarcolemma

Nucleus

Nebulin

Titin

Actin

Myosin

Plectin

Mitochondria

Intermediate filaments (desmin)

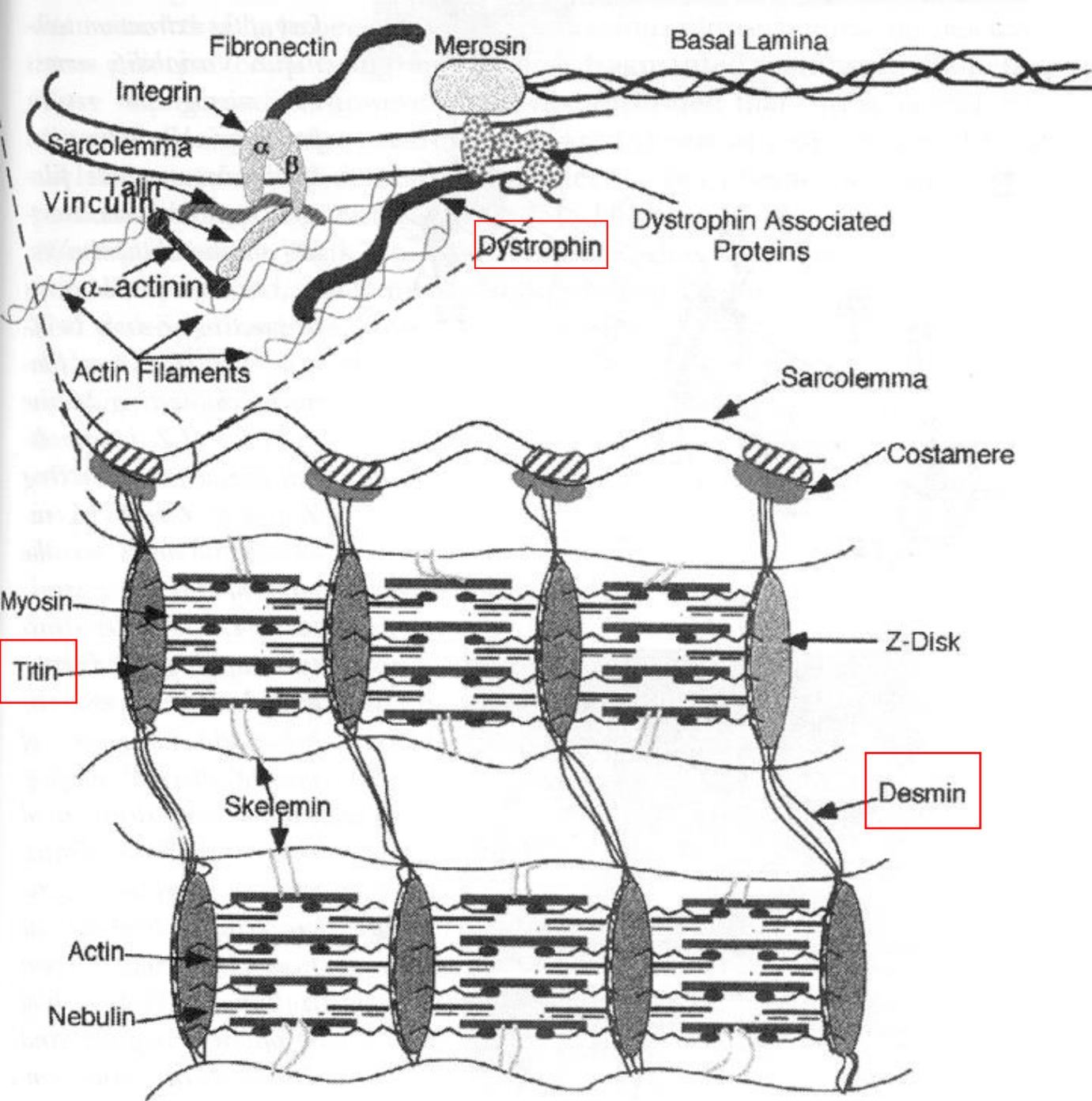
A

I

M

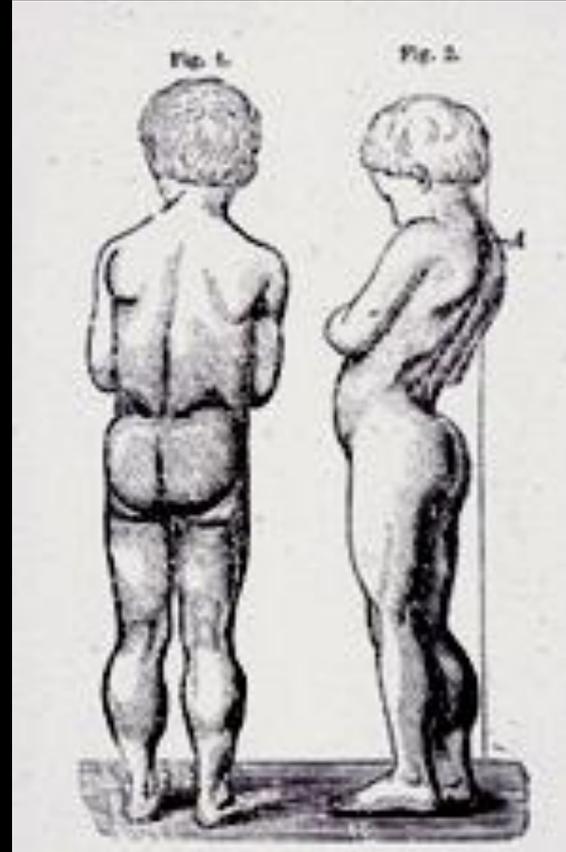
Z

Sarcomere



Proteínas do citoesqueleto

DISTROFIA MUSCULAR DE DUCHENE

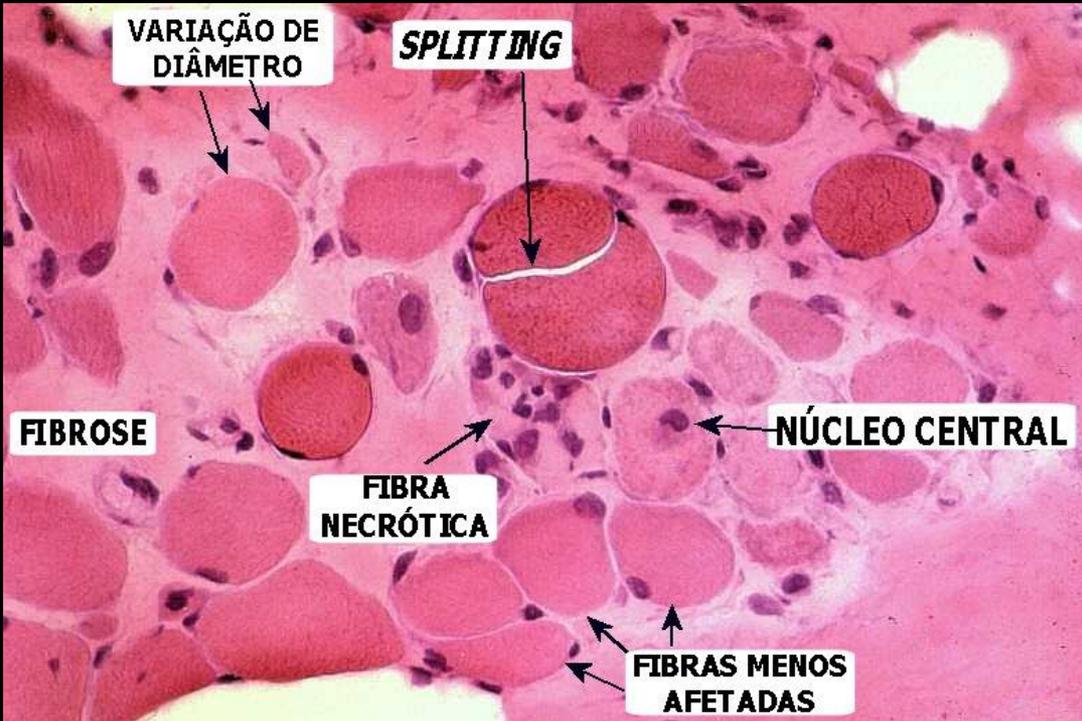


“Eu pensei que a humanidade já estava infringida de males suficientes...e não parabenizo o senhor pelo novo presente que a humanidade ganhou.”

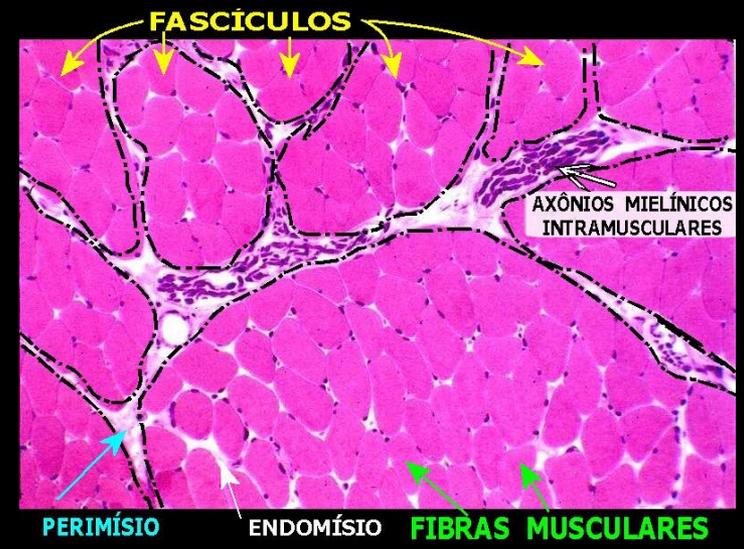
Distrofia muscular de Duchenne



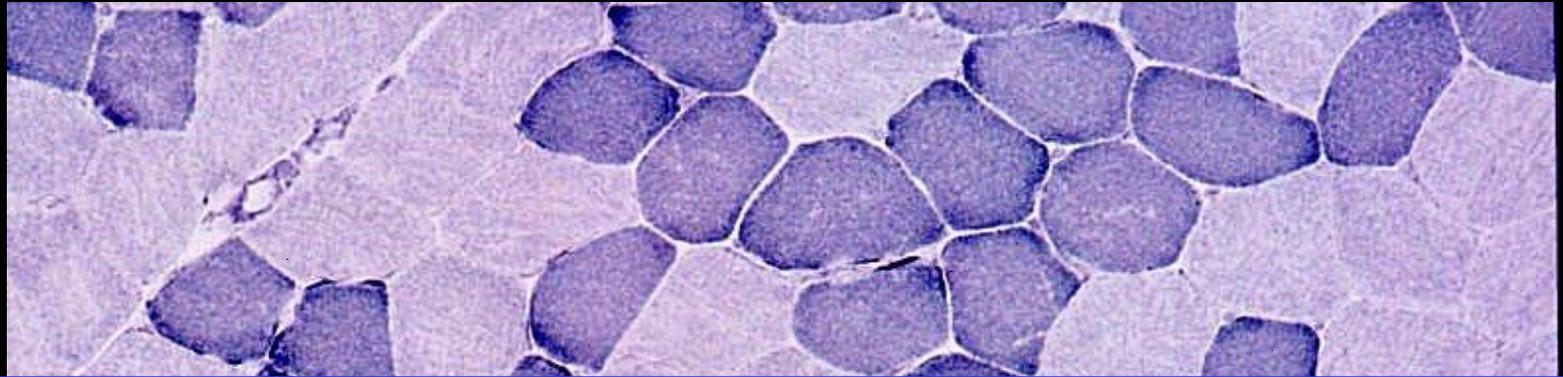
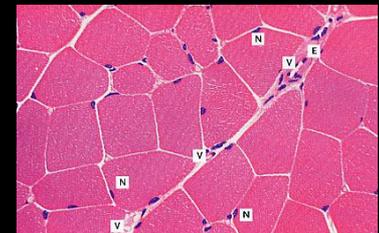
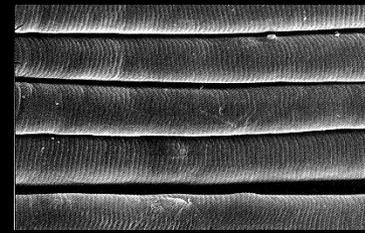
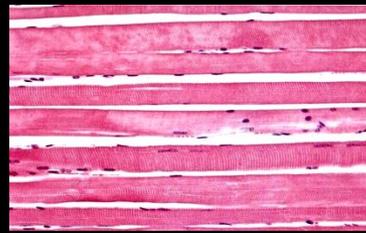
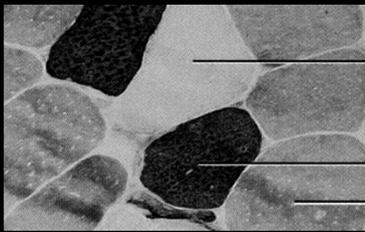
Distrofia Muscular



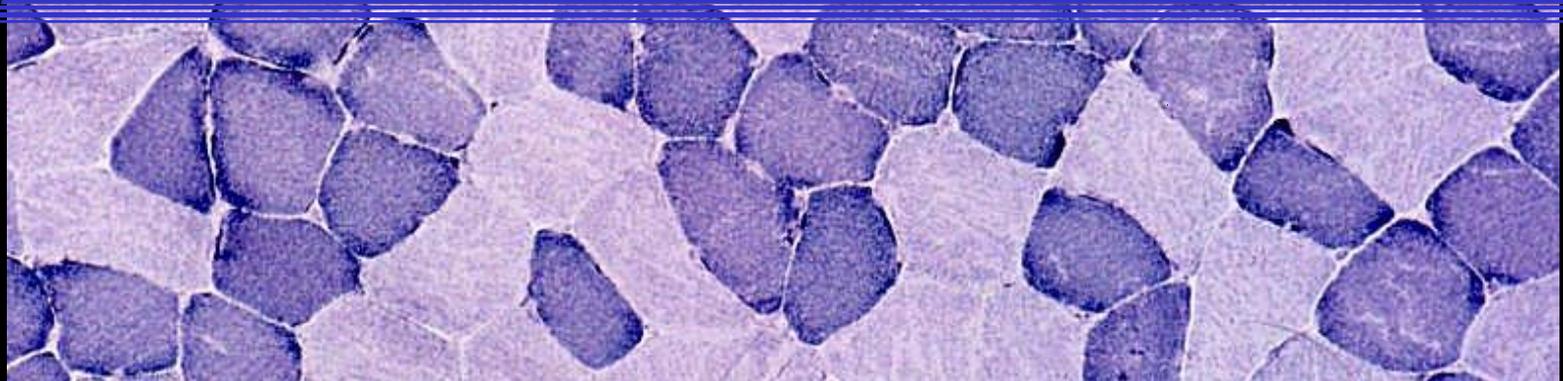
Normal



Muitas fibras numa distrofia mostram alterações ditas 'miopáticas'. Entre estas estão a presença de núcleos internos (não mais em posição subsarcolemal) e splitting ou partição da fibra em duas ou mais através de uma fenda longitudinal.



Fibra e Metabolismo Muscular Esquelético: Efeitos do Exercício Físico

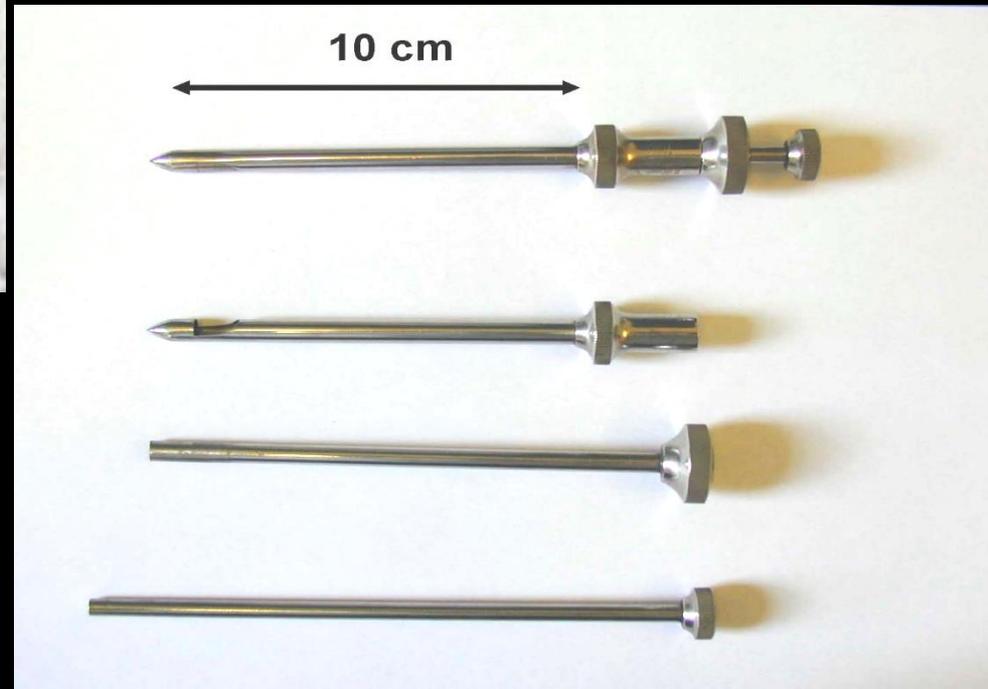


Histórico- Músculo Esquelético

- ✓ O músculo esquelético adaptado ao treinamento físico (↑ força) já era conhecido pelos gregos e romanos;
- ✓ Em 1628, William Harvey afirmou “the more muscular and powerful men are, the firmer the flesh”
- ✓ Estudos com exercício físico foram inicialmente realizados por ganhadores do prêmio Nobel
 - August Krogh- analisador de gases (Dinamarca, 1920)
 - AV Hill- produção de calor pelo ME (Inglaterra, 1922)
- ✓ Anos 60: advento do grande crescimento de pesquisa para verificar a adaptabilidade do músculo esquelético ao exercício.

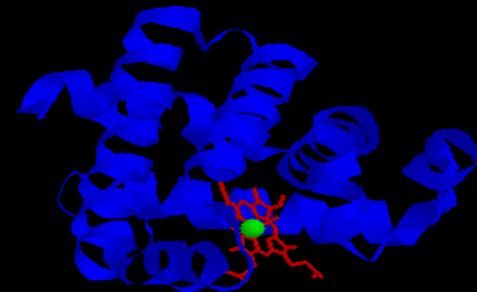
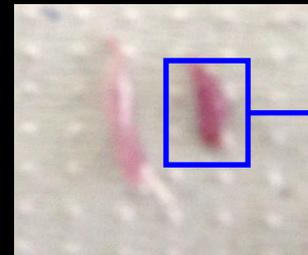
Bergström e Hultman (1966)- Biópsia do ME

análises histológicas, bioquímicas e metabólicas foram identificadas.



Classificações das Fibras Musculares

- 1873, anatomista francês Louis Antoine Ranvier

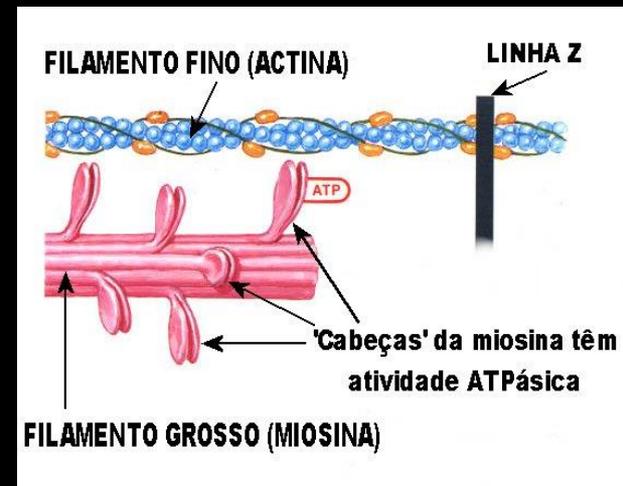
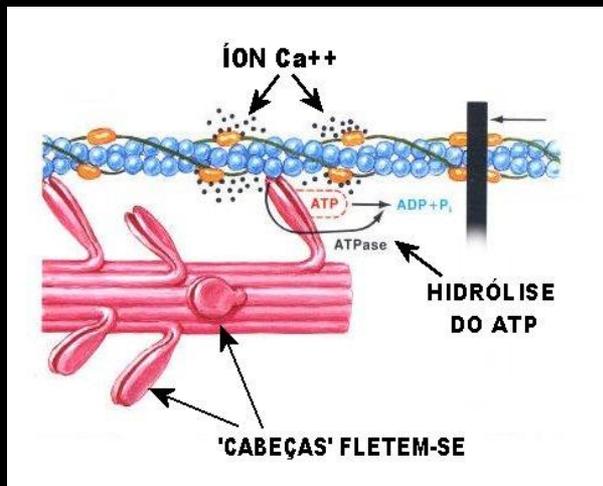


(Needham 1926)

A mioglobina (Mb) contendo ferro é uma das proteínas que transporta oxigênio (O_2), sendo o principal transportador intracelular de O_2 nos tecidos musculares, além de estocar oxigênio nos músculos.

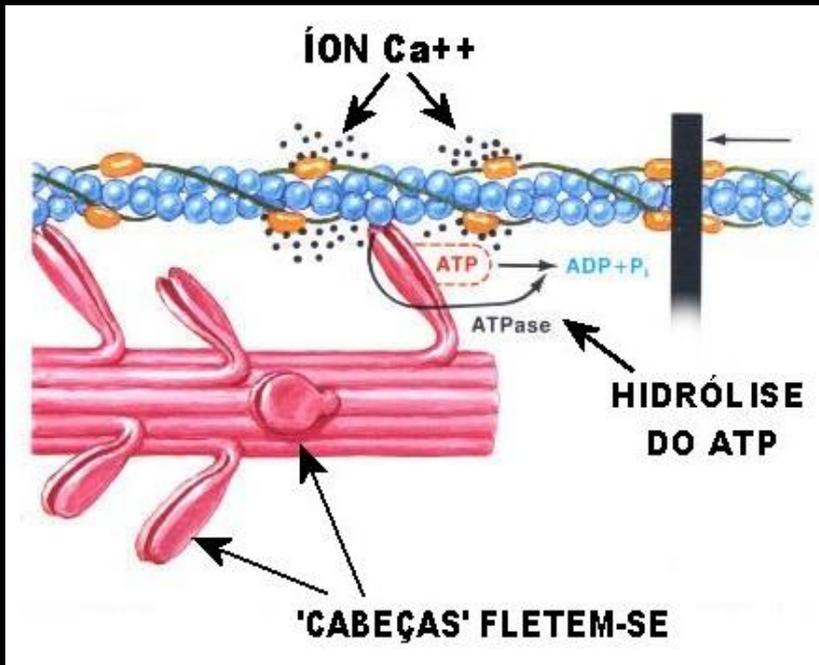
Características Contráteis das fibras musculares

Diferentes métodos histoquímicos têm sido proposto para diferenciar os subtipos de fibras musculares, mas o método mais usado para todos os propósitos é a histoquímica para a ATPase miosínica.



Velocidade de contração

Miosina ATPase Muscular



Enzima
miosina ATPase

Substrato

ATP

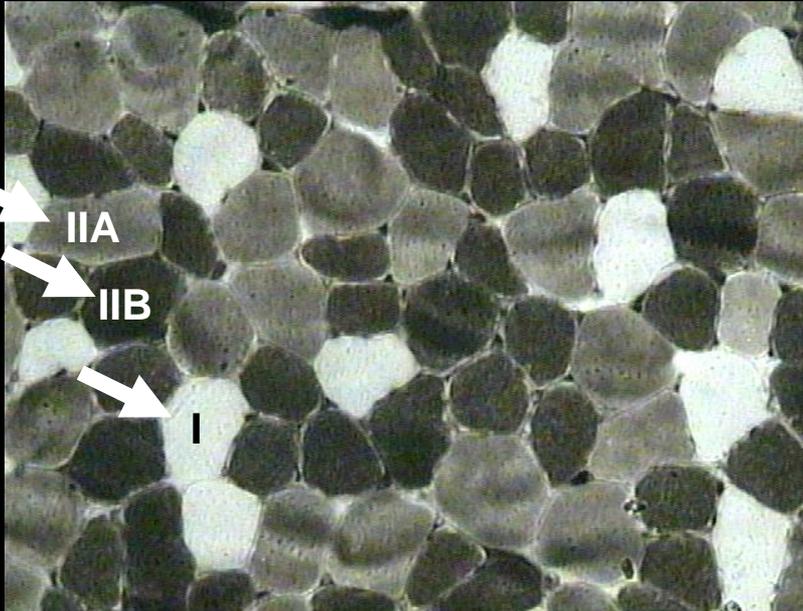
Produto

ADP + Pi

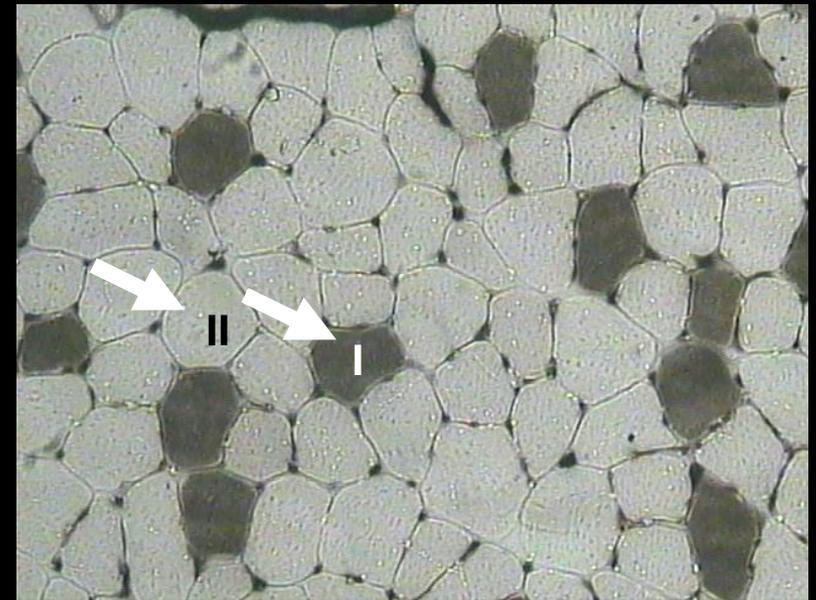
pH 10.3
pH 4.6

Características Contráteis das Fibras Musculares

pH 10.3

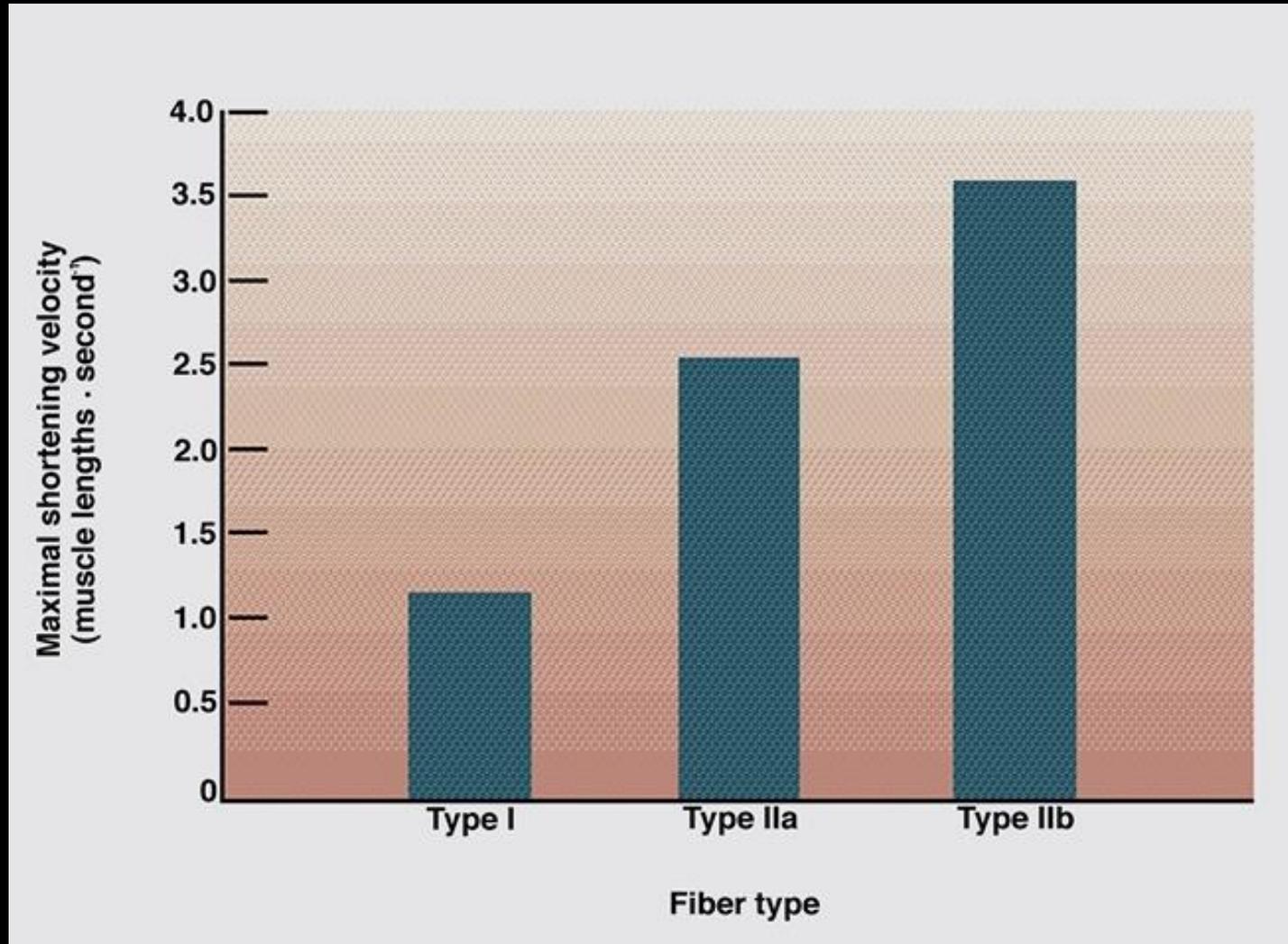


pH 4.3



Fibra Tipo I	lenta
Fibra Tipo IIA (intermediária)	rápida
Fibra Tipo IIB	rápida

Velocidade de Hidrólise do ATP

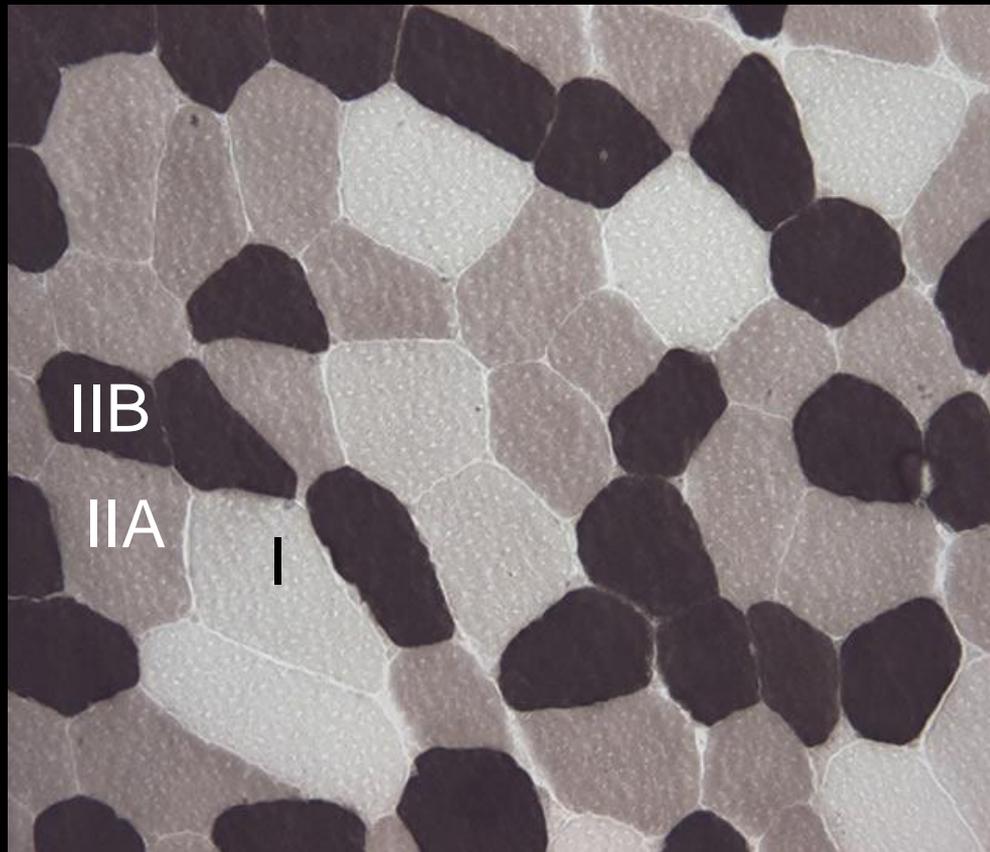


Perfil das Fibras Musculares Esqueléticas

36 humanos

Variação na proporção dos tipos de fibras em diferentes músculos.

**Estrutura
MOSAICO**

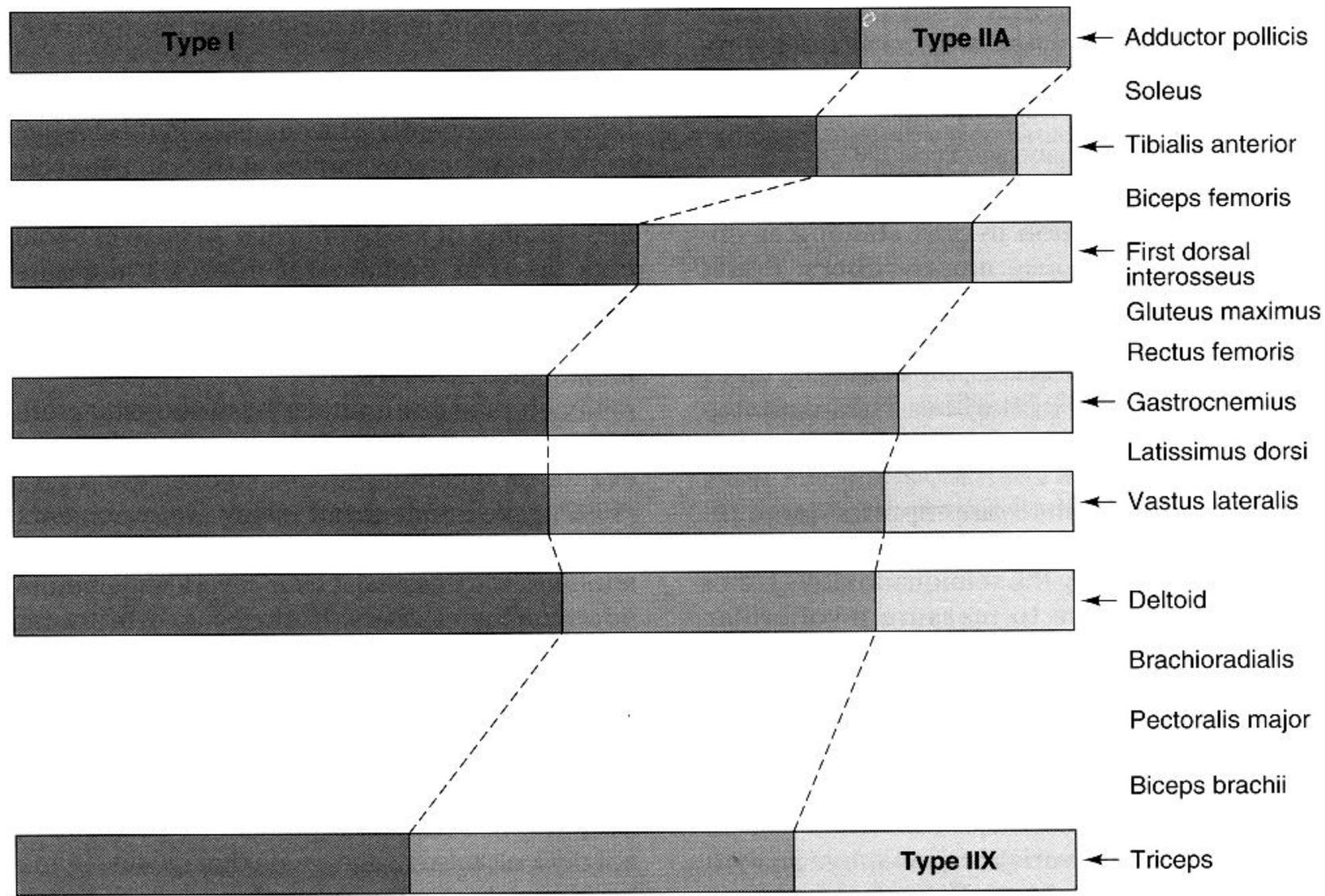


pH 10.3



Johnson, 1973

Proporção de Tipos de Fibras em Músculos



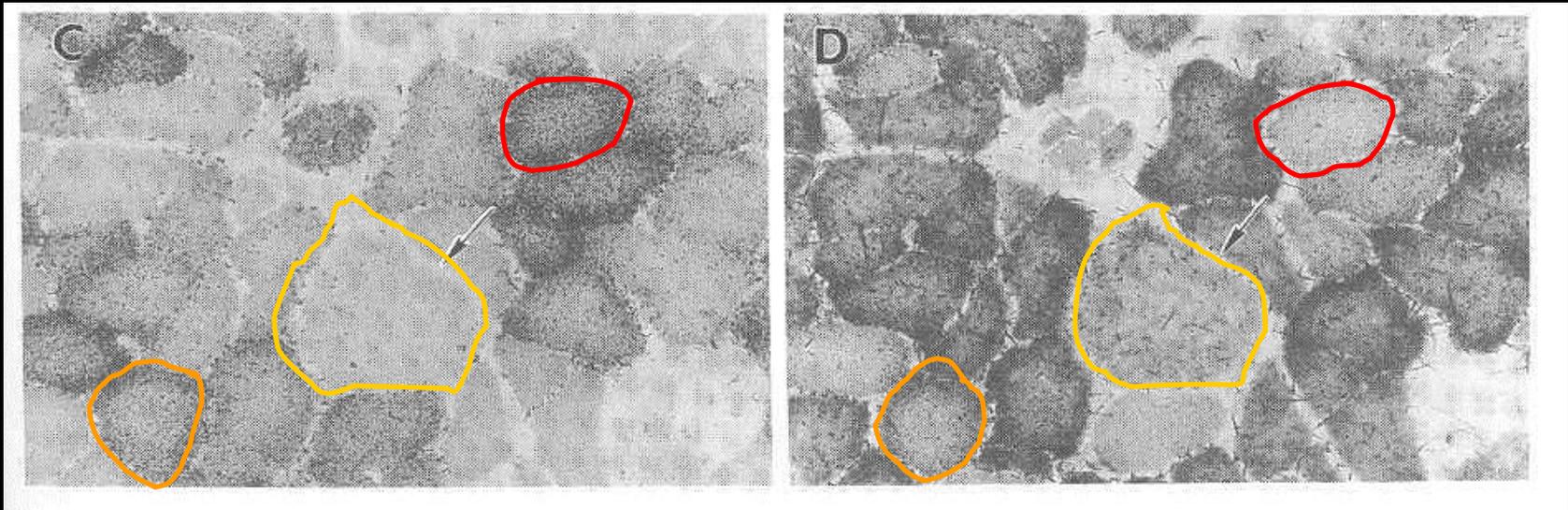
Características Bioquímicas das Fibras Musculares

Atividade Oxidativa

SDH (succinato dehidrogenase)

Atividade Glicolítica

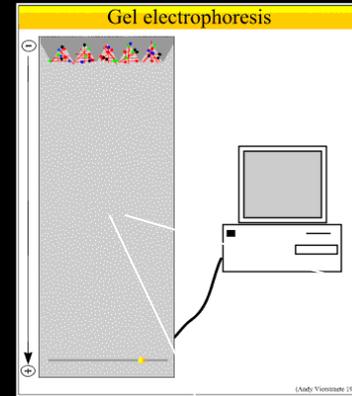
α -GPDH (Alfa glicerol fosfato dehidrogenase)



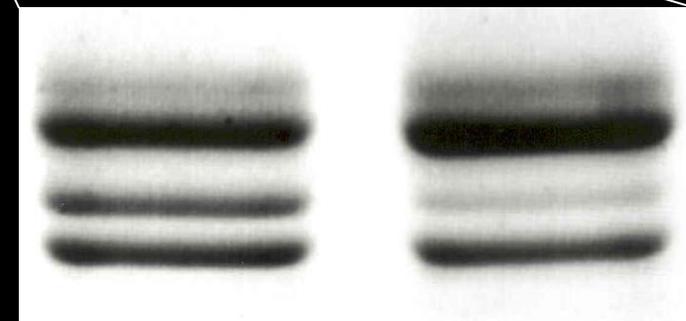
Fibra Tipo I	lenta	vermelha	oxidativa	SO
Fibra Tipo IIA (intermediária)	rápida	branca	oxida/glico	FOG
Fibra Tipo IIB	rápida	branca	glicolítica	FG

Características Moleculares das Fibras Musculares

1990, Staron & Pette



MHCIIx
MHCIIa
MHCIIb
MHC β



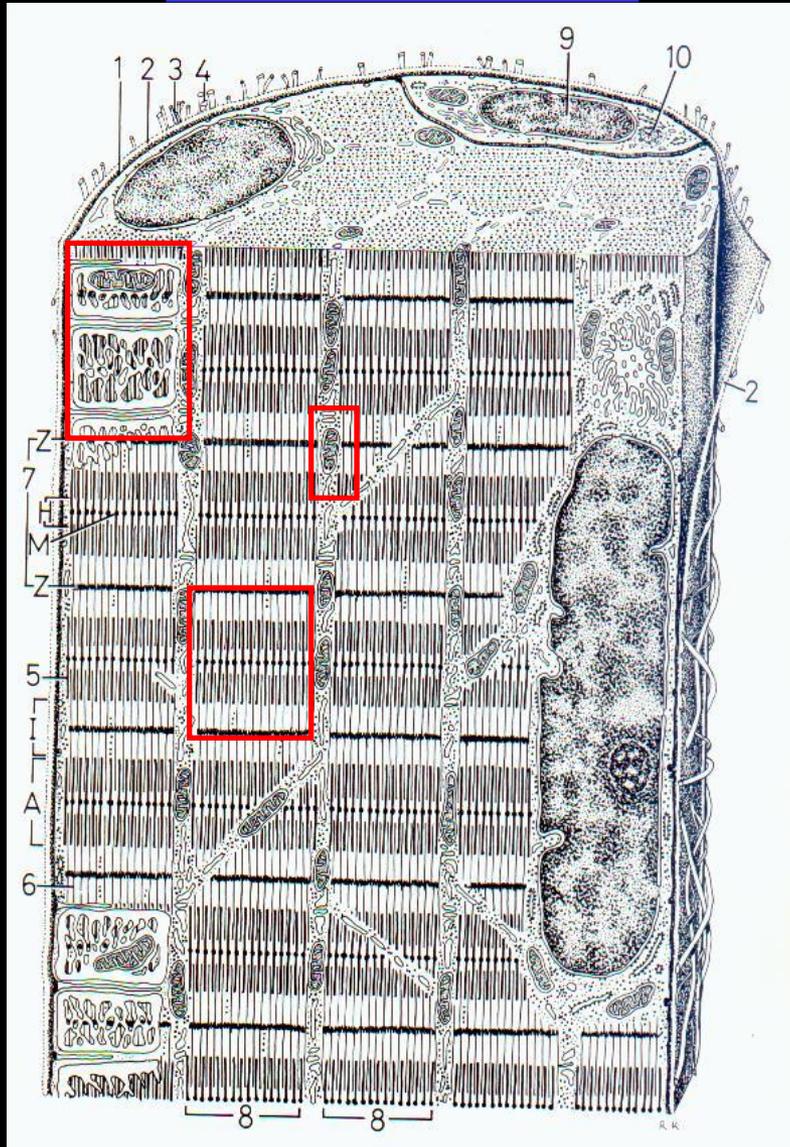
Classificação
das MHC

The text is enclosed in a starburst shape.

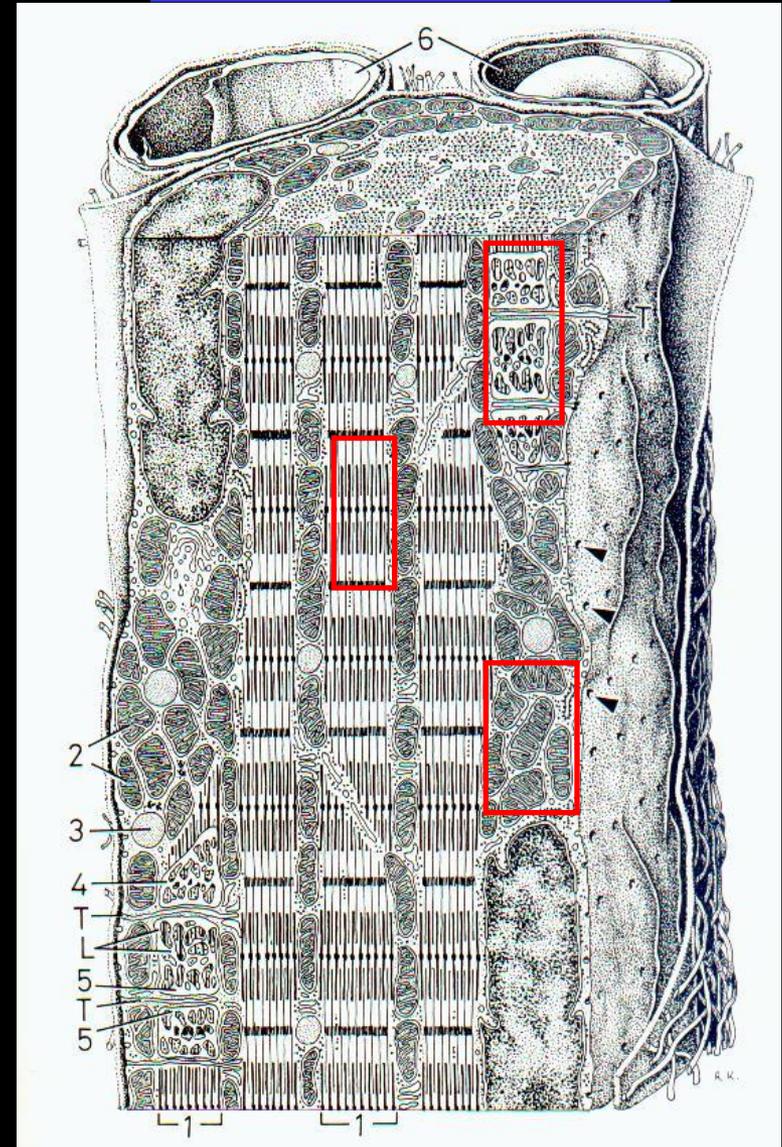
MHC β	Fibra Tipo I
MHCIIa	Fibra Tipo IIA
MHCII d/x	Fibra Tipo IID/X
MHCIIb	Fibra Tipo IIB

Características Estruturais das Fibras Musculares

Fibra Branca



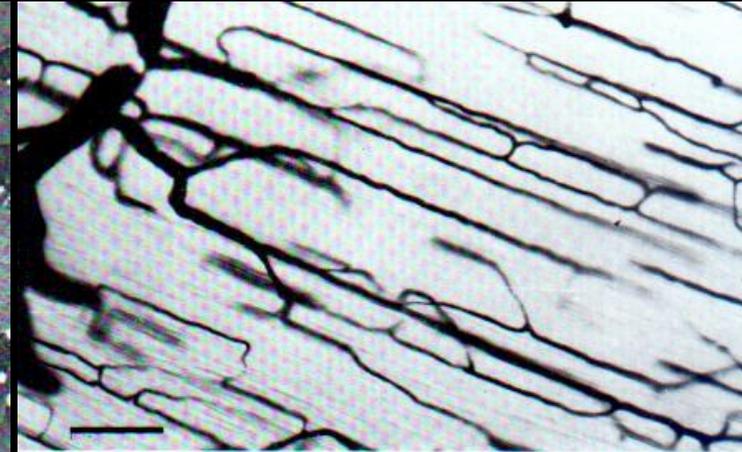
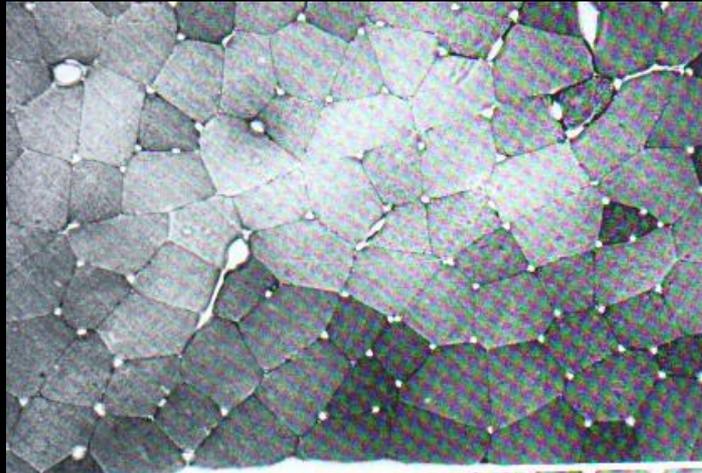
Fibra vermelha



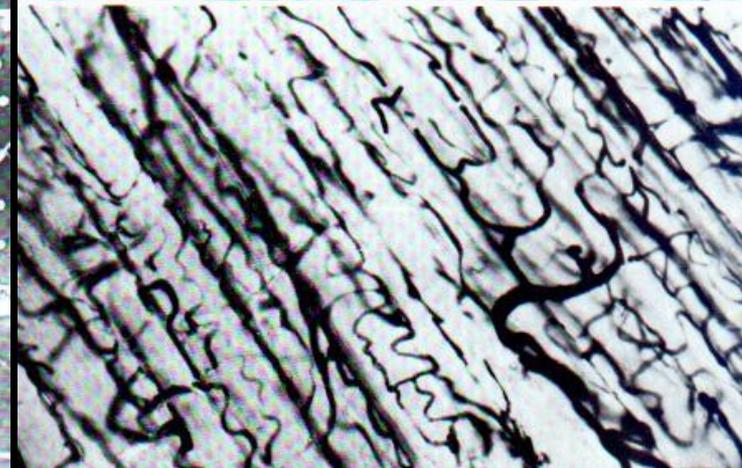
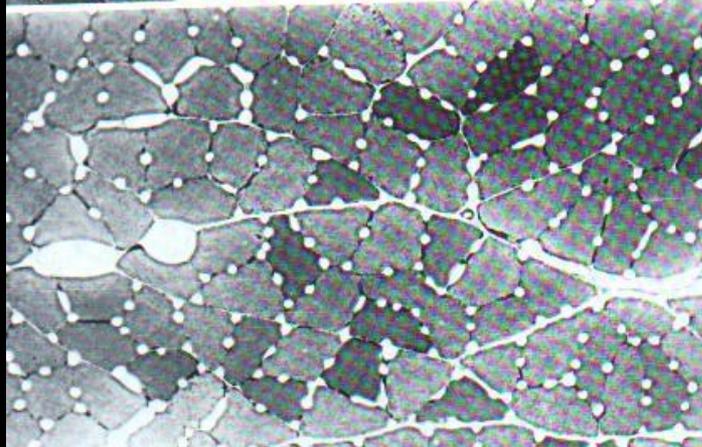
Características Estruturais das Fibras Musculares

CAPILARES

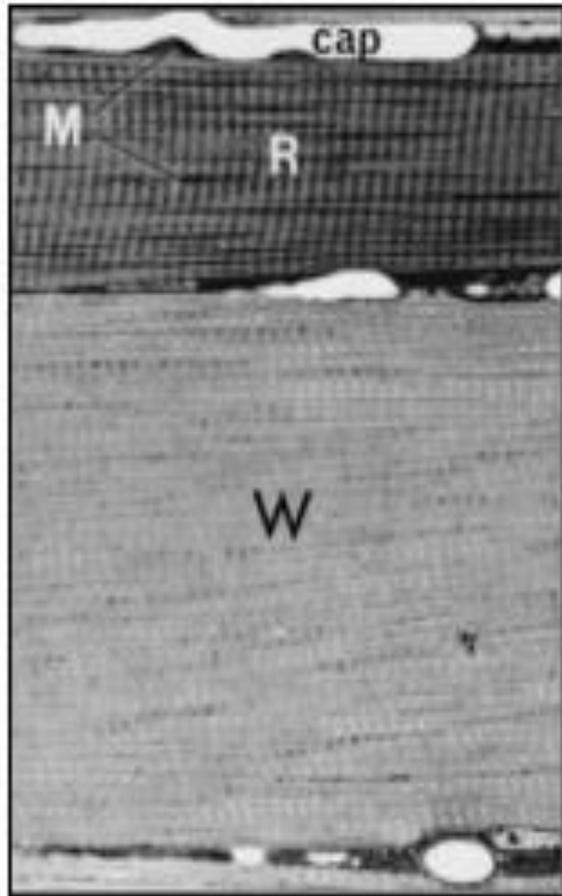
Fibra Branca



Fibra vermelha



Características estruturais das fibras musculares

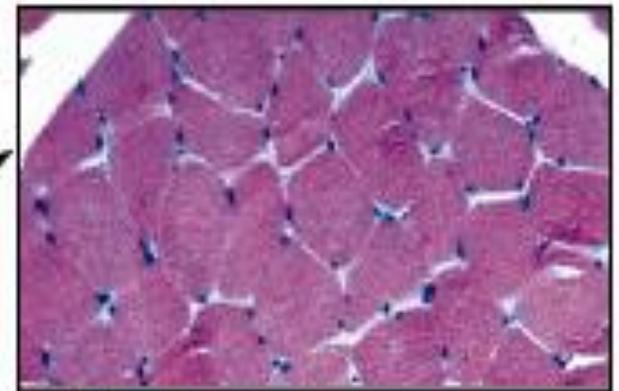


Slow fibers
Smaller diameter,
darker color due to
myoglobin; fatigue-
resistant



Slow

Fast fibers
Larger diameter, paler
color; easily fatigued

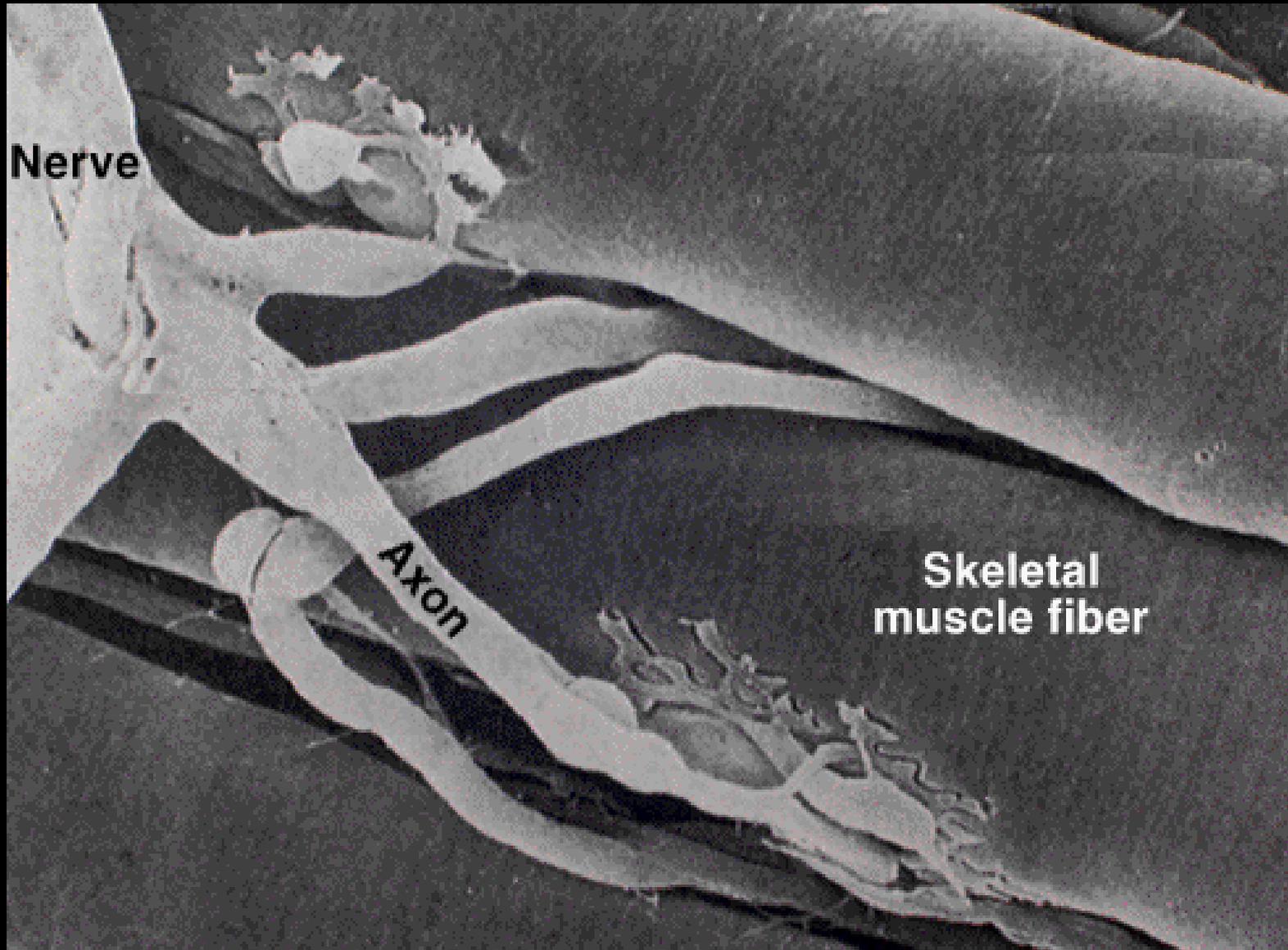


Fast

O que confere as fibras musculares diferentes características?



Características Funcionais das Unidades Motoras



S

FR

Flnt

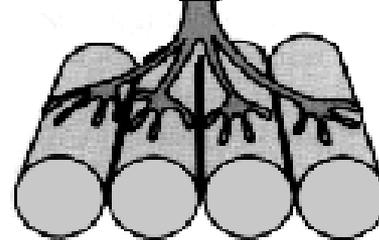
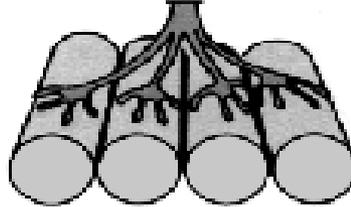
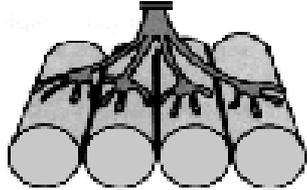
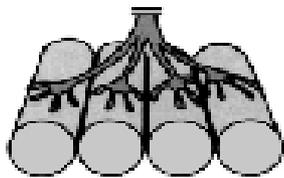
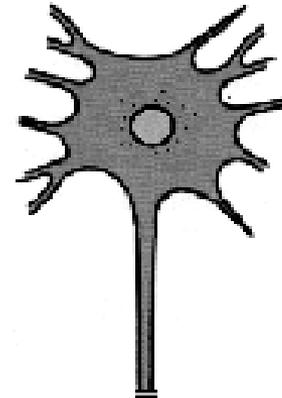
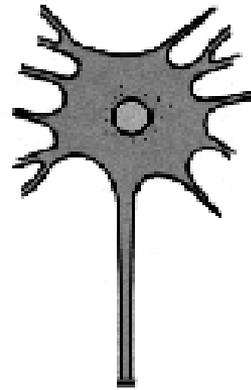
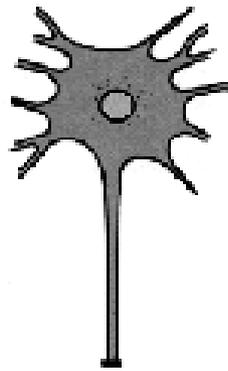
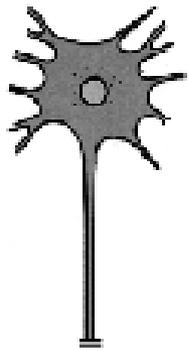
FF

Motoneuron

Muscle Fiber

Contractile Properties

Fatigue Properties



I

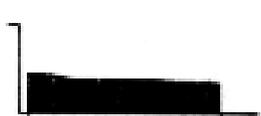
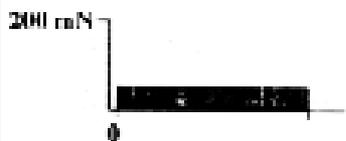
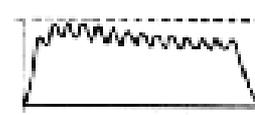
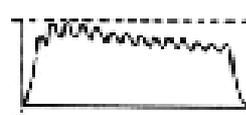
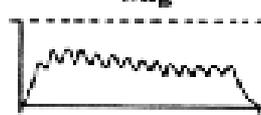
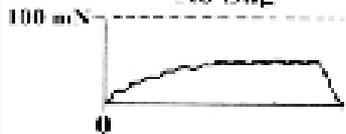
IIa

IIa - IIx

IIx - IIb

No Sag

Sag

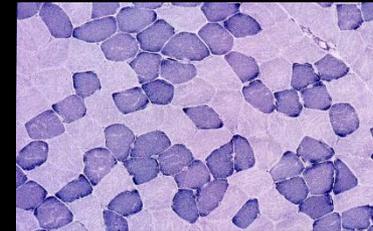
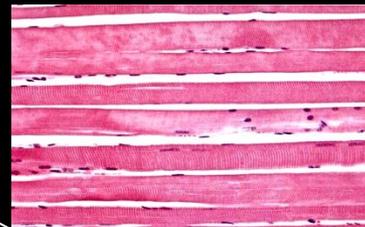
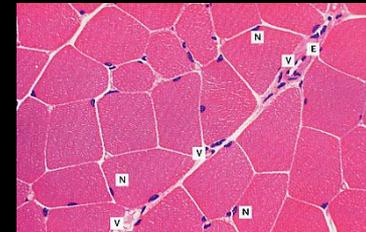
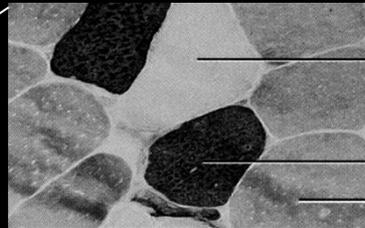


Características Funcionais das Unidades Motoras

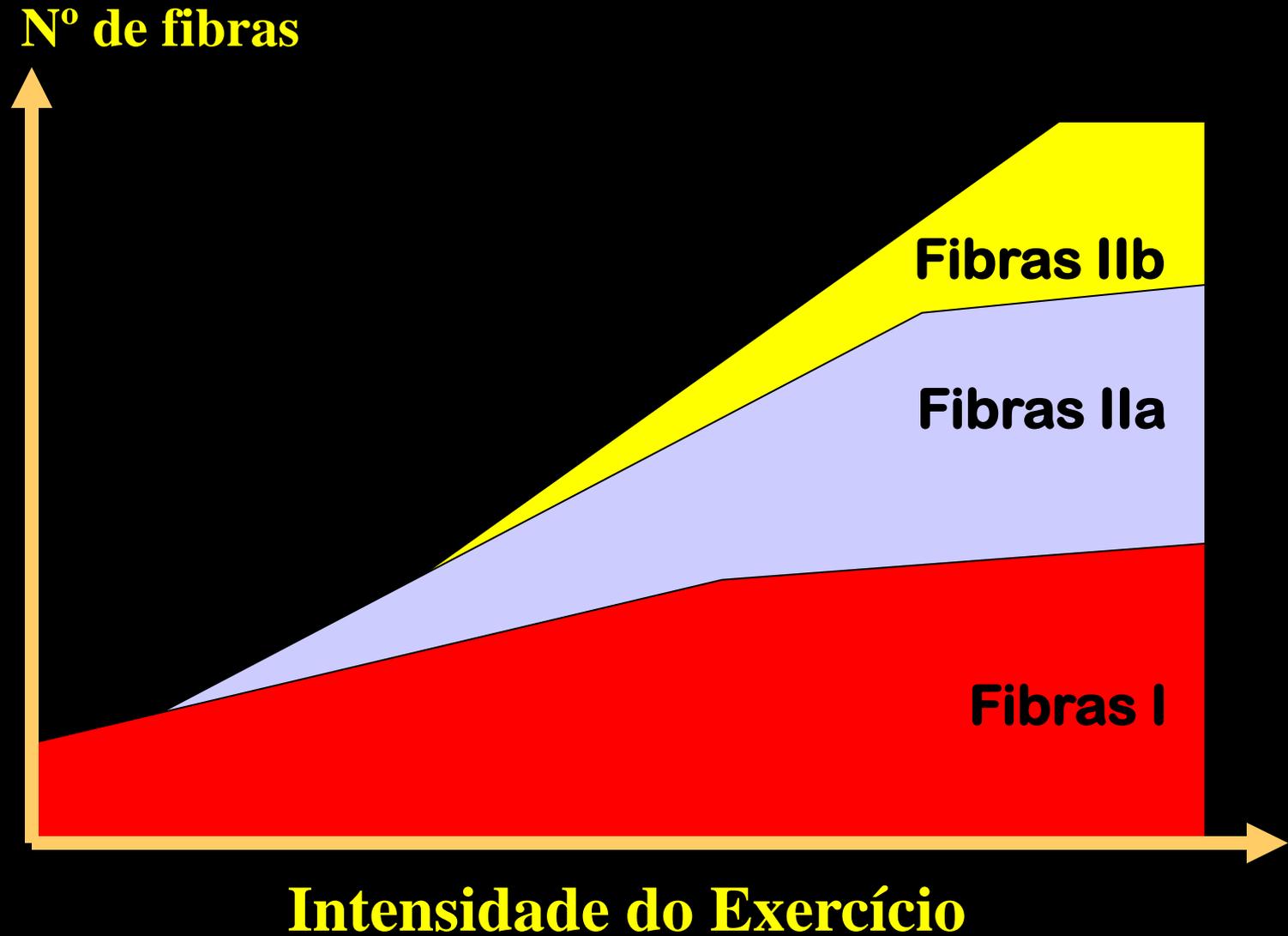
	Tipo I	Tipo IIa	Tipo IIb
Fibras por neurônio	300-800	200-400	10-180
Diam. nervo motor	Pequena	Grande	Grande
Veloc. cond. nerv.	Lenta	Rápida	Rápida
Tempo contração	110	50	50

Fibras musculares apresentam características bioquímicas, estruturais, moleculares e neurais diferenciadas.

Como acontece o recrutamento destas fibras durante o exercício físico ?

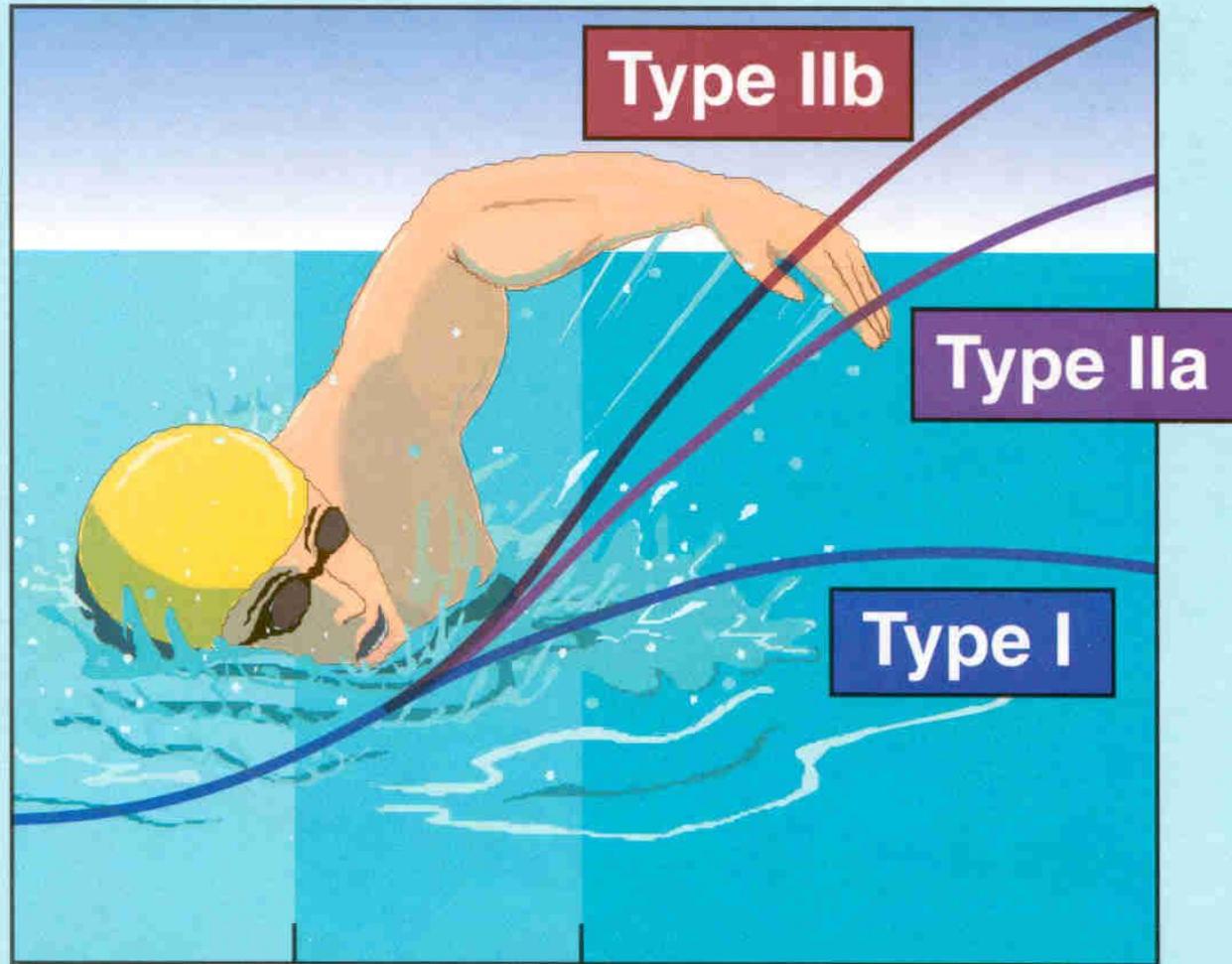


Recrutamento de unidades motoras durante o EF



Total available motor units

Number of active motor units



Type IIb

Type IIa

Type I

Light

Moderate

Heavy

Intensity of effort

Resumindo...

Características	Lentas Tipo I SO	Rápidas Tipo IIA FOG	Rápidas Tipo IIB FG
Diâmetro	Menor	Maior	Maior
Diâm. nervo motor	Menor	Maior	Maior
Capilarização	Maior	Menor	Muito menor
Força contração	Menor	Maior	Muito maior
Veloc. contração	Menor	Maior	Maior
Resistência fadiga	Maior	Menor	Muito menor

Características

Lentas

Rápidas

Rápidas

Tipo I

Tipo IIA

Tipo IIB

SO

FOG

FG

Metab. oxidativo

Maior

Menor

Muito menor

Metab. glicolítico

Menor

Maior

Muito maior

Glicogênio

Menor

Maior

Maior

Triglicerídeos

Maior

Menor

Menor

ATPase miosínica

Menor

Maior

Muito maior

Limiar de excitab.

Menor

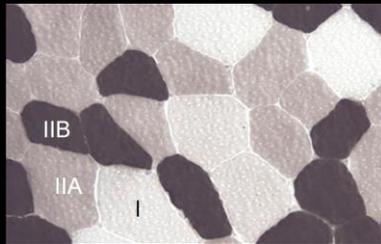
Maior

Maior

Metodologias utilizadas para a determinação do Tipo de Fibra e Metabolismo:

1. Histoquímica
2. Eletroforese
3. Imunohistoquímica

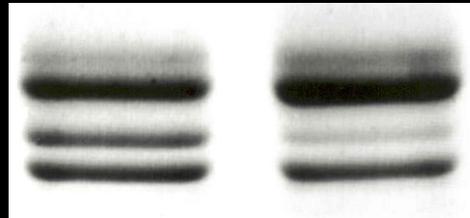
- **Histoquímica** Miosina ATPase, SDH, α -GPDH, PAS



- Diferentes pigmentações
- Área da fibra

- **Eletroforese**

MHCIIx
MHCIIa
MHCIIb
MHC1 β



- Composição molecular das MHC

- **Imunohistoquímica**

MHC1 β



- Anticorpos
- Área da fibra
- Alto custo

Metodologias utilizadas para a determinação do Tipo de Fibra:

1. Histoquímica
2. Eletroforese
3. Imunohistoquímica

I - Biópsia ou Extração do tecido

Humanos

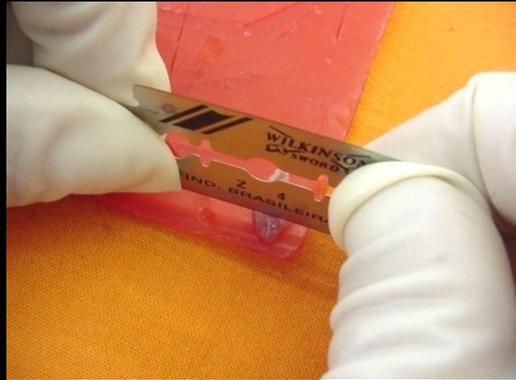


I - Biópsia ou Extração do tecido

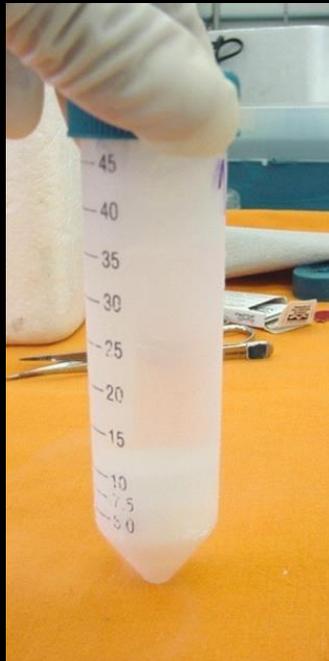
Animais de experimentação



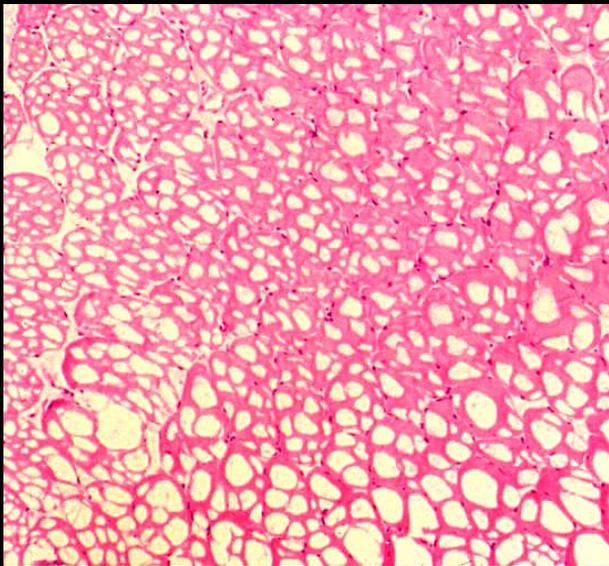
II - Montagem do tecido:



III - Congelamento do tecido:



III - Congelamento do tecido:



Tecido congelado em -20°C



Nitrogênio líquido -196° C

IV - Cortes:

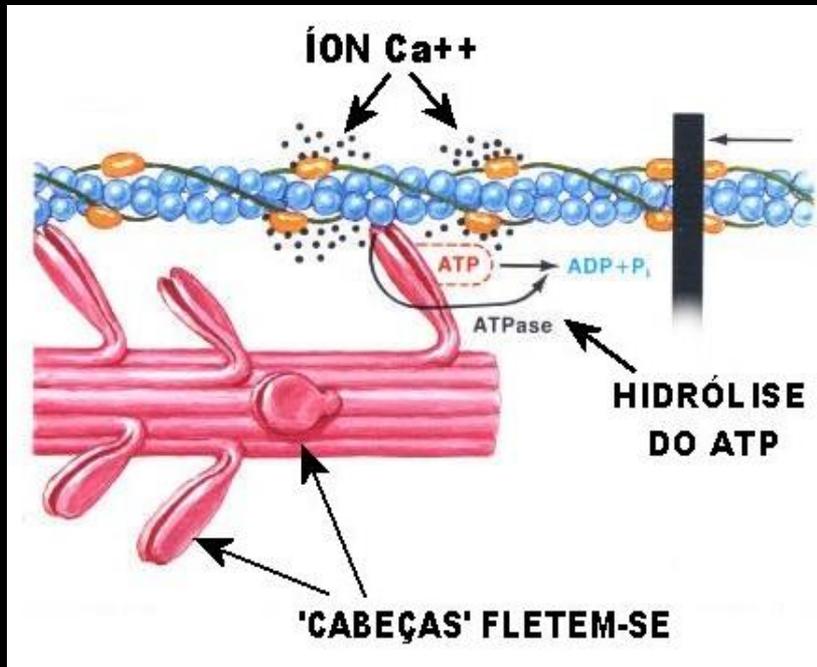


Criostato -25° C

Cortes seriados

10 μ m

V - Histoquímica ATPase:



Enzima
miosina ATPase

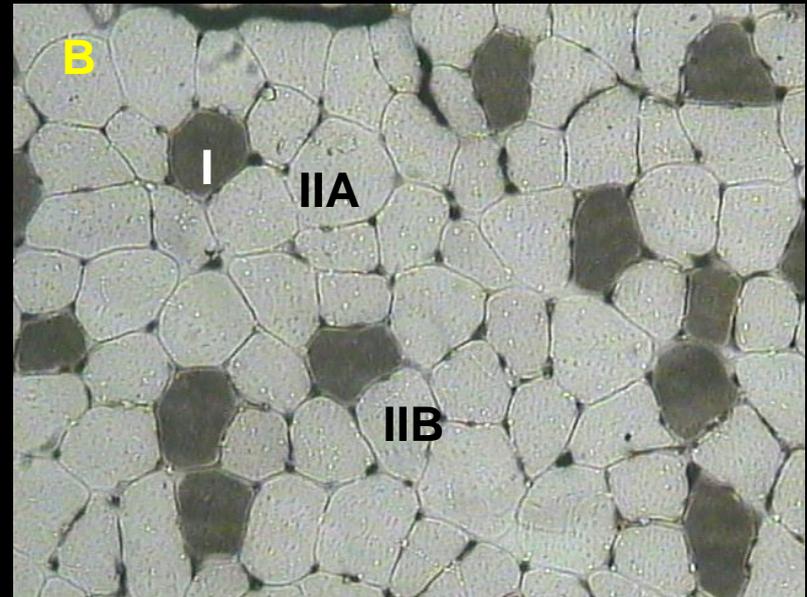
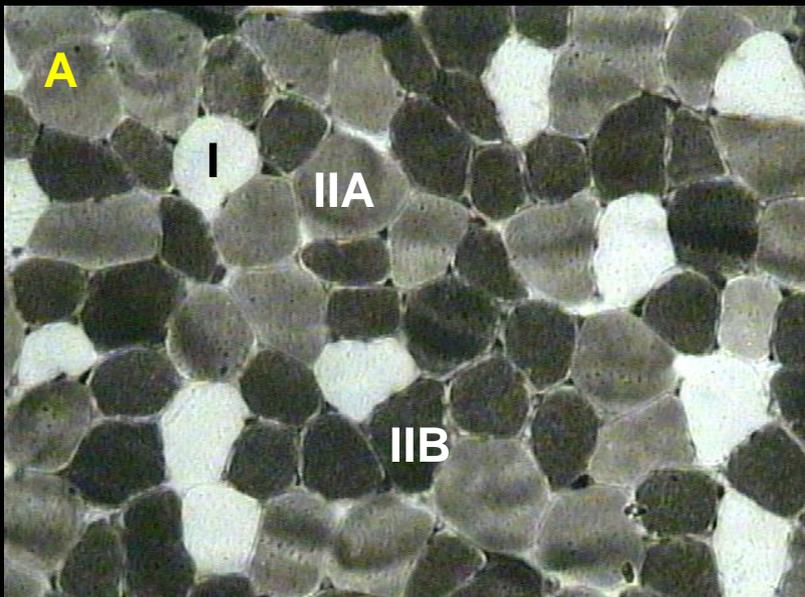
Substrato
ATP

Produto

ADP + P_i

pH 10.3
pH 4.3

	pH 4.3	pH 4.6	pH 10.3
Tipo I			
Tipo IIA			
Tipo IIB			



Coloração da Miosina ATPase com pré-incubação a pH=10.3 (A) e 4.3 (B)

Determinação do Tipo de Fibra

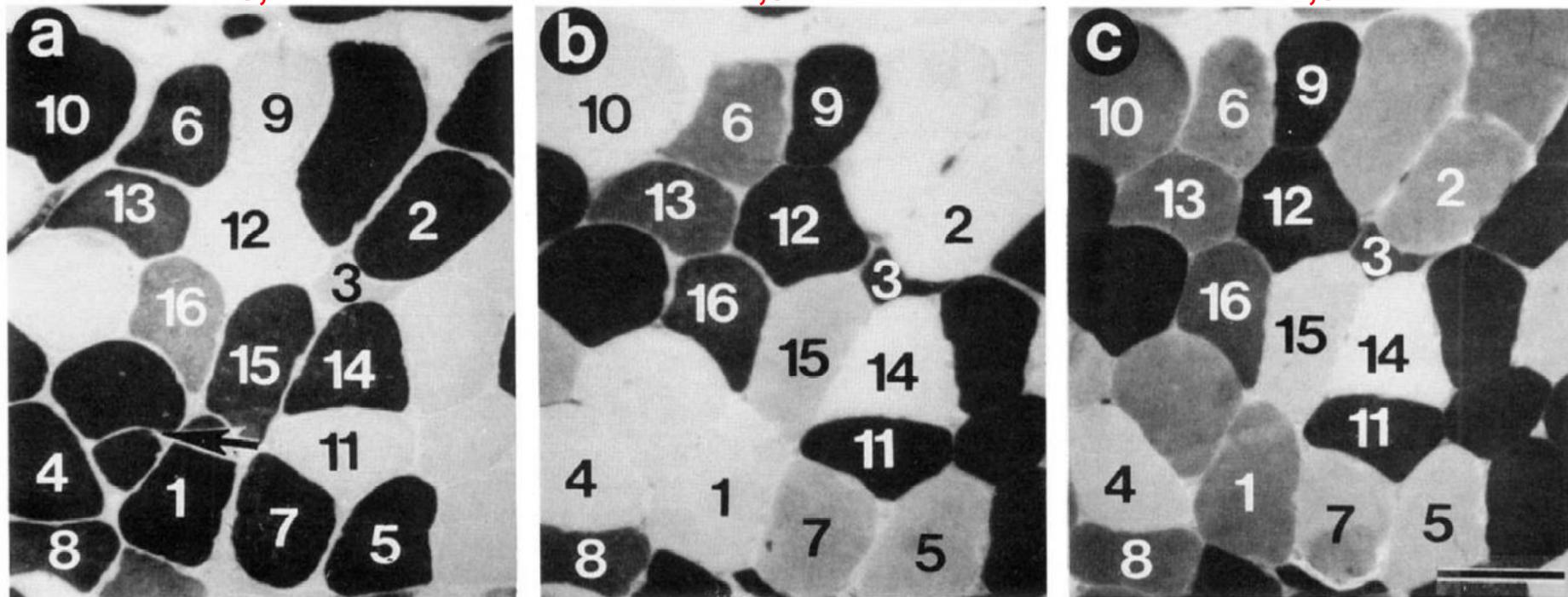
- Gel de eletroforese: **Isoformas de miosinas**
 - Proteínas com diferentes pesos deslocam-se diferente.



10,4

4,3

4,6



A



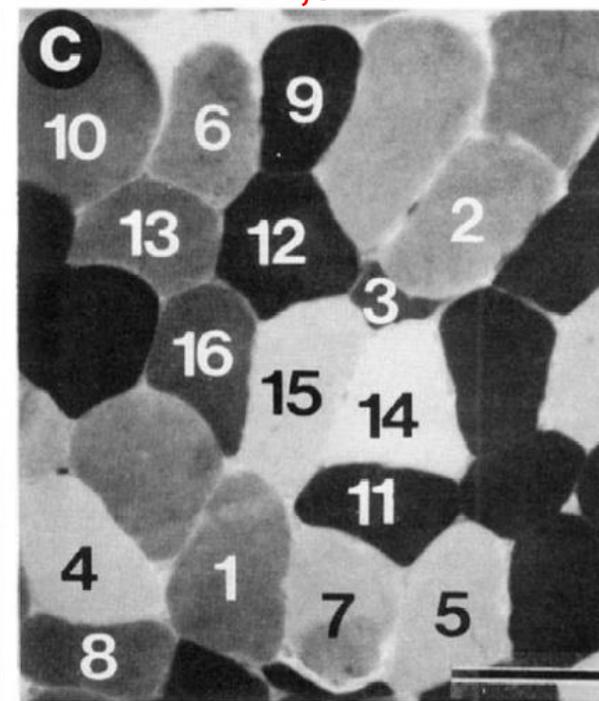
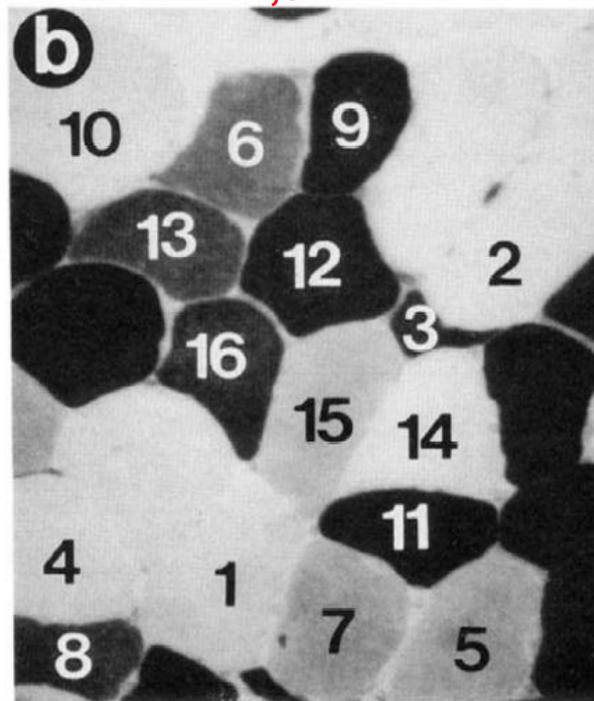
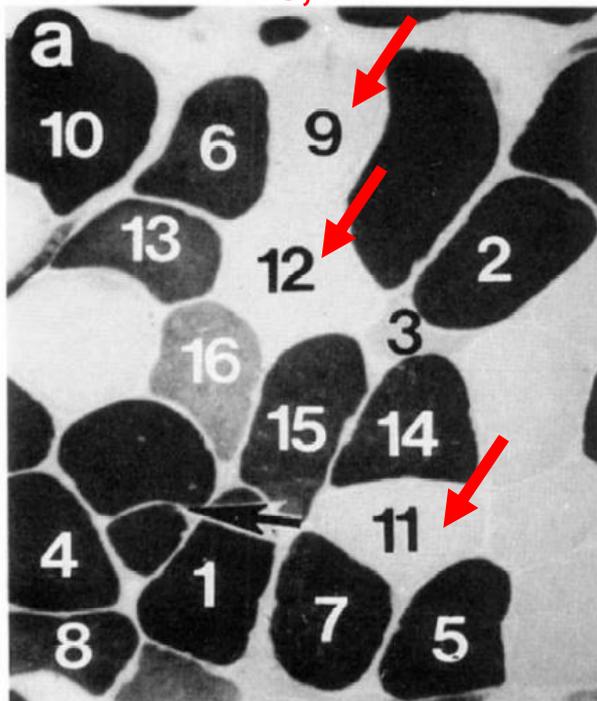
B

Figure 2. (A) Serial cross-sections of human vastus lateralis muscle assayed for mATPase activity after pre-incubation at pH 10.4 (a), 4.3 (b), and 4.6 (c). One Type IIB fiber has undergone fiber "splitting" (arrow). The numbered fibers are those whose myosin heavy chain content is given in B. Fibers 9, 11, and 12 were histochemically identified as Type I; fibers 3 and 16 as Type IC; fibers 5, 6, 7, 8, 13 and 15 as Type IIAC; fiber 14 as Type IIA; fibers 2 and 4 as Type IIAB; and fibers 1 and 10 as type IIB. Bar = 100 μ m. (B) Myosin heavy chain analysis of microdissected fragments from histochemically identified single fibers. The numbers correspond to the same fibers marked in A. Fibers 2 and 3 were co-electrophoresed. MHCIIa, myosin heavy chain IIa; MHCIIb, myosin heavy chain IIb; MHCI, myosin heavy chain I.

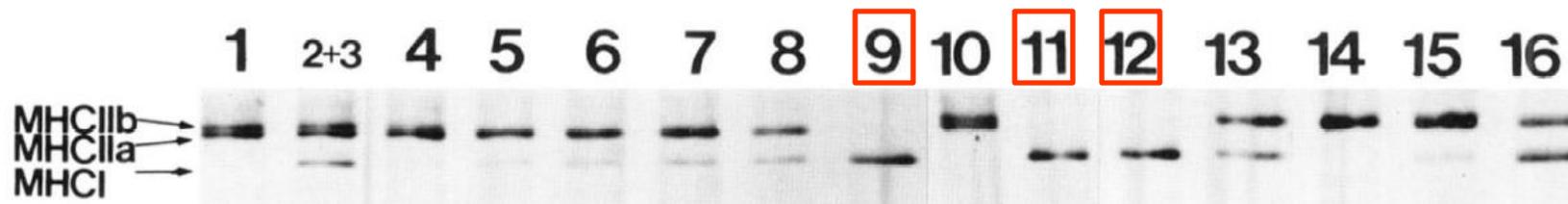
10,4

4,3

4,6



A

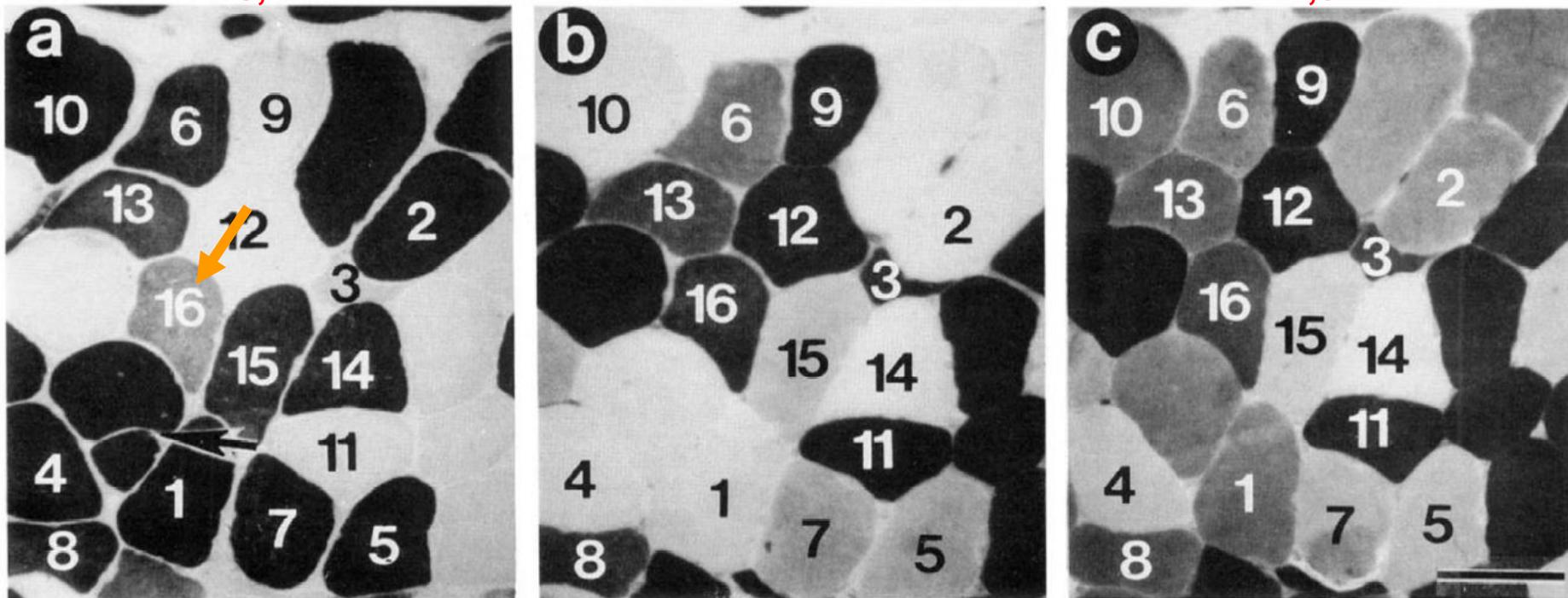


B

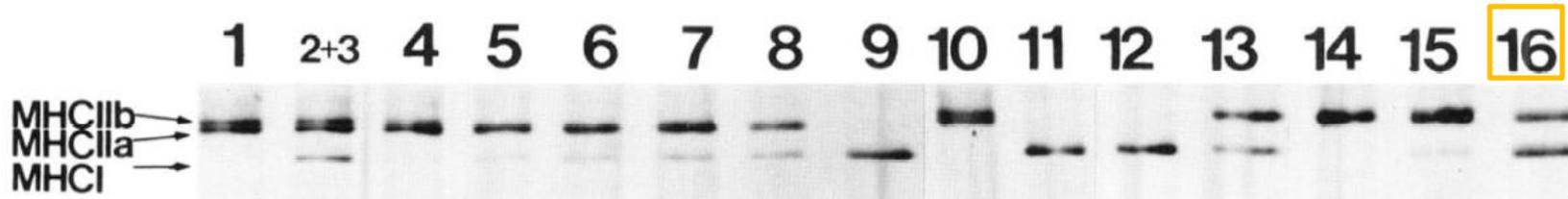
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10,4

4,6



A



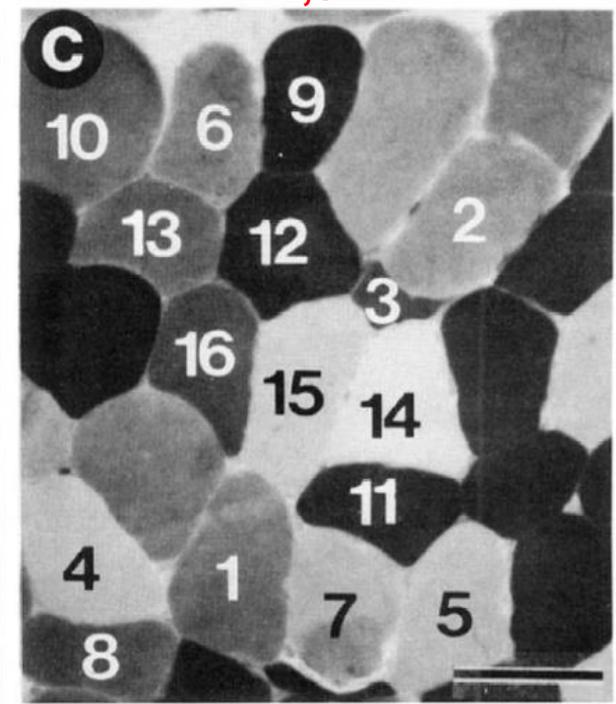
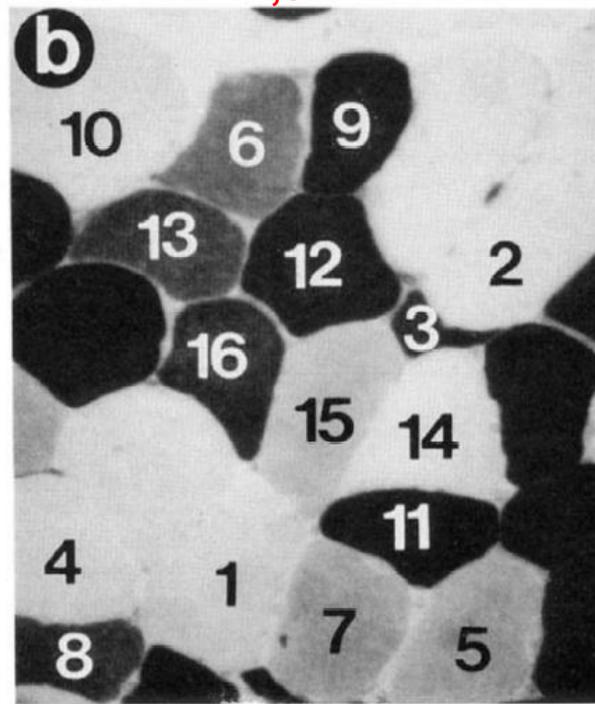
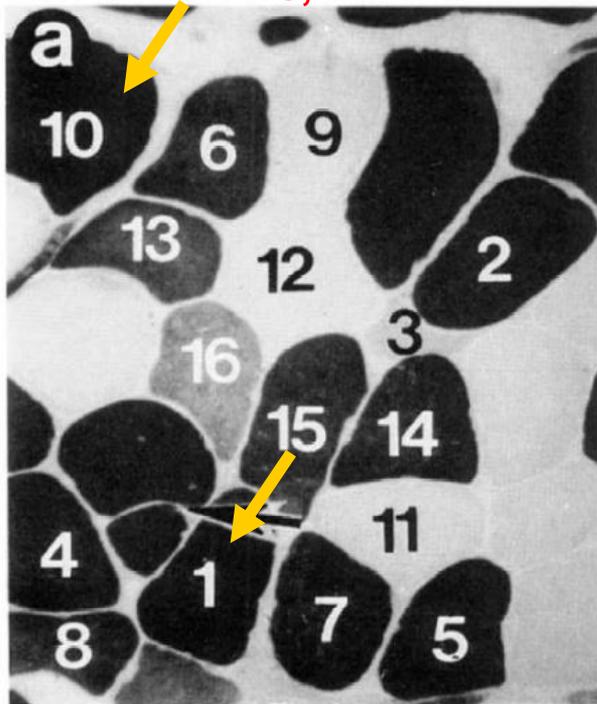
B

Figure 2. (A) Serial cross-sections of human vastus lateralis muscle assayed for mATPase activity after pre-incubation at pH 10.4 (a), 4.3 (b), and 4.6 (c). One Type IIB fiber has undergone fiber "splitting" (arrow). The numbered fibers are those whose myosin heavy chain content is given in B. Fibers 9, 11, and 12 were histochemically identified as Type I; fibers 3 and 16 as Type IC; fibers 5, 6, 7, 8, 13 and 15 as Type IIAc; fiber 14 as Type IIA; fibers 2 and 4 as Type IIAb; and fibers 1 and 10 as type IIB. Bar = 100 μ m. (B) Myosin heavy chain analysis of microdissected fragments from histochemically identified single fibers. The numbers correspond to the same fibers marked in A. Fibers 2 and 3 were co-electrophoresed. MHCIIa, myosin heavy chain IIa; MHCIIb, myosin heavy chain IIb; MHCI, myosin heavy chain I.

10,4

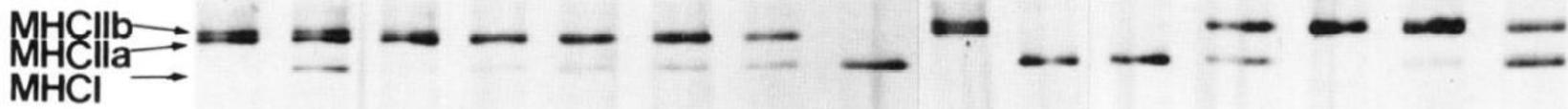
4,3

4,6



A

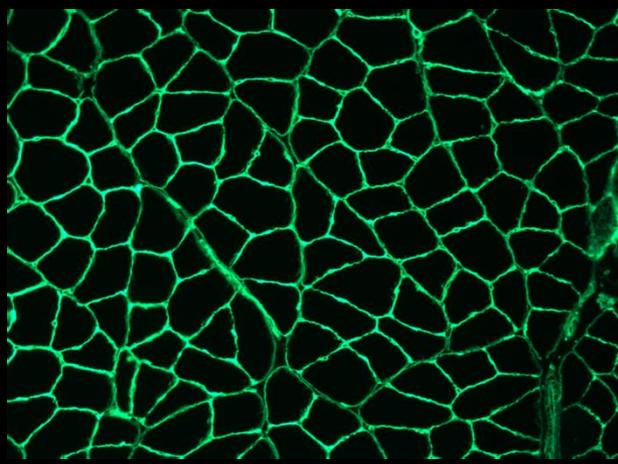
1 2+3 4 5 6 7 8 9 10 11 12 13 14 15 16



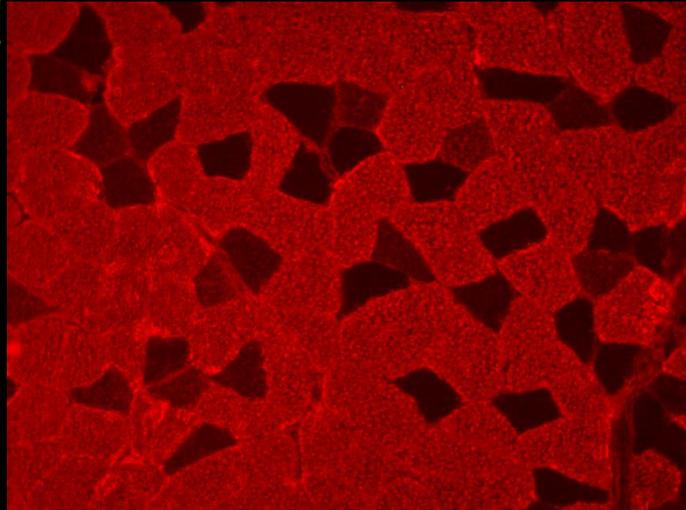
B

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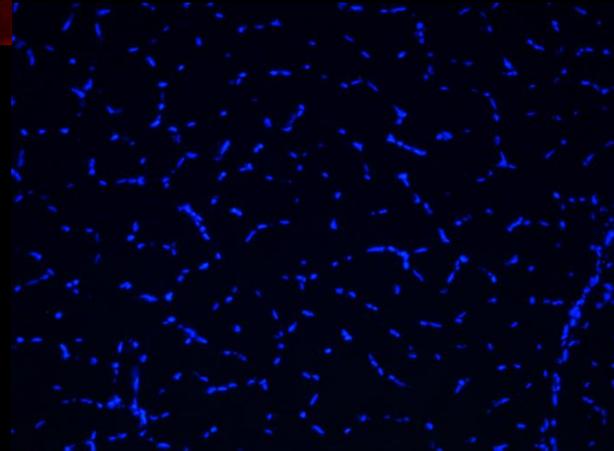
Imunohistoquímica



Lamina-
Lamina Basal



MHC-I β



Dapi- Núcleo

É possível alterar o tipo de fibra?





> % Fibras rápidas

∴ o Tipo de Fibra é um dos fatores que afetam a performance



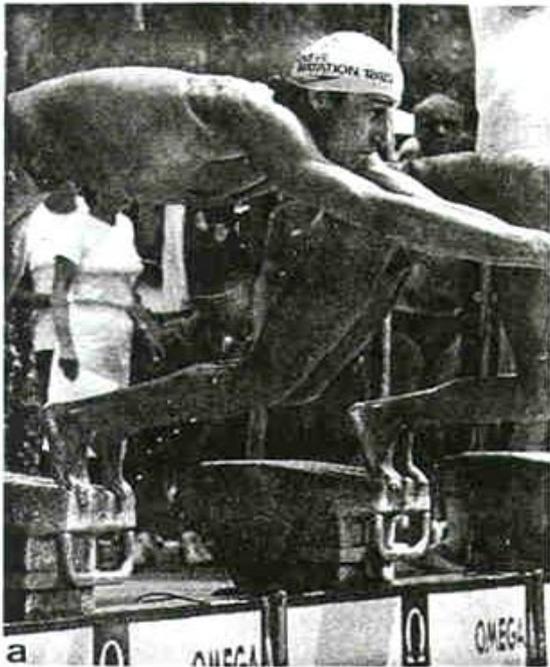
> % Fibras lentas



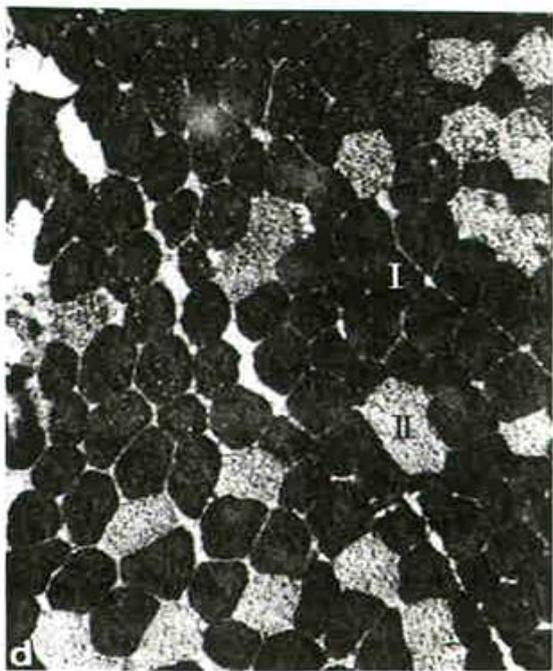
Como dissociar o componente genético do ambiental no efeito do treinamento físico?

Estudos Transversais

Estudos com gêmeos



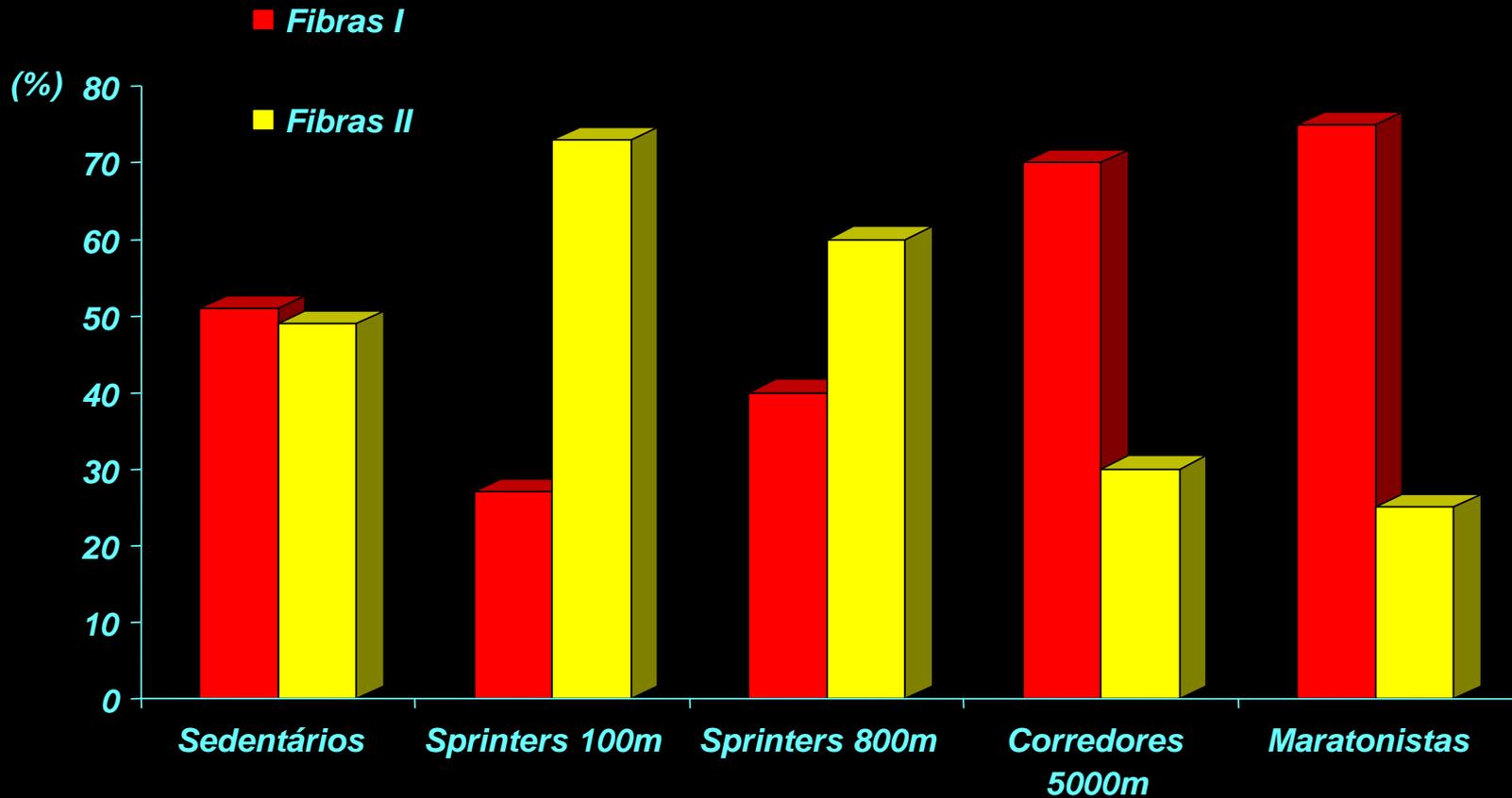
Estudos escandinavos
Década de 70



pH 4,3

Variações na % de distribuição de fibras

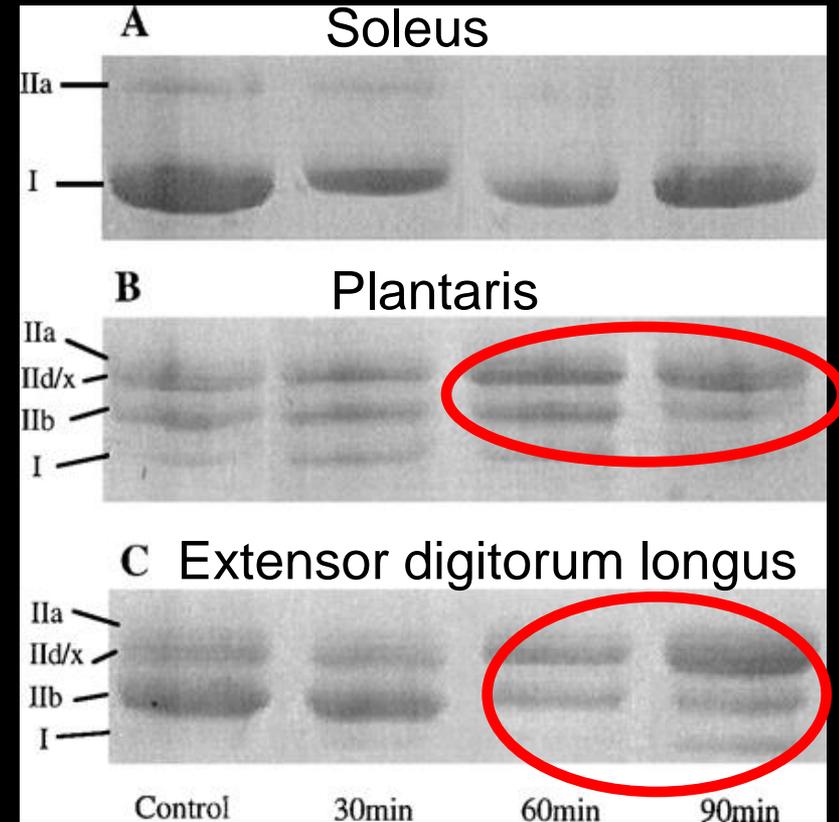
Tipo de fibra de acordo com modalidade praticada
(Vastus lateralis)



Mudança de Tipos de Fibra com TF aeróbio: Princípio da Proximidade

Ratas treinadas 75% VO_2 max. em sessões com 30, 60 ou 90 min de duração, por 10 semanas.

- **Fig. 3.** SDS-PAGE gels ilustrando as alterações nas isoformas de **MHC**



$I\beta \leftrightarrow I \& IIa^* \leftrightarrow IIa \leftrightarrow IIa \& IIx^* \leftrightarrow IIx \leftrightarrow IIx \& IIb^* \leftrightarrow IIb$



% de fibras tipo IIx/B em fisiculturistas

O autor observou que fisiculturistas de elite chegavam a ter só 1% de fibras do tipo IIb/x.



(Macdougall *et al*, 1982/84)

% de fibras tipo IIx/B em “*Power lifts*”

Foi verificado que esses atletas possuíam em média 1,3% de MHCIIb, enquanto pessoas ativas tinham 12%.



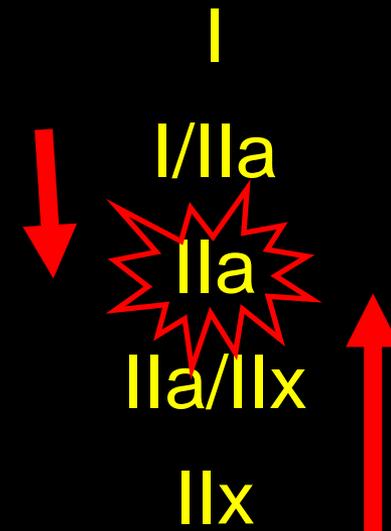
(FRY *et al*, 2003)

Mudança de Tipos de Fibra com TF força: Princípio da Proximidade

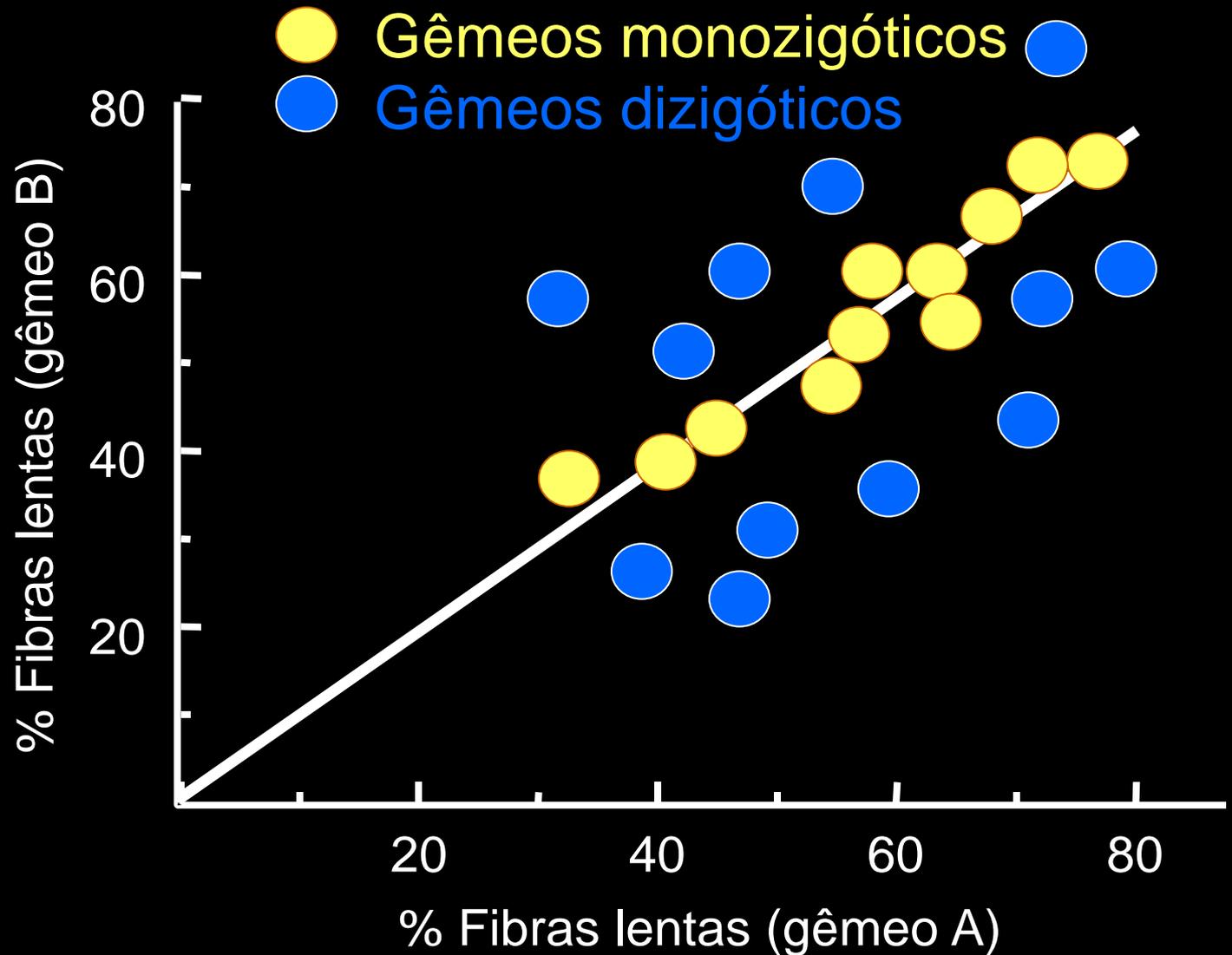
Table 1. CSA of fibers obtained before and after 12 wk of resistance training

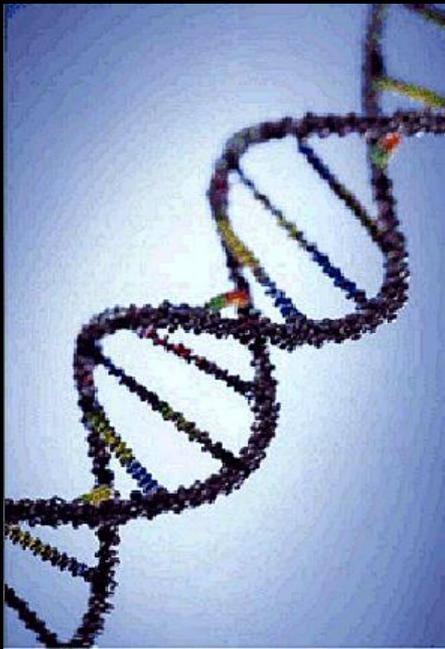
MHC Isoform	No. of Fibers		Fiber CSA, μm^2	
	Pre	Post	Pre	Post
I	86 (42%)	69 (42%)	5,337 \pm 152 ^a	6,933 \pm 228*
IIa	8 (4%)	0	6,635 \pm 332 ^b	
IIa/IIx	62 (30%)	90 (55%)	6,702 \pm 178 ^b	8,691 \pm 190*
IIx	45 (22%)	4 (3%)	6,683 \pm 239 ^b	8,697 \pm 526*
IIx	3 (2%)	0	7,436 \pm 280 ^b	

Fiber cross-sectional area (CSA) values are means \pm SE. No. of fibers indicates the number of fibers isolated from pre- and posttraining muscle biopsies with the corresponding percentage of total pre- or posttraining fibers in parentheses. *Significant difference ($P < 0.05$) between pre- and posttraining fibers containing similar myosin heavy chain (MHC) isoforms. For the pretraining fibers, any 2 means with different superscript letters are significantly different ($P < 0.05$).



Predisposição genética





GENÉTICA



PERFORMANCE ESPORTIVA

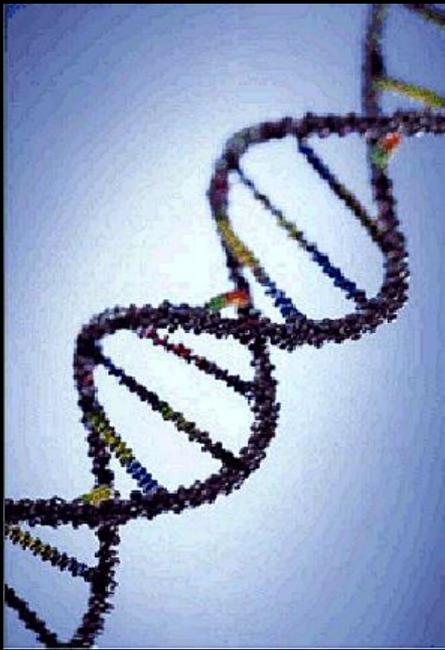


MEIO AMBIENTE

TREINAMENTO



Embora o potencial genético não possa ser modificado, é possível maximizar a performance através de um treinamento adequado



Modificações Genéticas



Desempenho Esportivo

A utilização de terapia gênica para melhora do rendimento esportivo constitui doping?

Genes Candidatos ao Doping Genético

- **EPO (eritropoietina),**
- **IGF-1 (fator de crescimento 1 semelhante à insulina),**
- **GDF-8 (miostatina),**
- **O VEGF (fator de crescimento vascular),**
- **LEP (leptina)**
- **gene codificador da endorfina.**



PPAR-Delta



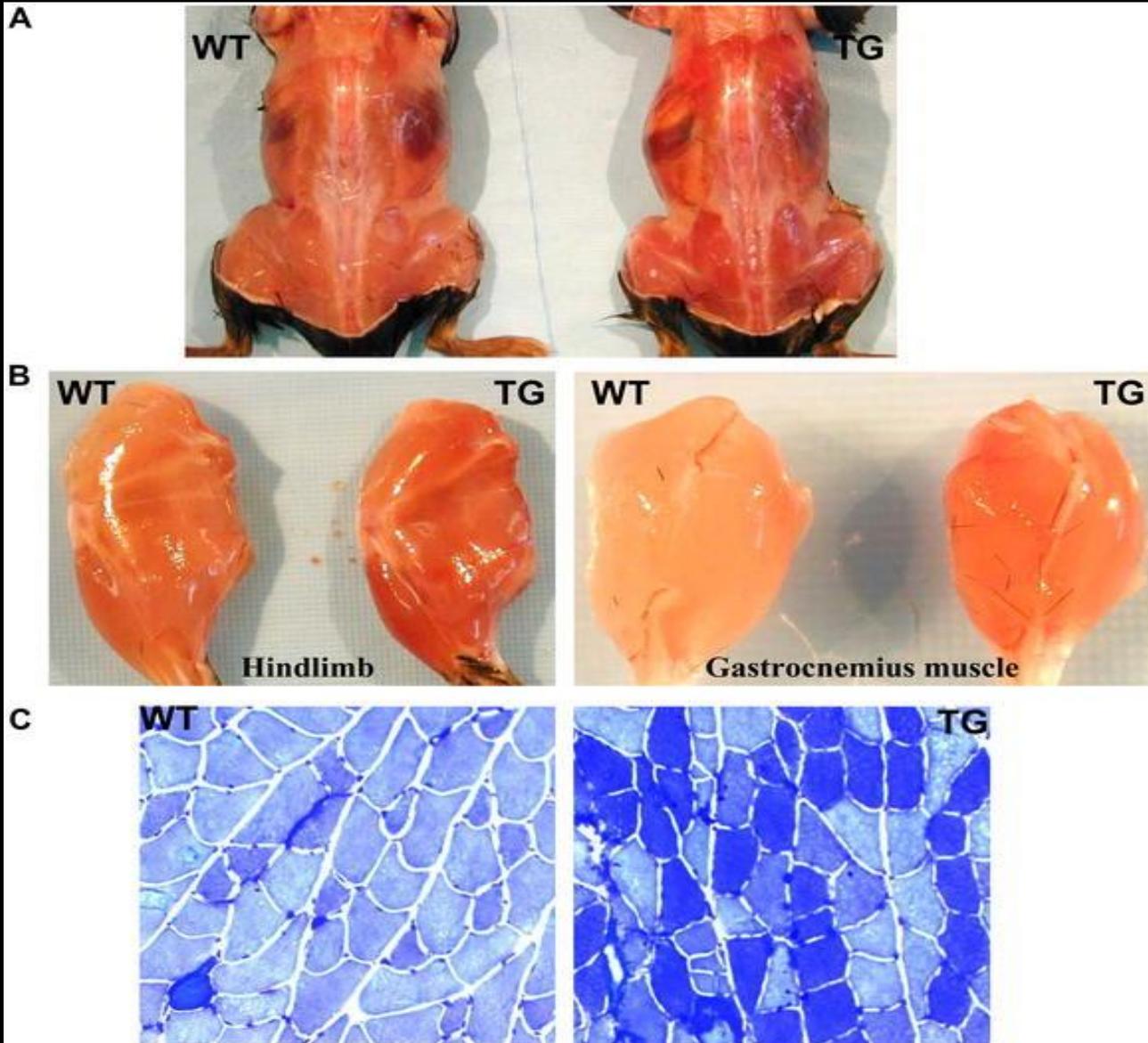
“Camundongo Maratonista”

Um grupo de cientistas dos EUA e do Sul da Coreia produziram o que eles chamam de “camundongo maratonista”. Esse camundongo superexpressa o gene “*Peroxisome Proliferator-Activated Receptor*” (PPAR-Delta), um gene importante para a regulação de diversos genes relacionados com o aumento de fibras de “contração lenta”.

O que esses animais tem de diferente?

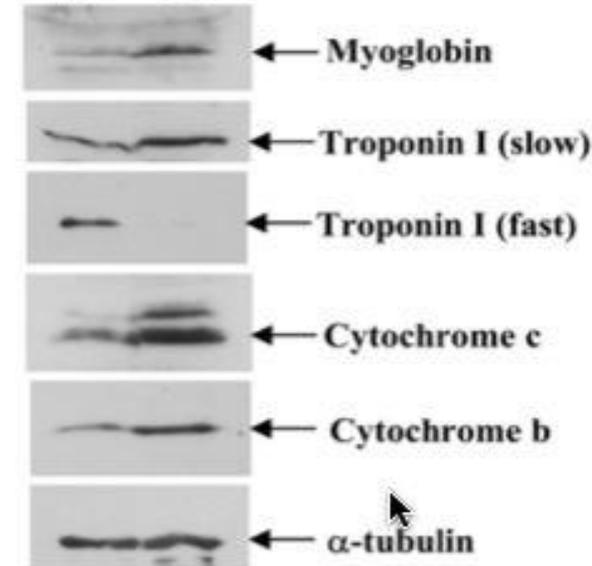
- ✓ correm duas vezes mais do que o camundongo normal.
- ✓ eles podem correr uma hora à mais do que sobre a média de 90 min que normalmente os camundongos correm (sem treinamento prévio).
- ✓ ↑ no % de fibras do tipo I e ↑ de lipólise.

PPAR-Delta



western

WT TG



PPAR-Delta

Esses achados não apenas sugerem um aumento de endurance muscular, mas também a **perda de peso**

- Esses animais tem **resistência ao ganho de peso** quando submetidos a uma dieta hipercalórica e hiperlipídica (que normalmente levam os animais à obesidade).
- Talvez, uma futura perspectiva para o tratamento da obesidade...

Linhagens transgênicas PPAR (α e $\beta\delta$)

– Superexpressão dos receptores (fenótipos antagônicos)

PPAR $\beta\delta$



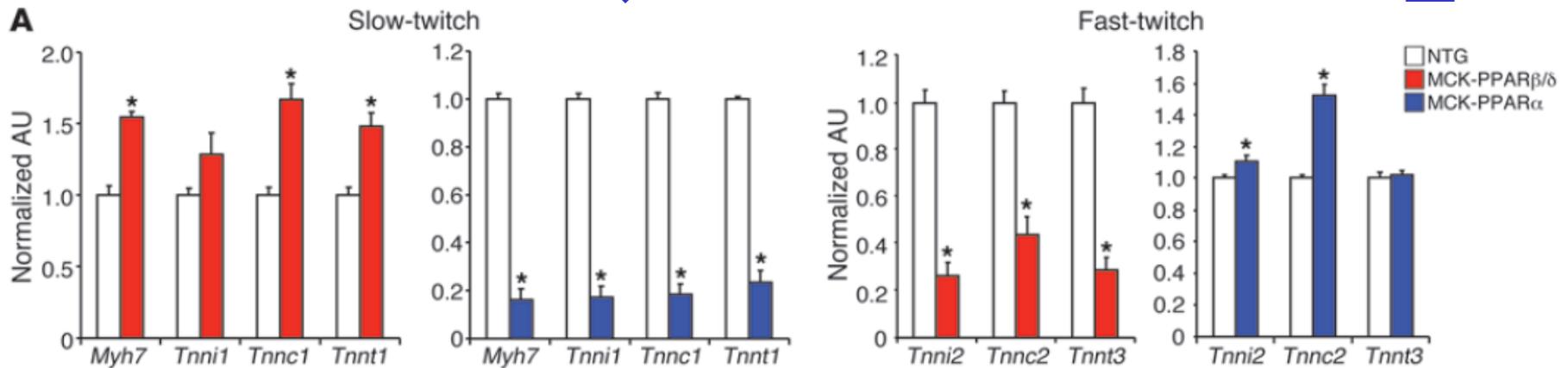
PPAR α



PPAR $\beta\delta$



PPAR α

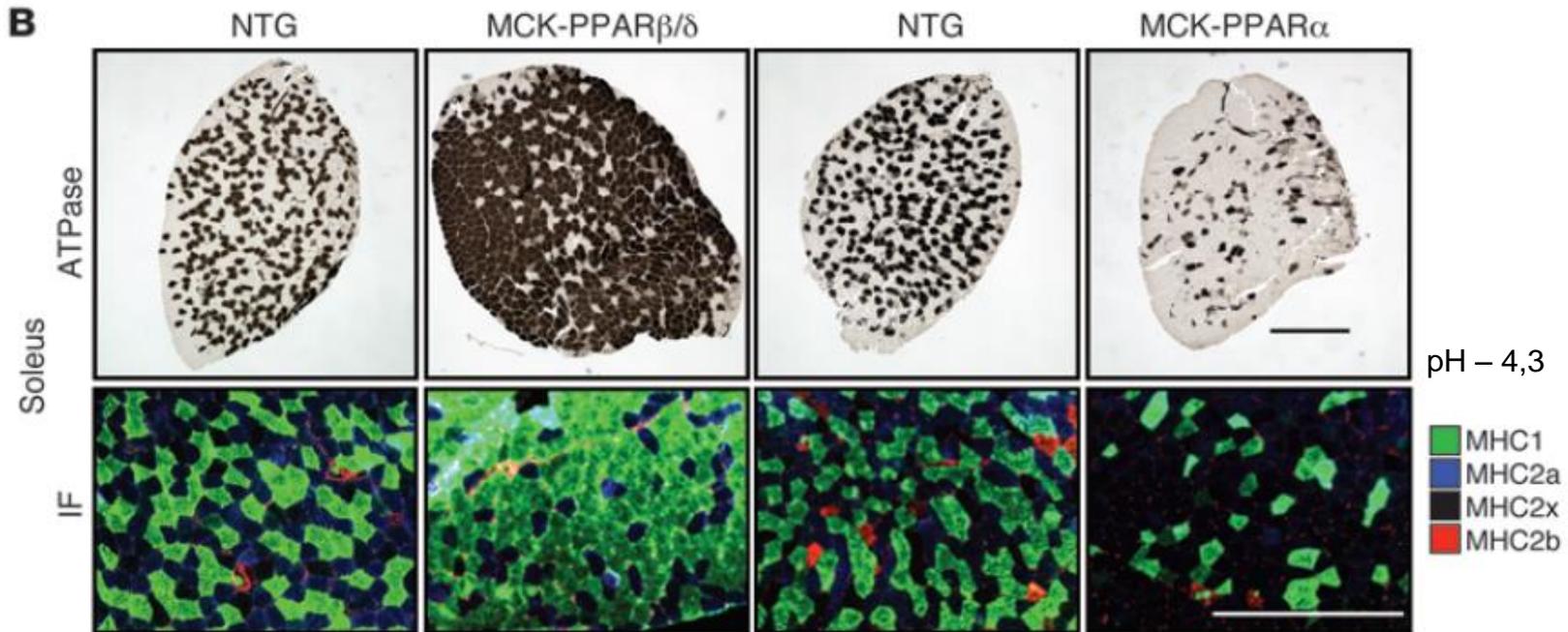


qRTPCR

Quantificação de Atividade ATPase Miosínica e Imunofluorescência

> Proporção fibras I

< Proporção fibras I

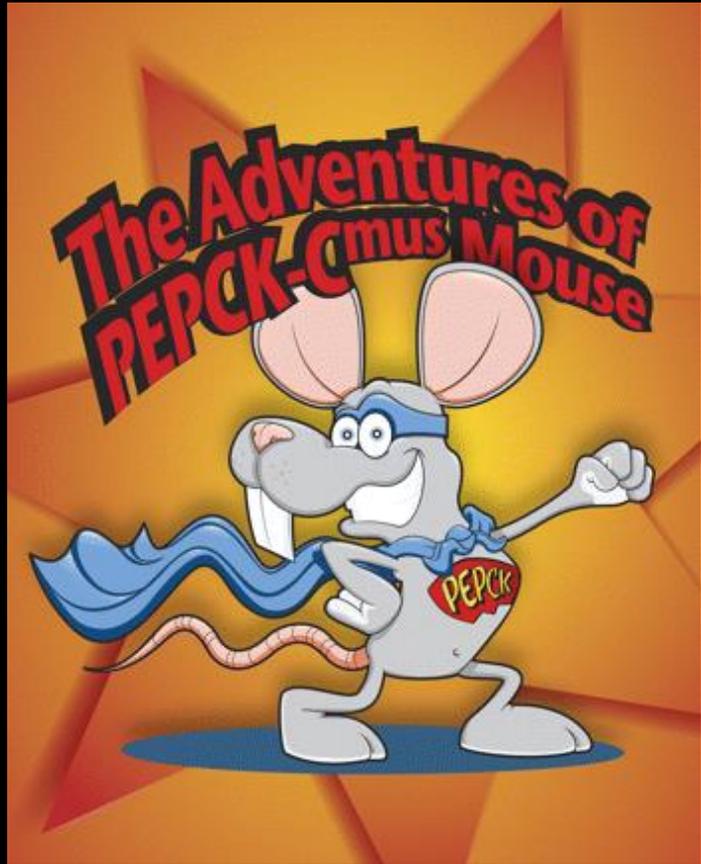


MHCI - verde

Fenótipos opostos decorrentes da superexpressão de ambos os receptores mostra mecanismo molecular oposto dos PPARs em relação à tipagem de fibras, controle metabólico e atividade ATPasica
Sulfato de amônia reage na fibra funcional – fibra do tipo I

PEPCK-C

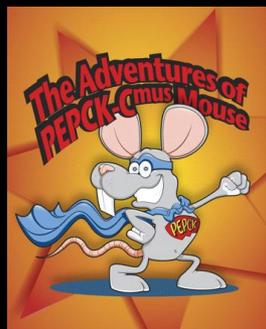
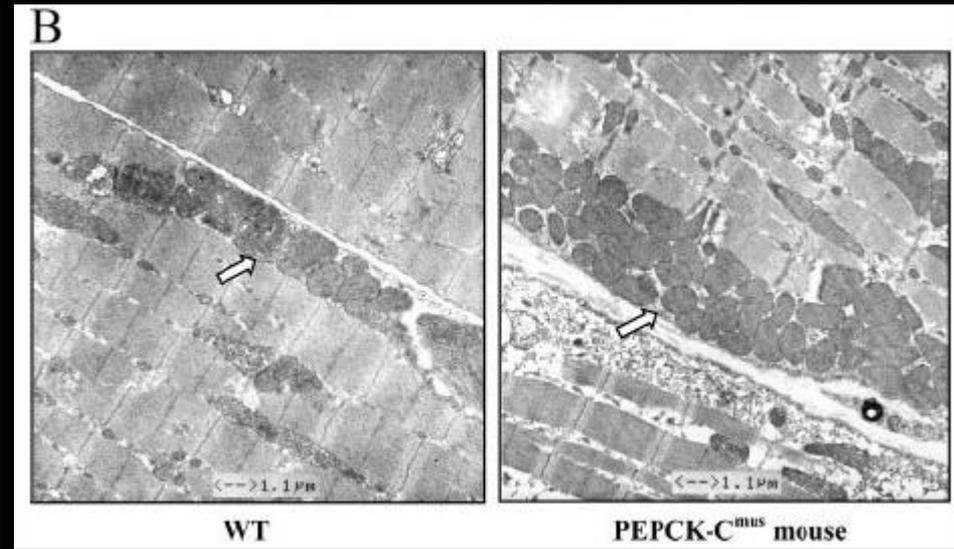
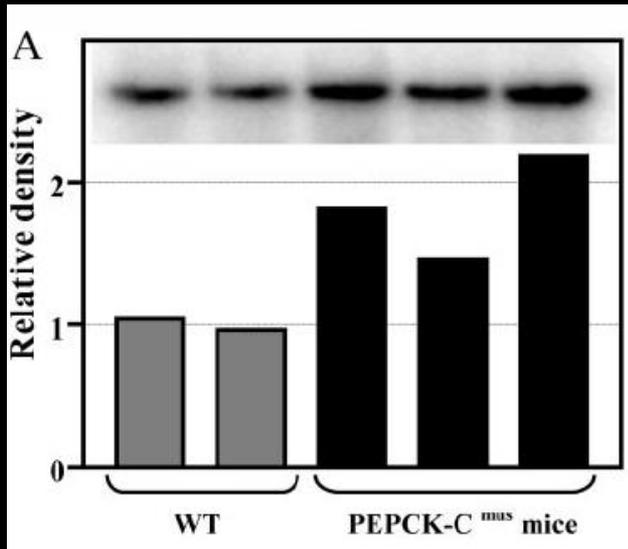
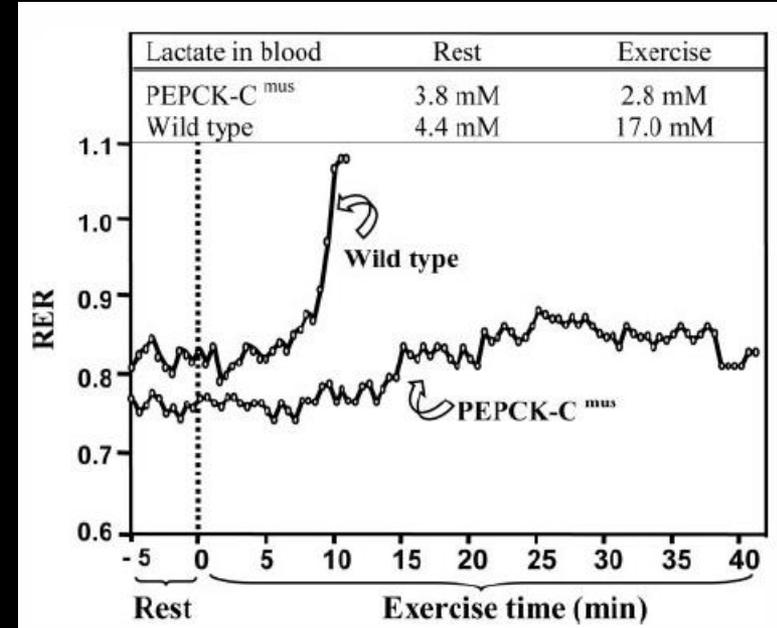
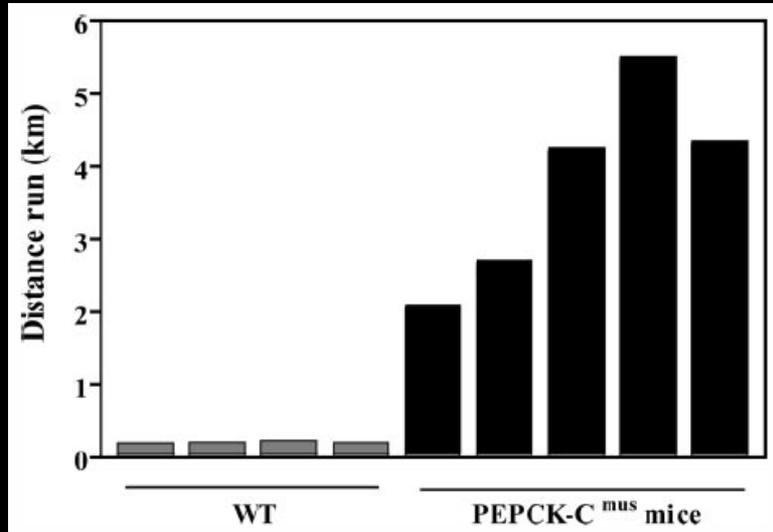
Hakimi, P et al. *The Journal of Biological Chemistry* 2007, 282:32844 - 55



More Powerful Than
a Locomotive?
PEPCK-C^{mus} Supermouse
vs.
Wild Type



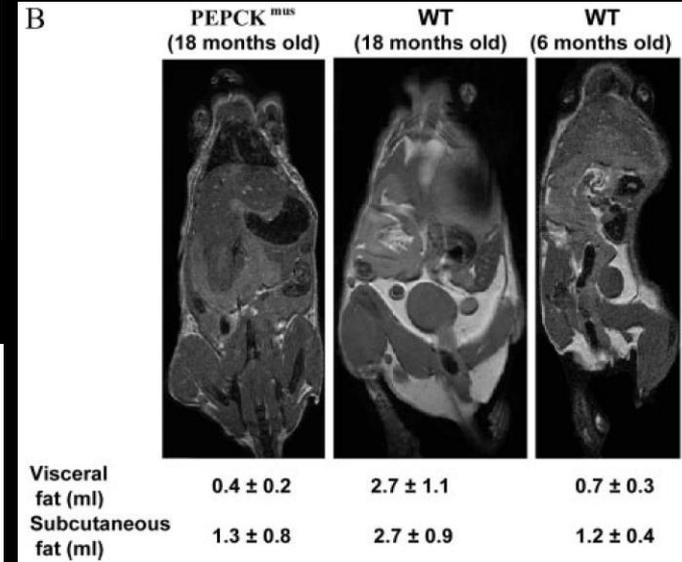
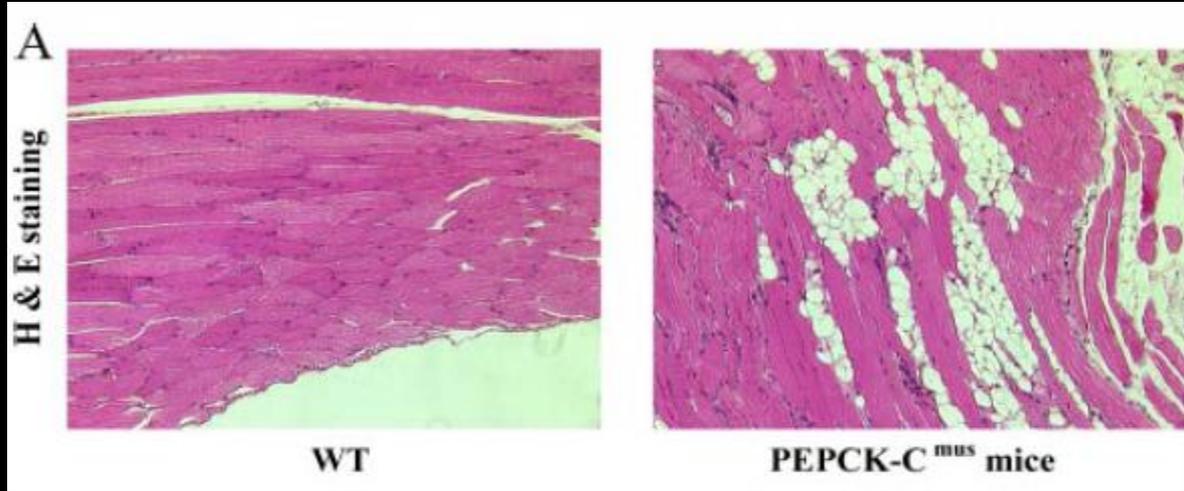
PEPCK-C



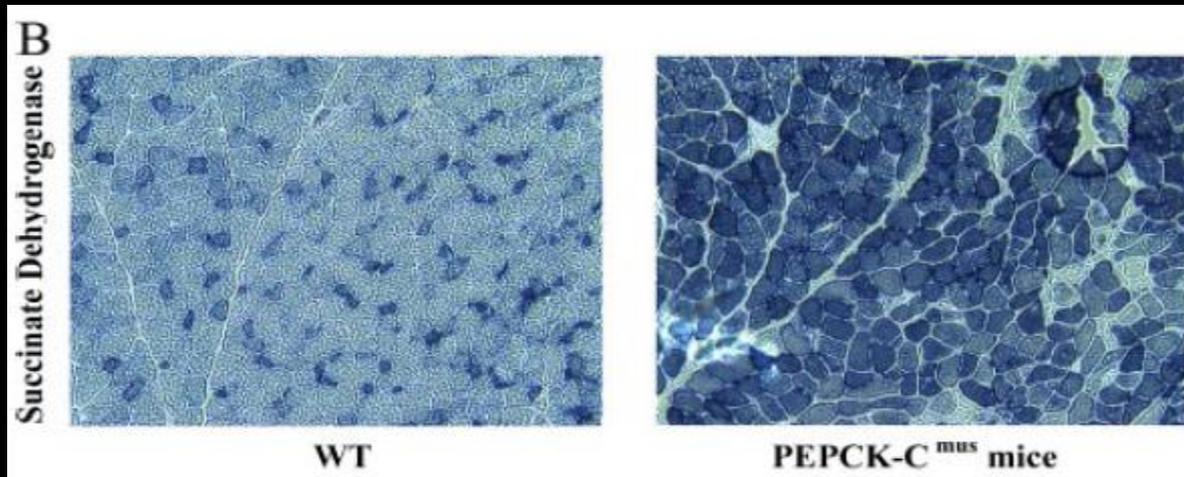
PEPCK-C



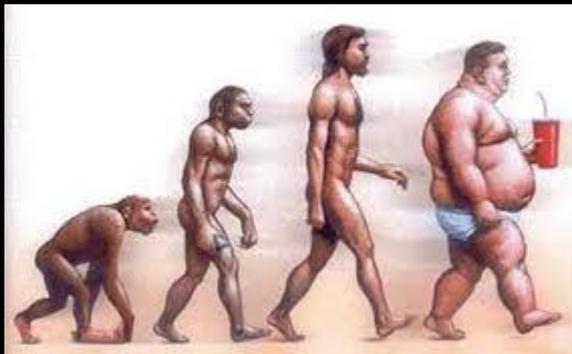
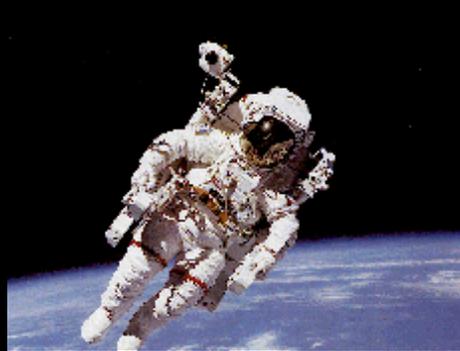
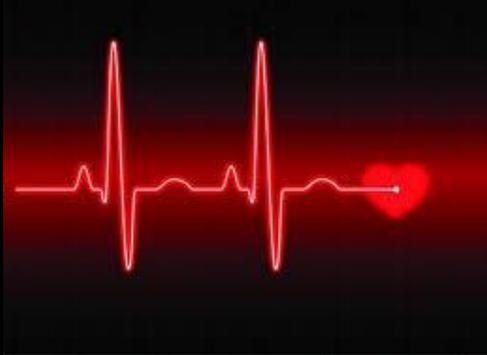
Gordura intramuscular



Atividade Oxidativa



Inatividade, Patologias e Tipos de Fibra Muscular: Efeitos do Exercício

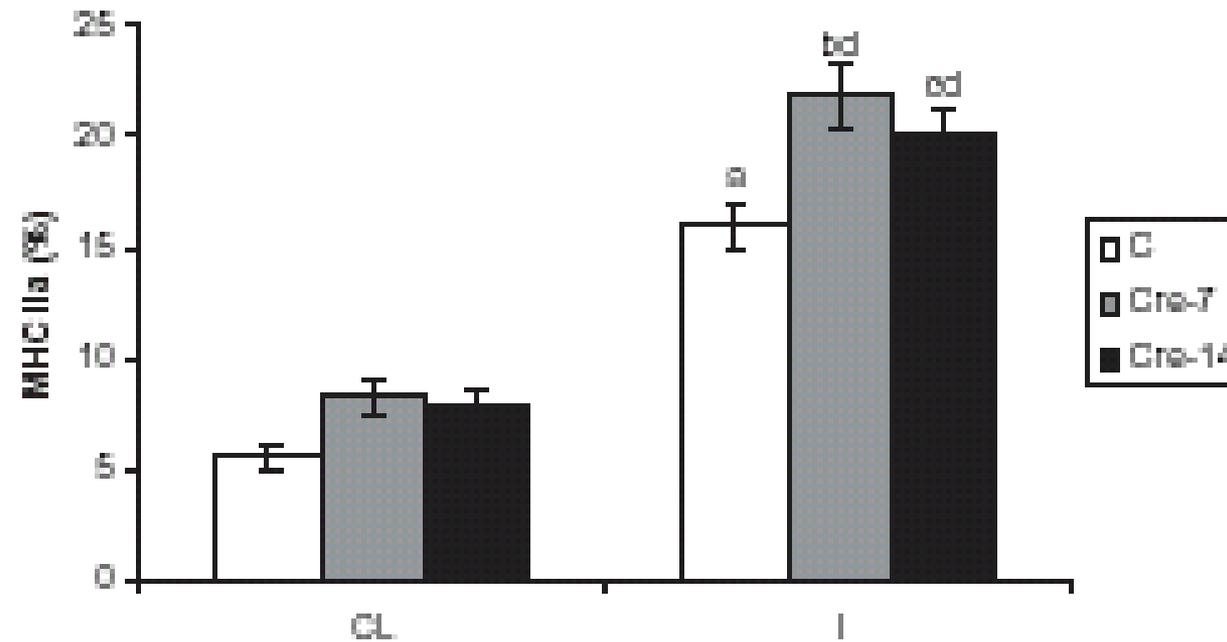
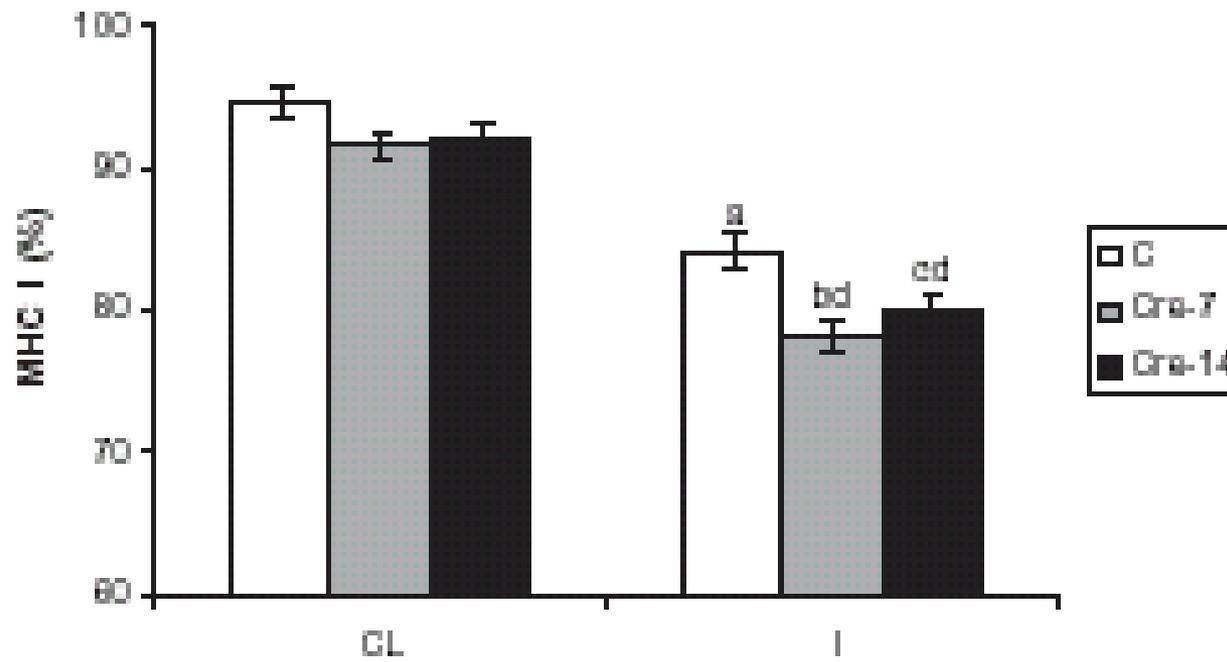


Insuficiência Cardíaca, Hipertensão Arterial, Obesidade, Desuso/Imobilização

Lentas ➔ Rápidas

7 dias de imobilização

Músculo sóleo

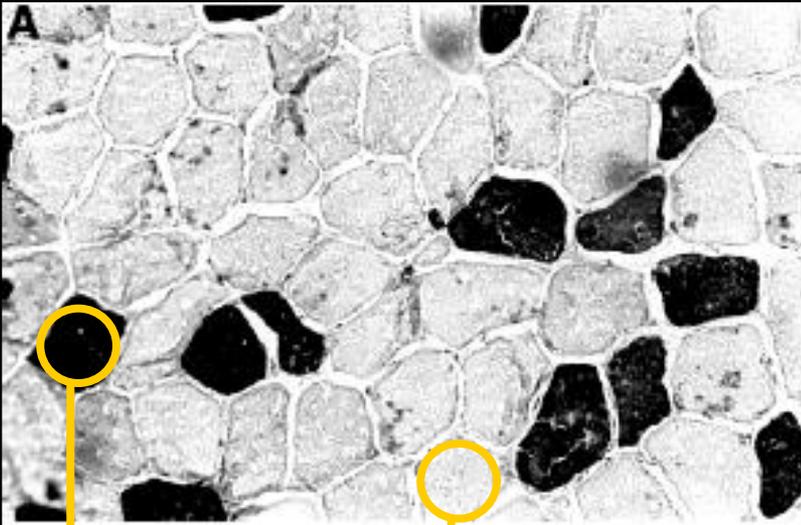


Insuficiência Cardíaca Congestiva

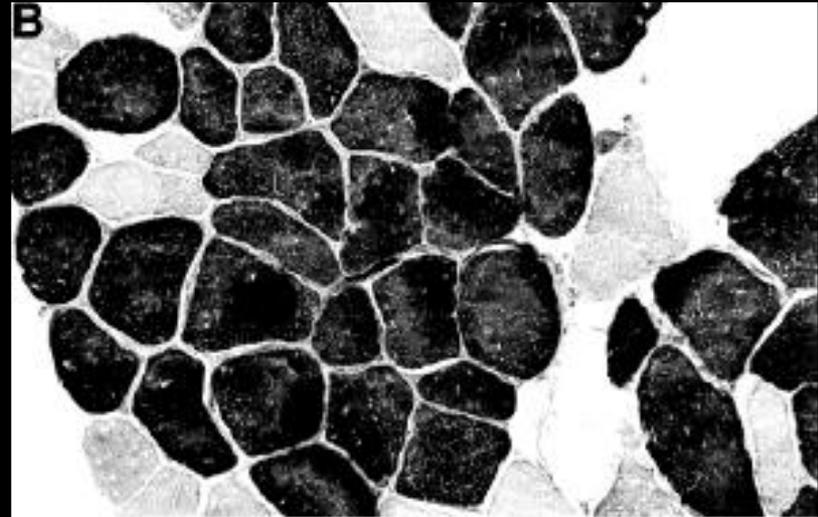
↑ Fibras do tipo II fibras

↓ Fibras do tipo I e atrofia muscular

▲ CONTROLE



▲ IC



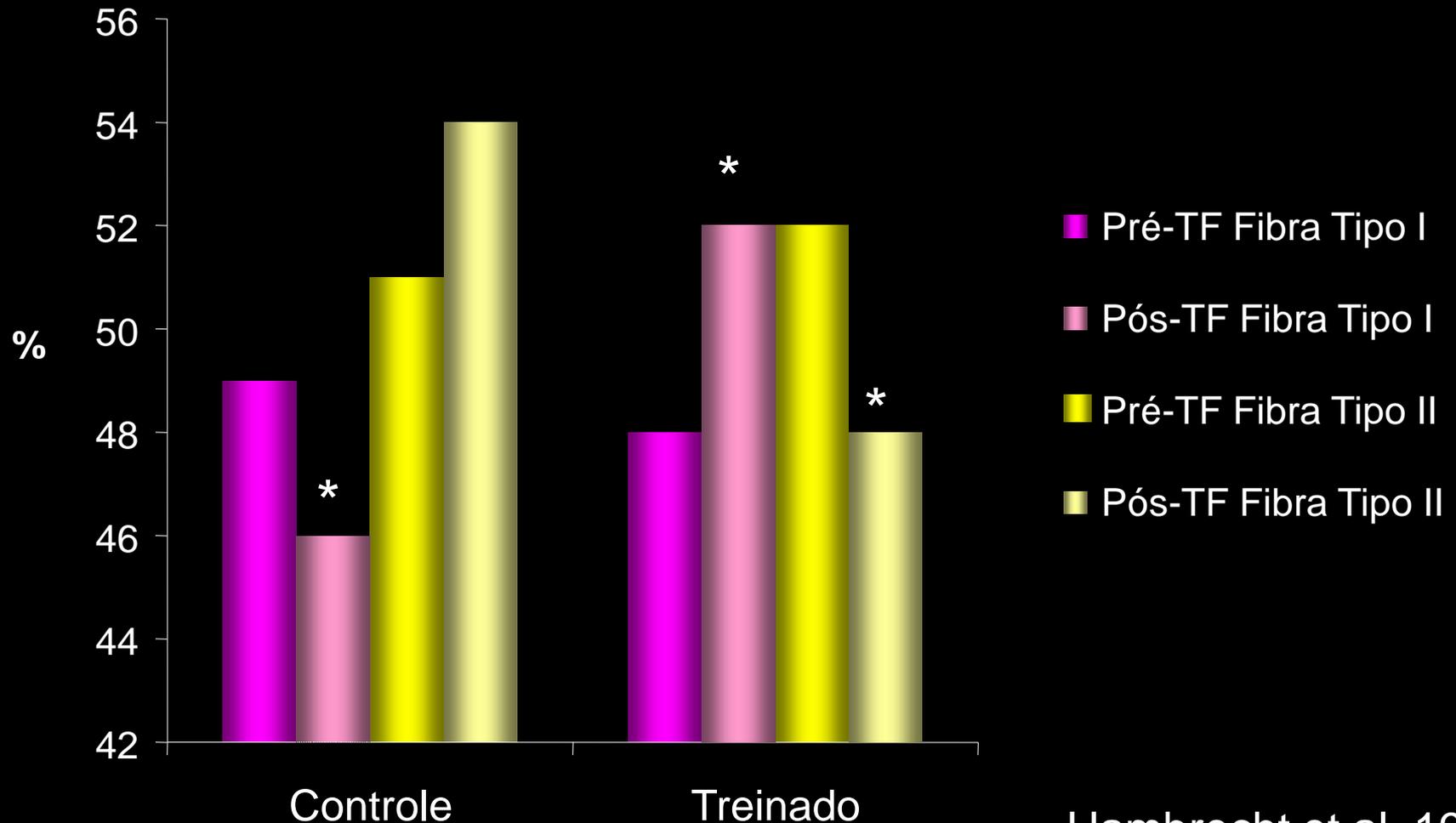
pH 9.4 – vasto lateral

Tipo II

Tipo I

TF na ICC- Fatores Periféricos

TF, 6 meses, 40 min, 5x/sem, 70% VO₂ max



TF na HA

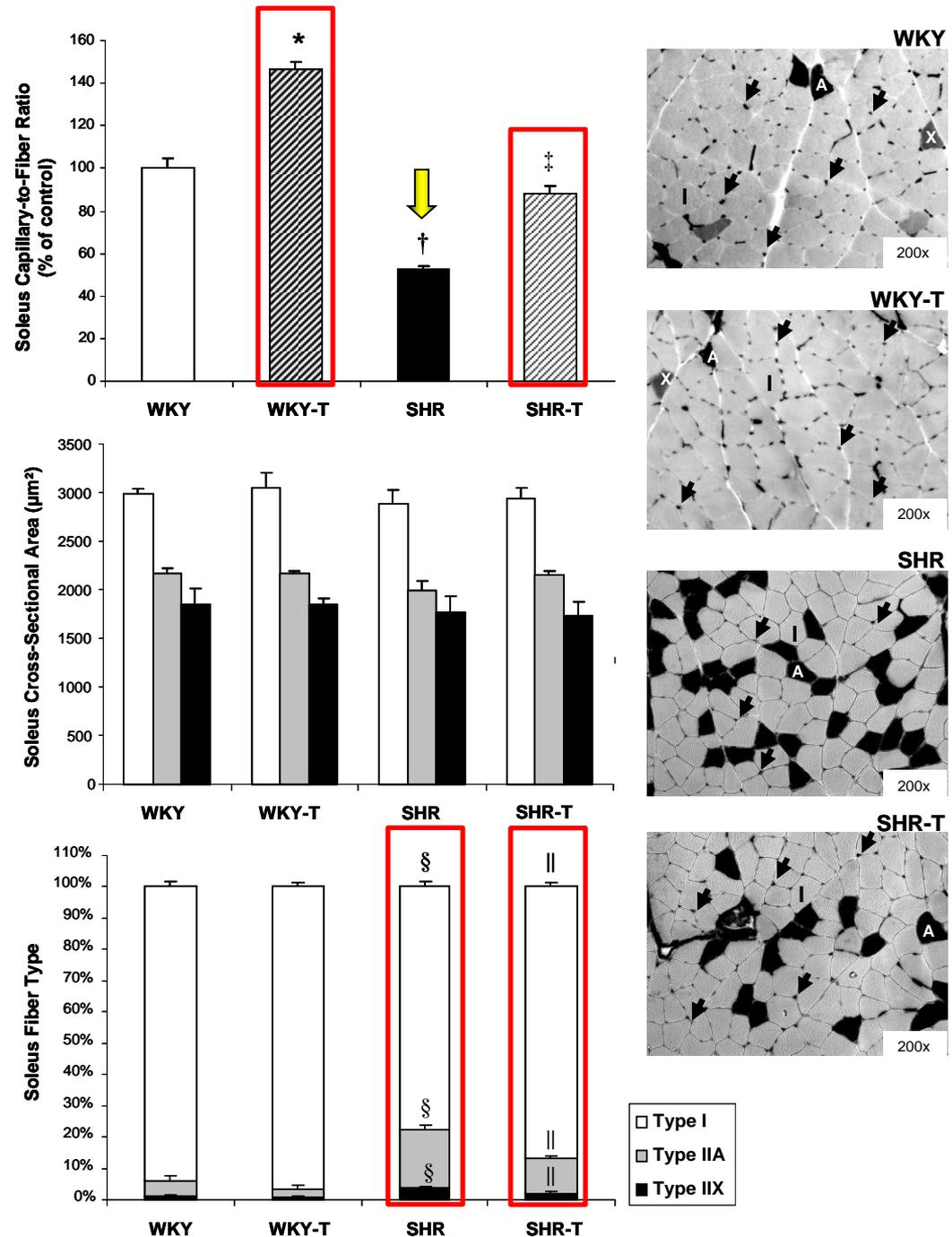
10 sem, 60 min, 5x/sem, natação

Razão Capilar:Fibra →

Área de Secção Transversa →

Proporção de Tipos de Fibra →

Fernandes T et al. 2012



TF na Obesidade- Fatores Periféricos

TF, 6 sem, 90 min, 5x/sem, esteira

TABLE 2. *Fiber type composition of skeletal muscle of trained and sedentary obese Zucker rats and their lean littermates*

	Trained Obese	Sedentary Obese	Lean Littermates
Soleus			
%I	77.4±1.9*	77.9±2.0*	83.3±1.6
%IIa	17.7±1.9	17.5±1.8	13.2±1.7
%IIb	4.9±0.7	4.9±0.9	3.6±0.5
	(16)	(20)	(19)
Plantaris			
%I	9.5±0.6	9.1±0.5*	11.1±0.6
%IIa	67.9±2.0	63.8±1.5	68.0±1.6
%IIb	23.6±1.7	26.3±1.6	21.2±1.6
	(17)	(22)	(21)
EDL			
%I	4.67±0.8	3.53±1.0	5.3±0.6
%IIa	64.0±3.6	67.8±4.1	60.2±2.5
%IIb	31.3±4.2	28.7±4.8	34.7±2.3
	(7)	(7)	(5)

Values are means ± SE. * Significantly different from lean rats ($P < 0.05$). Values in parentheses are the number of observations.



Envelhecimento



Enhanced Expression of Myogenic Regulatory Genes in Aging Skeletal Muscle

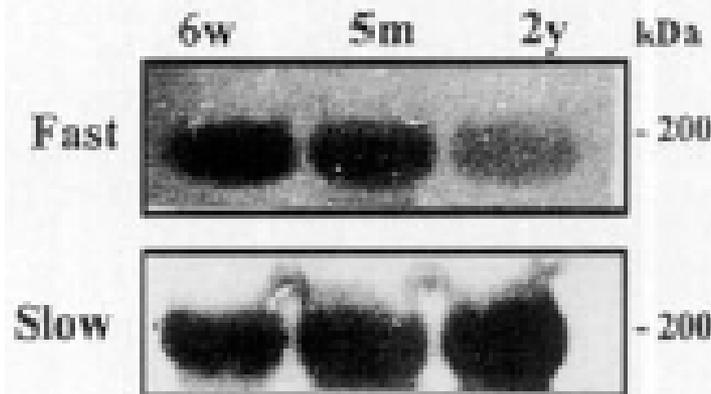
1995

TABLE 1

Mean Narrow Fiber Diameter and Fiber Type of the Quadriceps of Young (1), Adult (5), and Old (20) Mice

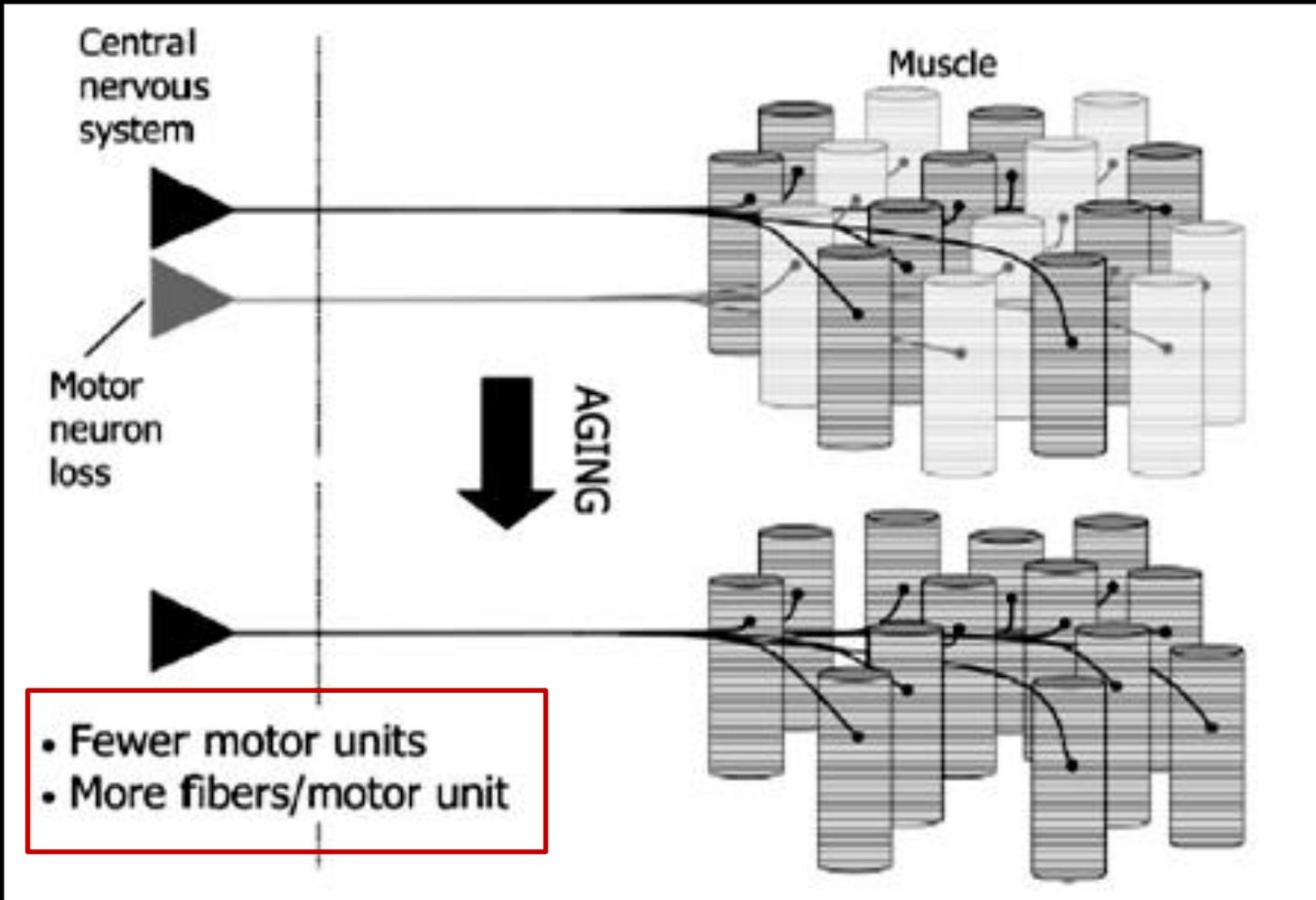
	Age (months)		
	1	5	20
(A) Total fibers (I + II)/field	136 ± 6.74	38 ± 2.2	63 ± 1.93
(B) Fiber diameter (μm)	32 ± 2.42	72 ± 2.45	44 ± 3.24
(C) Fiber type I/field	23 ± 2.35	12 ± 0.85	44 ± 2.95
(D) Fiber type I diameter (μm)	ND	70 ± 0.88	42 ± 1.12
% Type I	19.7	26.4	64
(E) Fiber type II/field	113 ± 7	26 ± 1.7	18 ± 2.5
(F) Fiber type II diameter (μm)	ND	72.5 ± 2	52 ± 3
% Type II (a + b)	80.3	73.5	36.8
(G) Isolated muscle weight/leg (g)	0.26 ± 0.006	0.55 ± 0.008	0.44 ± 0.013

Note. All values given are means ± standard error. ND, not determined. (A) $P < 0.001$ (1 vs 5; 1 vs 20; 5 vs 20); (B) $P < 0.001$ (1 vs 5); $P < 0.01$ (1 vs 20); $P < 0.001$ (5 vs 20); (C) $P < 0.001$ (1 vs 5; 1 vs 20; 5 vs 20); (D) $P < 0.0001$ (5 vs 20); (E) $P < 0.001$ (1 vs 5; 1 vs 20; 5 vs 20); (F) $P < 0.001$ (5 vs 20); (G) $P < 0.001$ (1 vs 5; 1 vs 20; 5 vs 20). The values derive from 29 (young), 12 (adult), and 21 (old) mouse muscles.



Envelhecimento

Unidades Motoras



Sumário

Efeito do treinamento físico:

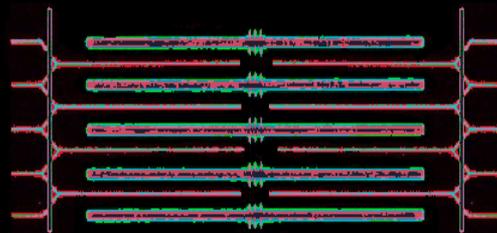
- ✓ Treinamento de *endurance*, adaptação dose-dependente (↑ tipo I)
- ✓ Treino de força (↑ tipo IIA)
- ✓ Inatividade e Patologias Cardíacas (↑ tipo IIB)
- ✓ Envelhecimento (↑ tipo I)

OBRIGADO PELA ATENÇÃO !

Email: tifernandes@usp.br



Contração Muscular

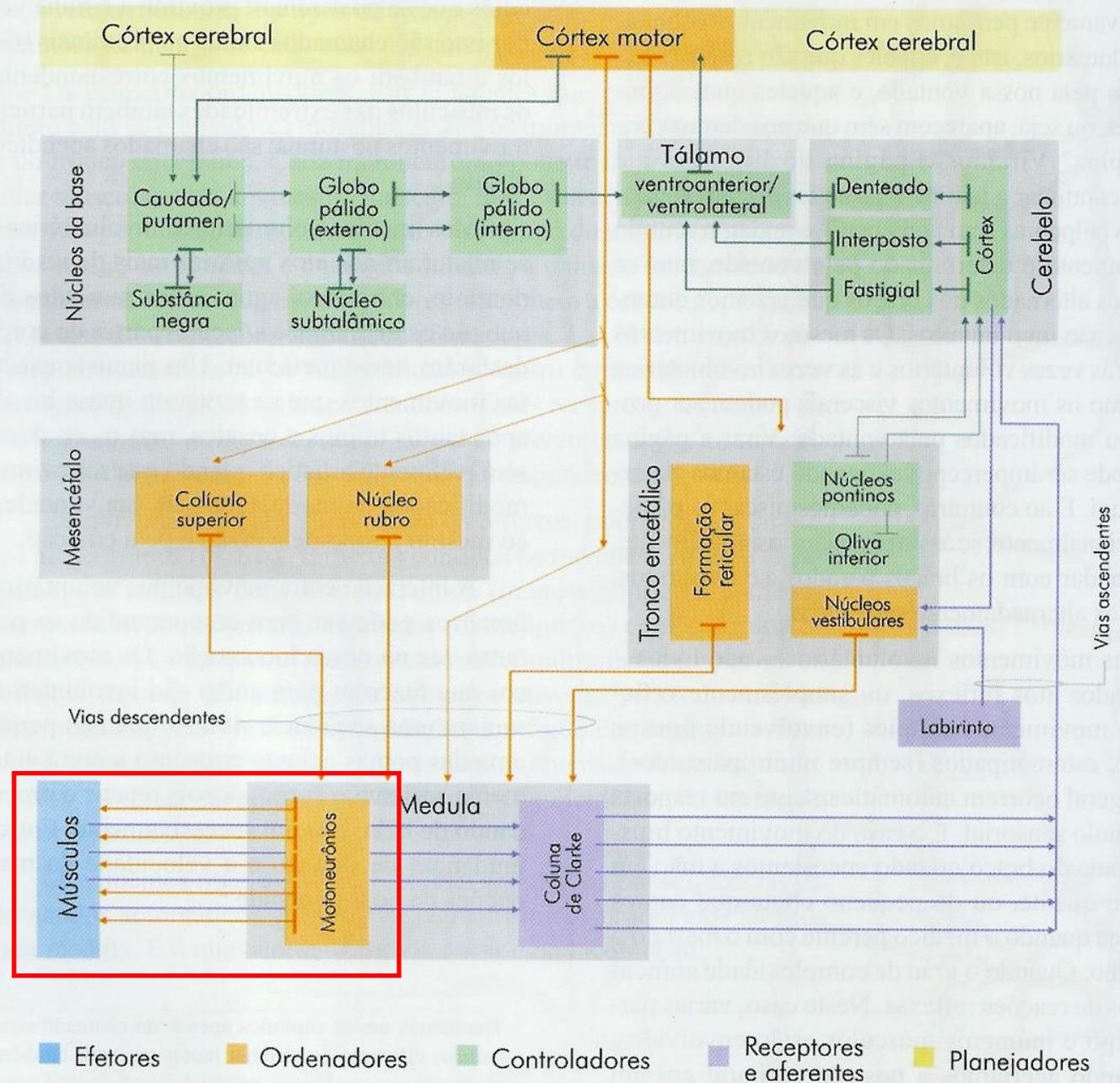


CIENTÍSTA RESPONSÁVEL PELA DESCOBERTA DA RELAÇÃO ENTRE MÚSCULOS E NERVOS



Swiss biologist Victor Albrecht von Haller (1708–1777)

Controle Motor



► **Figura 11.1.** Diagrama de blocos descritivo do sistema motor. As cores de cada bloco diferenciam as estruturas eferentes, ordenadoras, controladoras e planejadoras. As setas mostram as principais conexões do sistema.

Estrutura do Neurônio

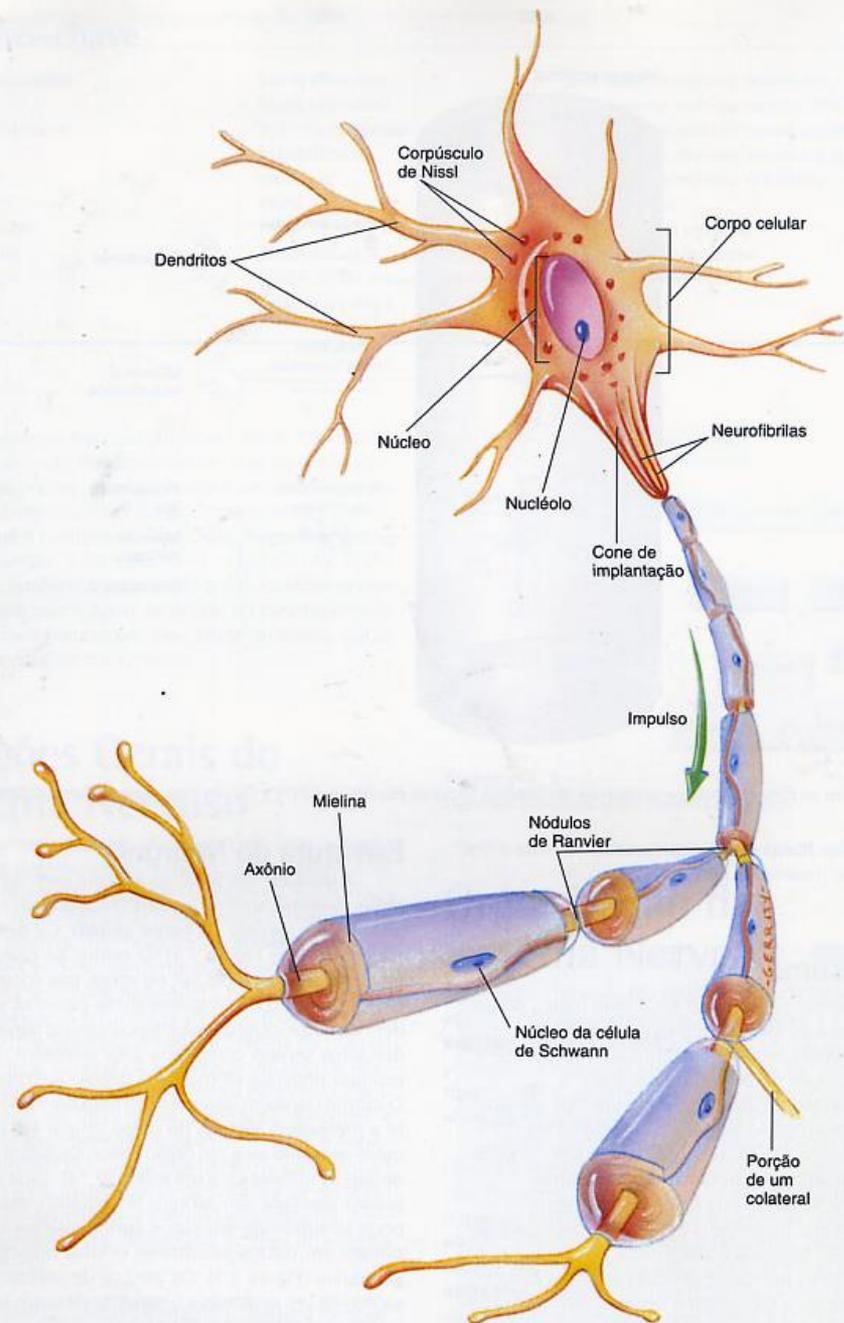


Figura 7.3
As partes de um neurônio.

Sinapse Química

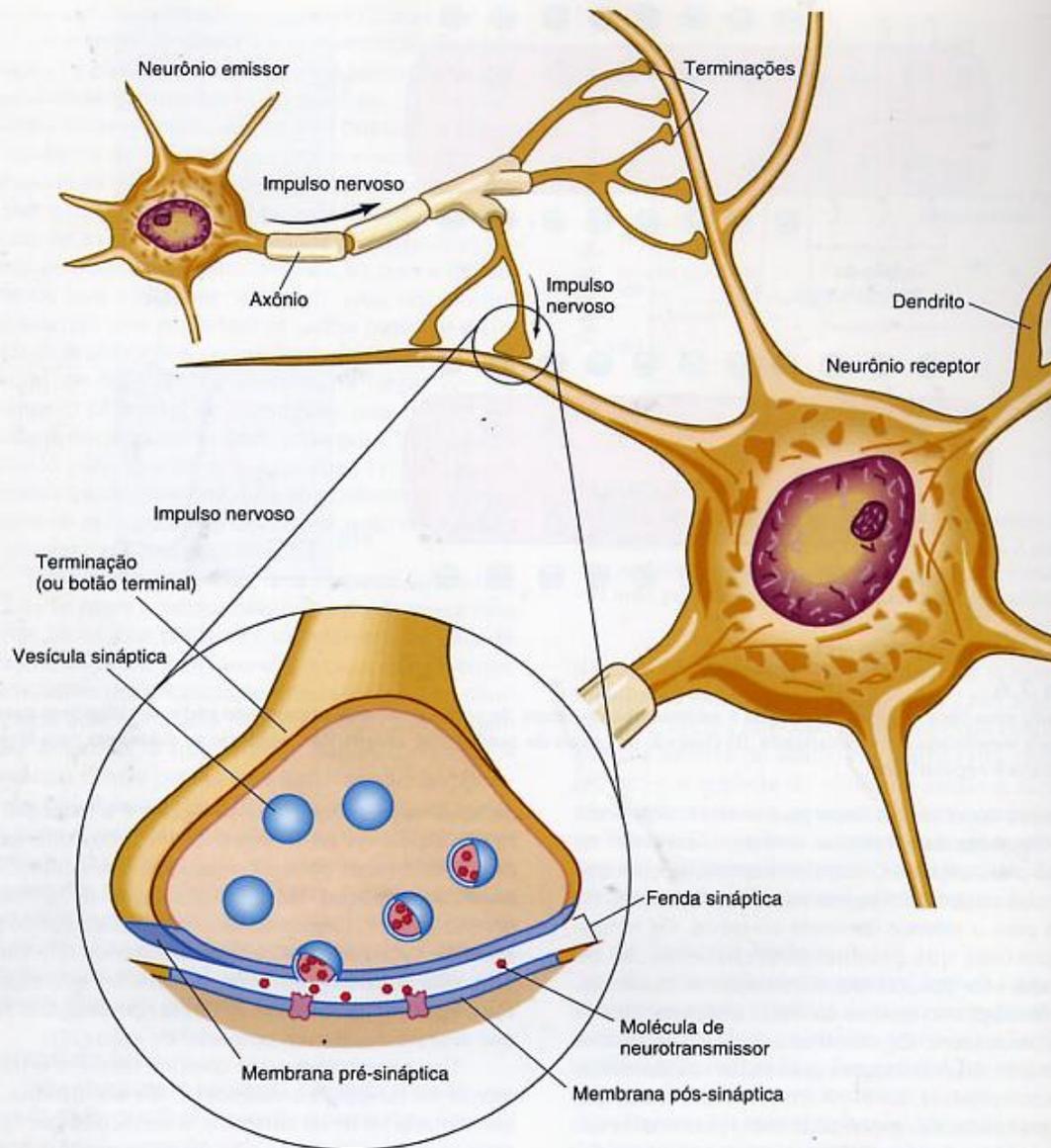


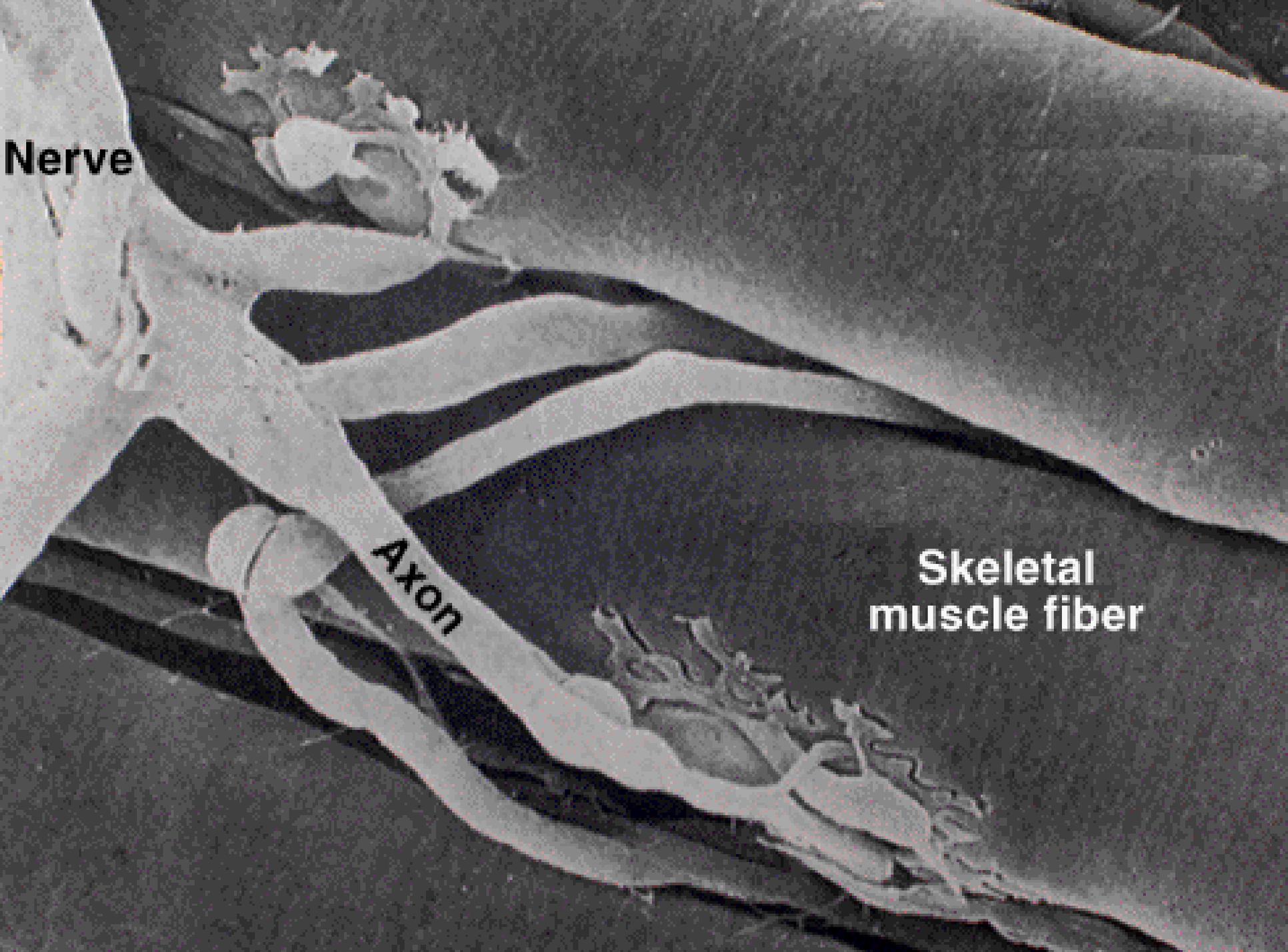
Figura 7.7

Estrutura básica de uma sinapse química. Nessa ilustração idealizada, podem ser observados os elementos essenciais da sinapse: as terminações do axônio contendo as vesículas sinápticas, a fenda sináptica e a membrana pós-sináptica.

Nerve

Axon

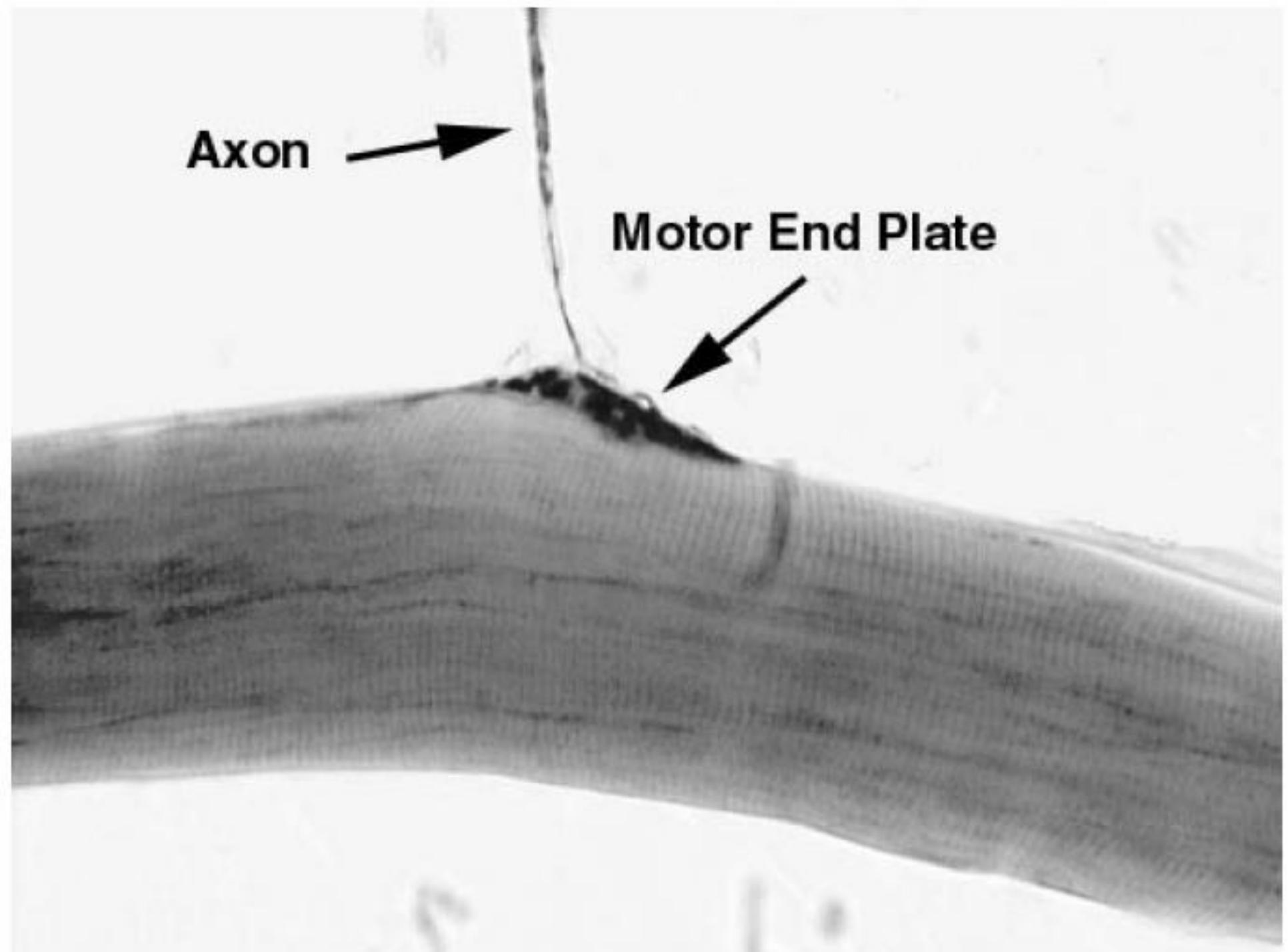
**Skeletal
muscle fiber**



Axon



Motor End Plate



Junção Neuromuscular

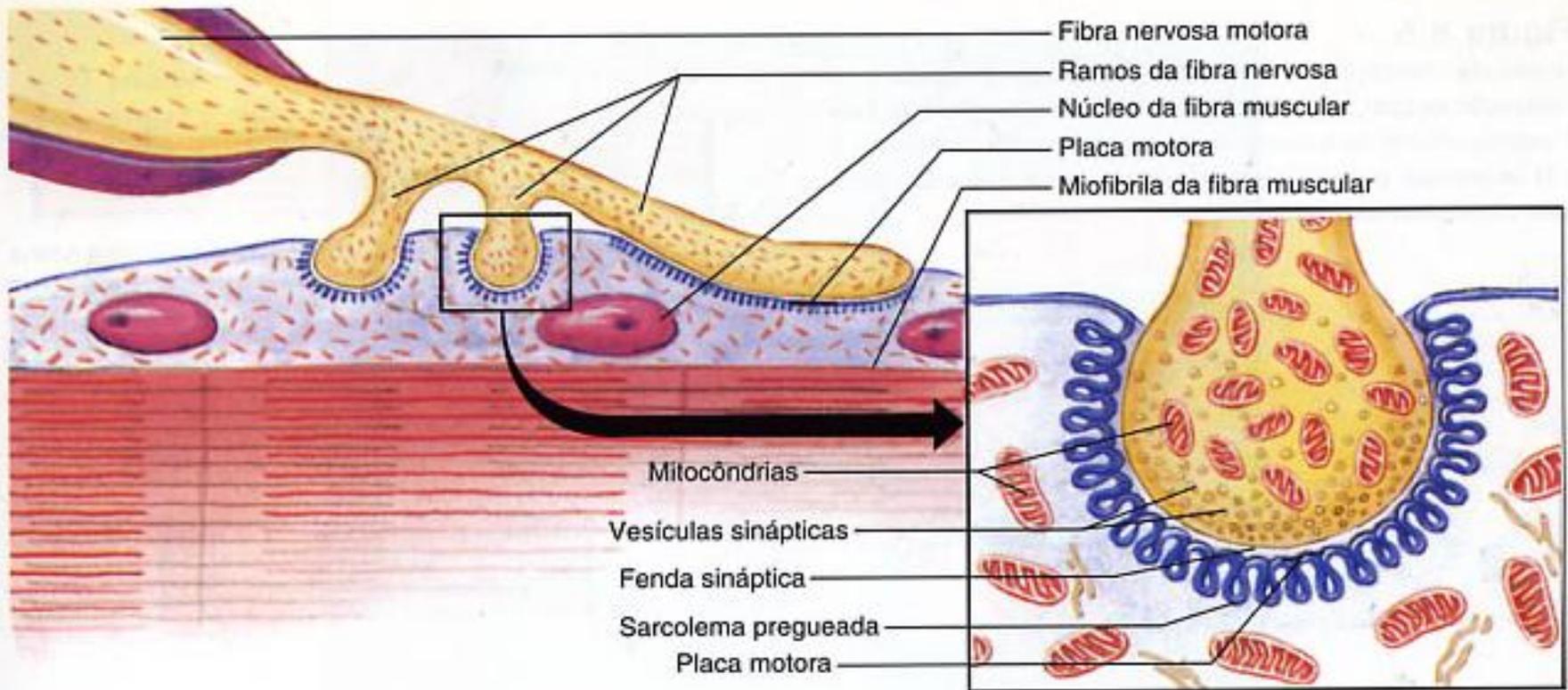
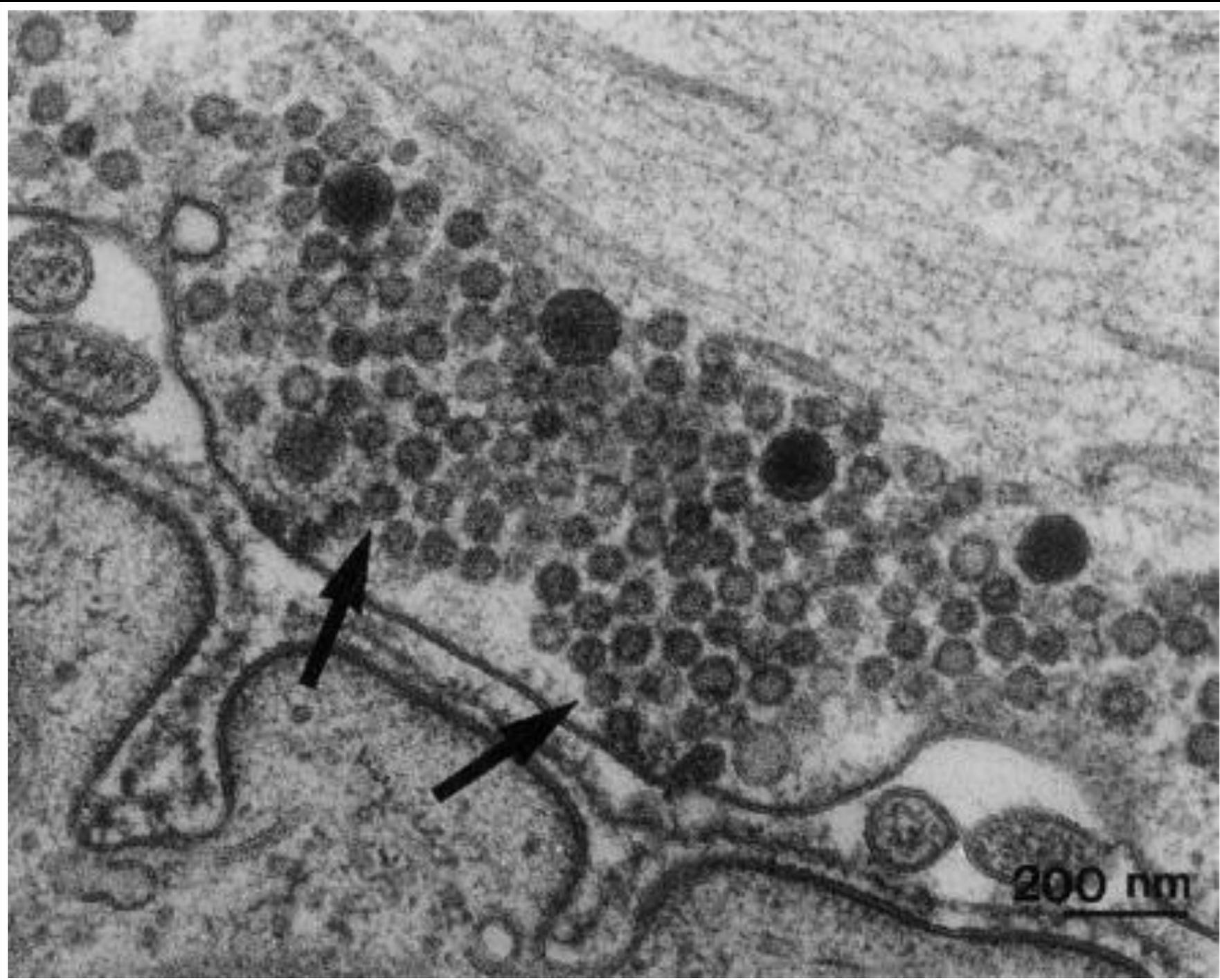
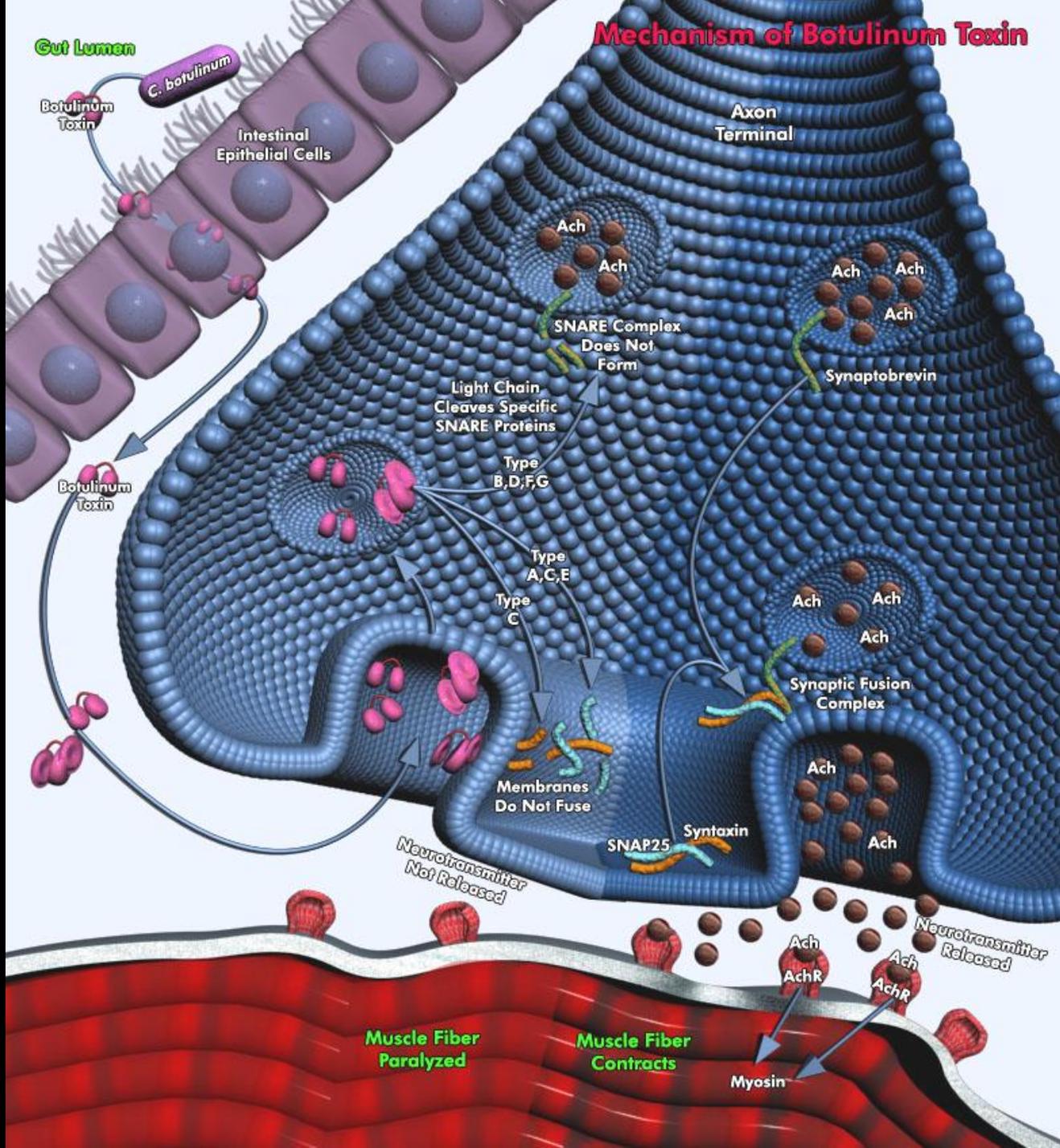


Figura 8.4

O ponto de conexão entre um motoneurônio e uma fibra muscular individual é denominado junção neuromuscular. O neurotransmissor acetilcolina é armazenado nas vesículas sinápticas, na extremidade da fibra nervosa.



Mechanism of Botulinum Toxin



Potencial de Ação

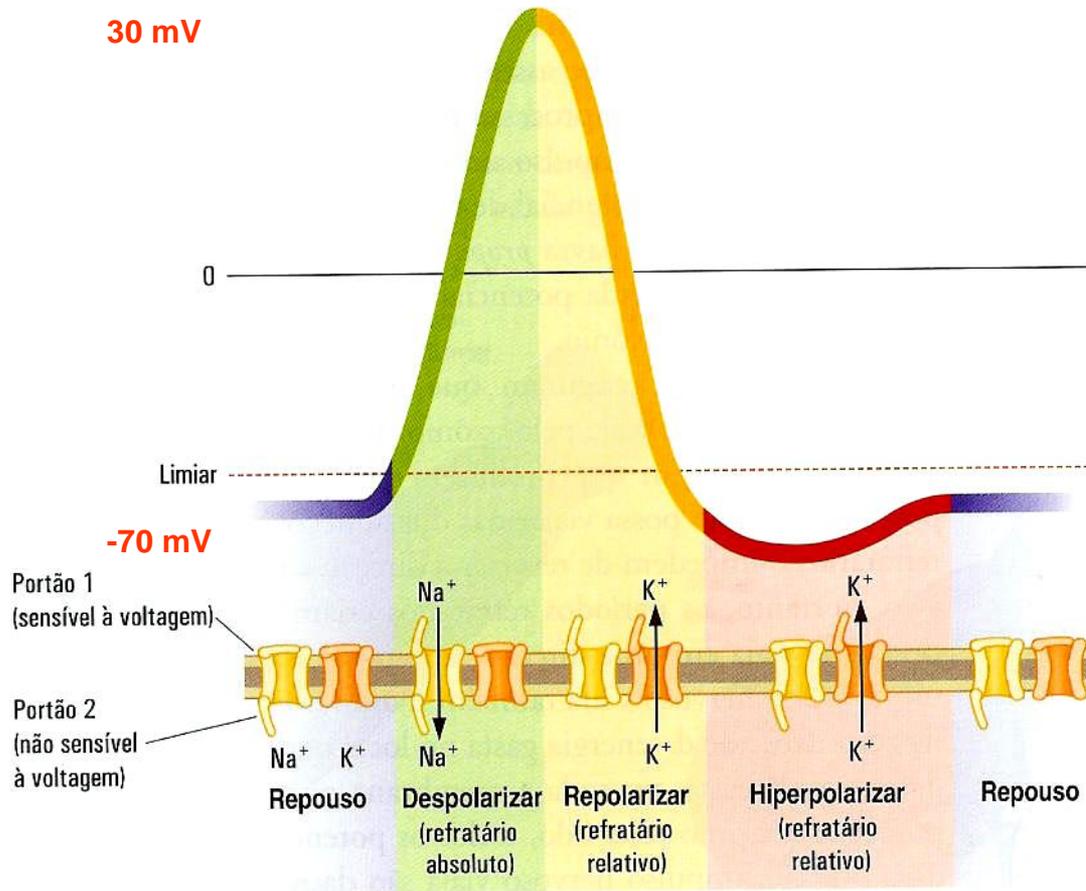
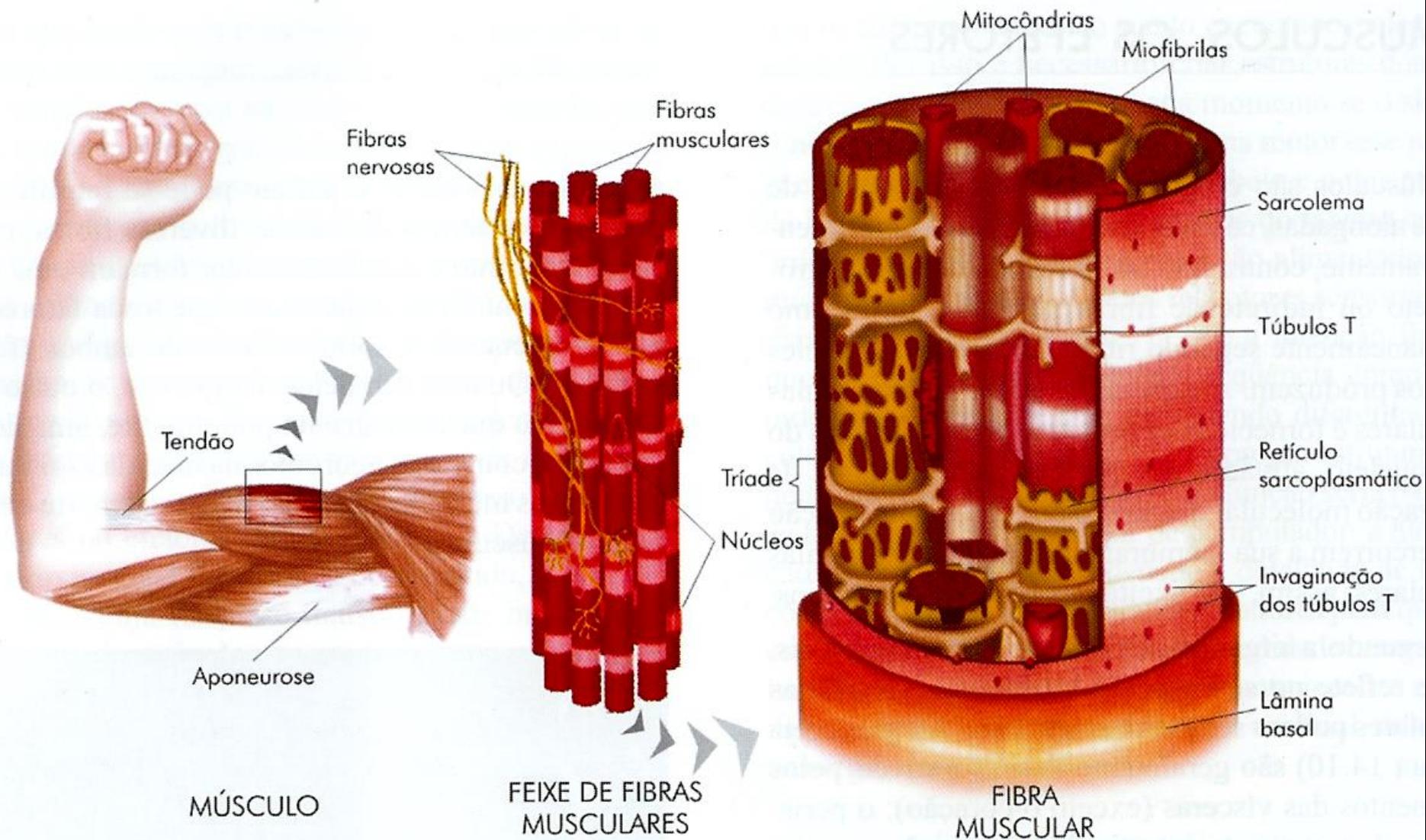


Figura 4-14

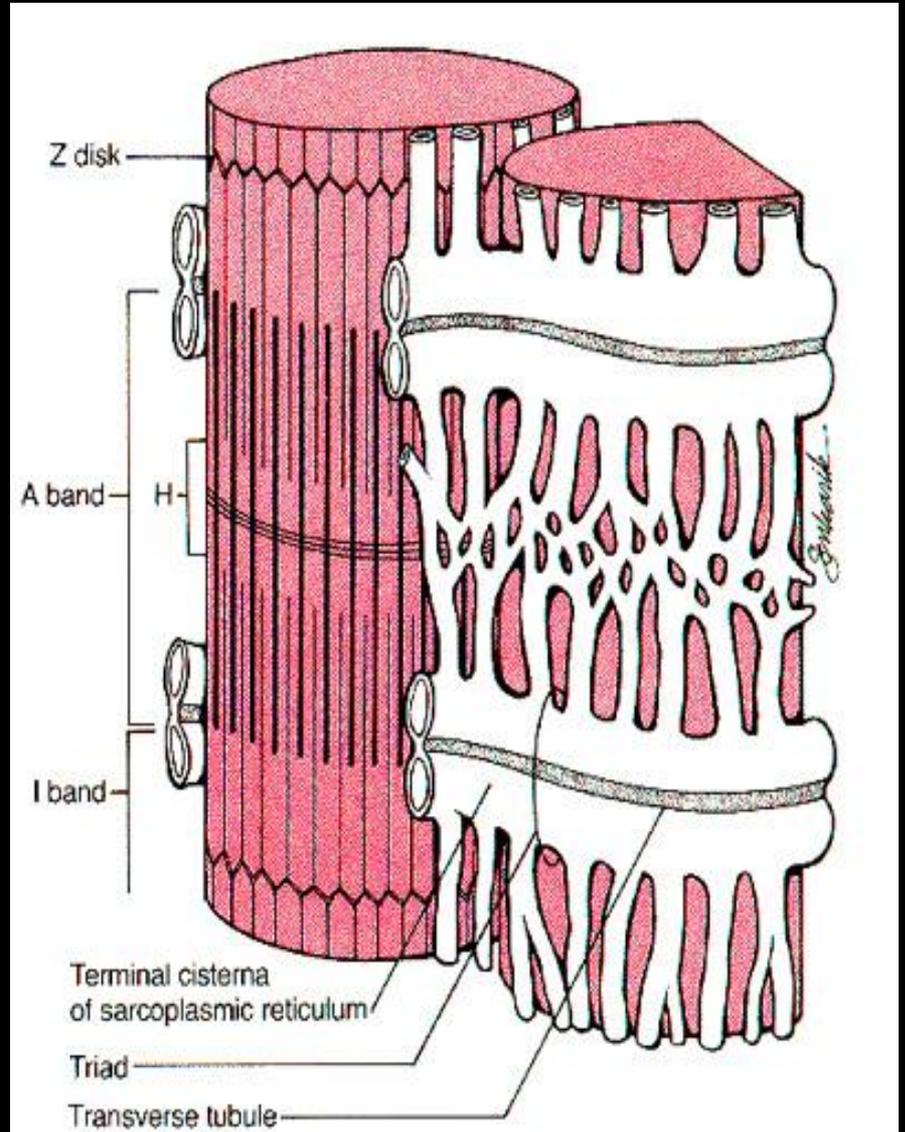
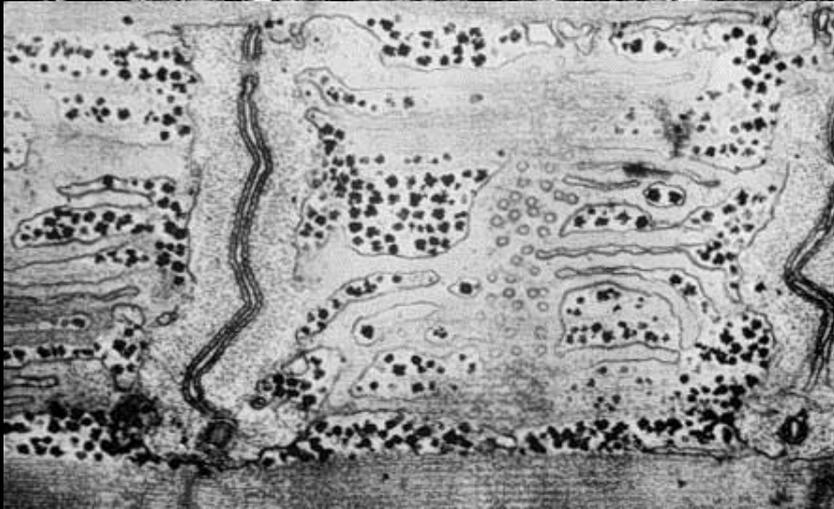
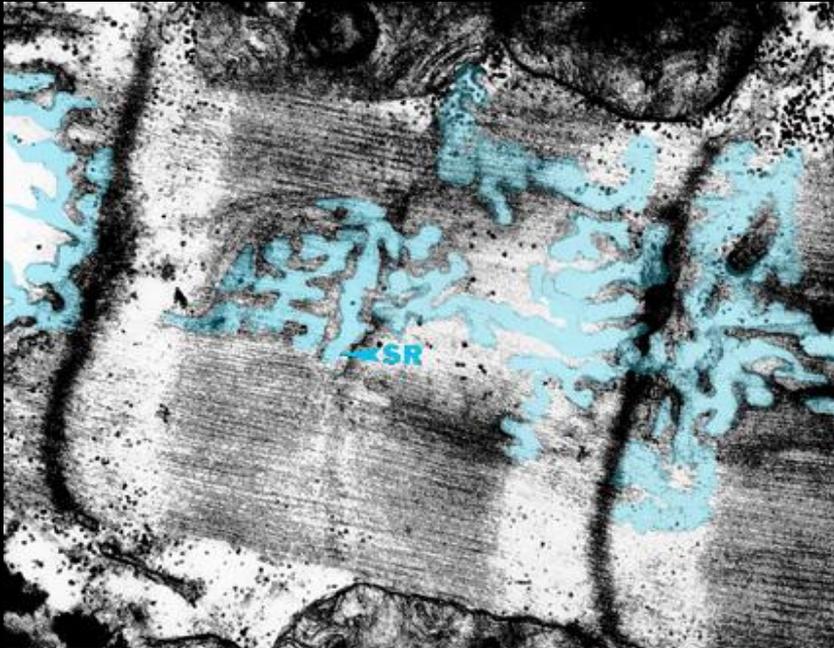
As alterações em canais de sódio e potássio sensíveis à voltagem são responsáveis pelas fases do potencial de ação. A abertura do portão 1 dos canais de sódio inicia a despolarização, que é finalizada com o fechamento do portão 2. O portão do canal de potássio se abre mais lentamente e contribui com a repolarização e com a hiperpolarização. A recuperação da condição inicial dos portões está associada à restauração do potencial de repouso. A membrana está em estado refratário absoluto quando o portão 2 dos canais de sódio se fecha e refratário relativo até que o potencial de repouso da membrana seja restaurado.



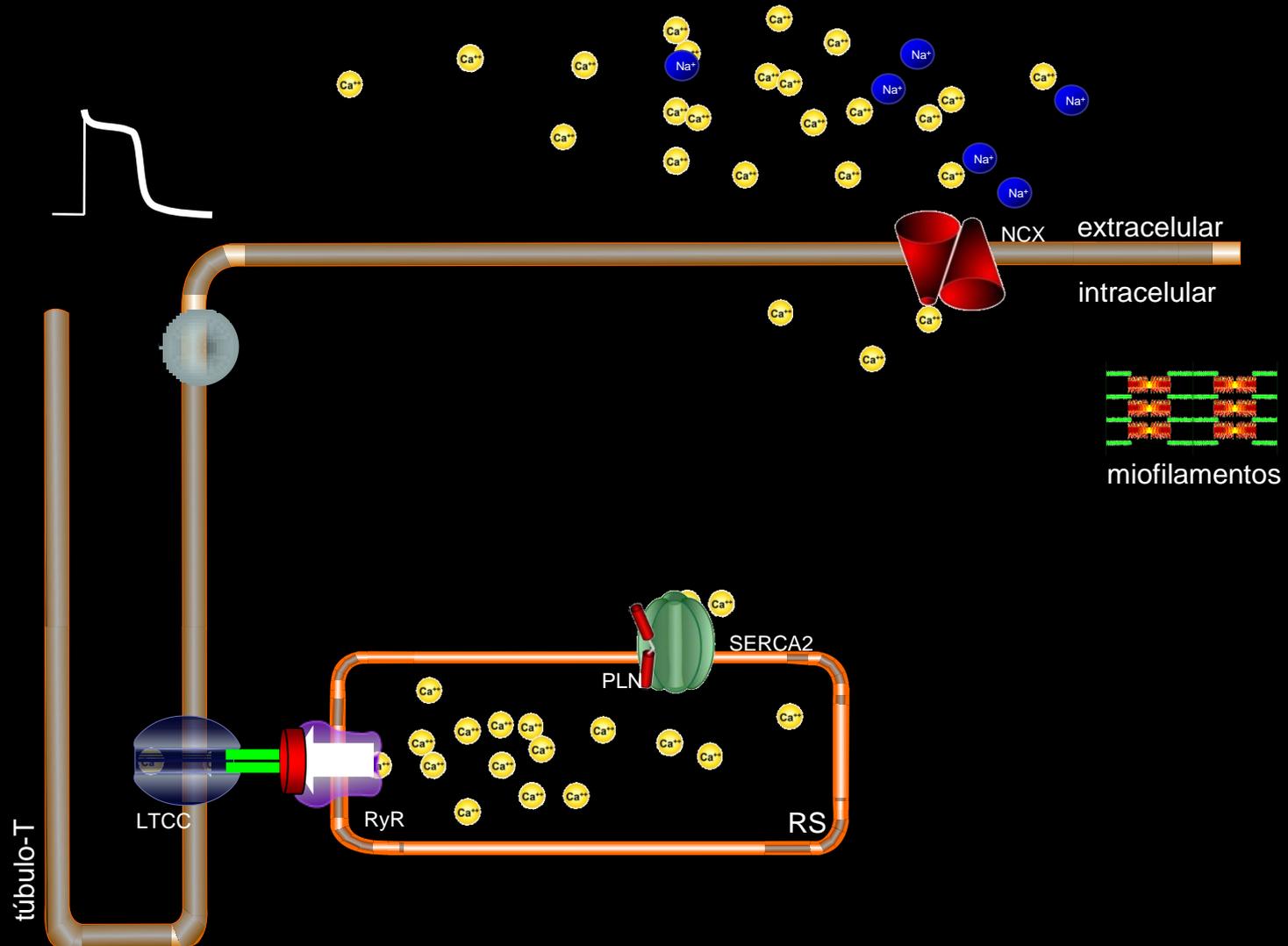


► **Figura 11.3.** Microestrutura das fibras musculares. À esquerda, um músculo estriado esquelético tomado como exemplo. No meio, um feixe de fibras musculares com as fibras nervosas que a inervam. À esquerda, uma reconstrução idealizada que revela os componentes internos de uma única fibra muscular. Modificado de M.F. Bear et al. (1996) *Neuroscience*. Williams & Wilkins, Baltimore, EUA.

Interação retículo – proteínas contrácteis

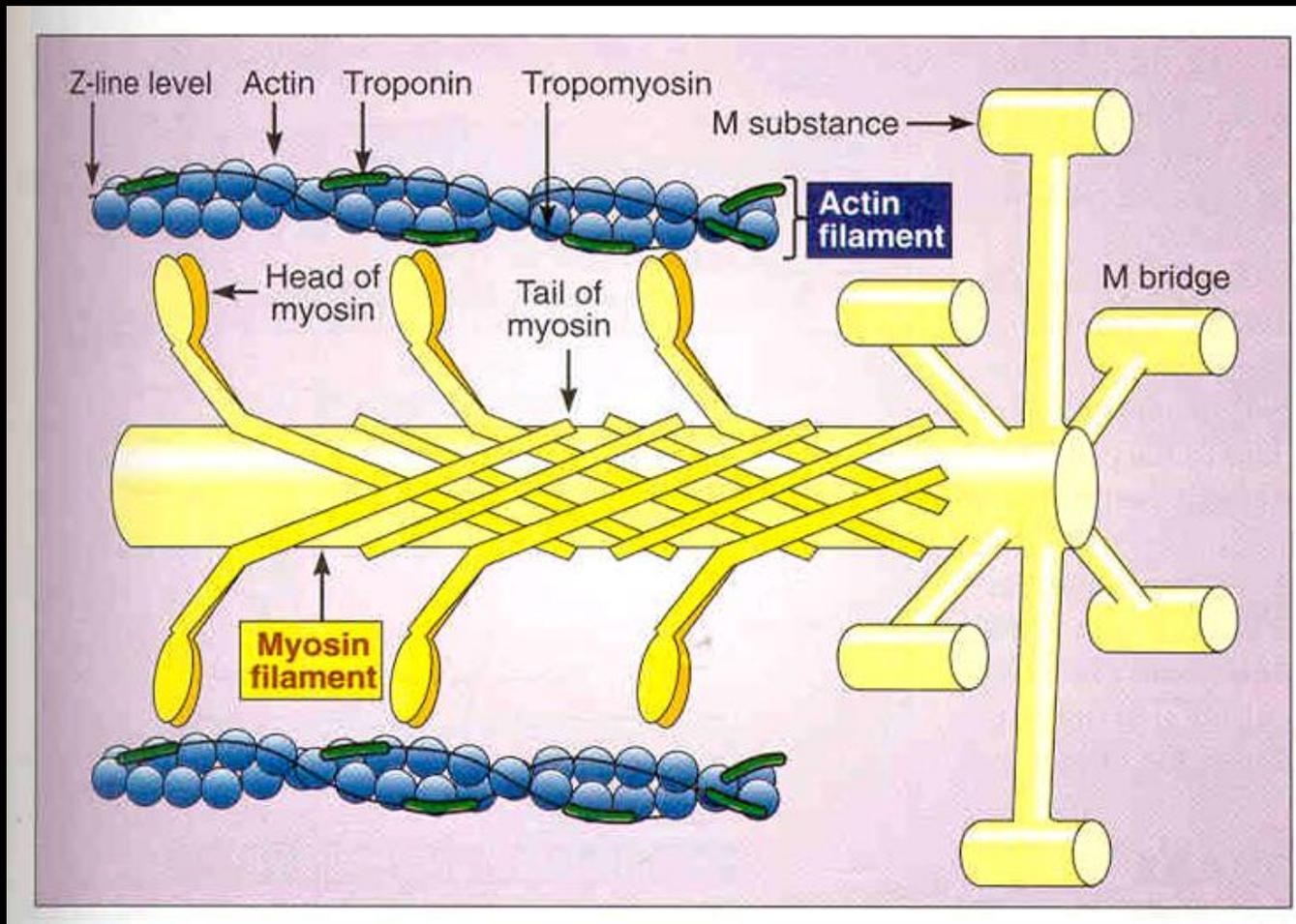


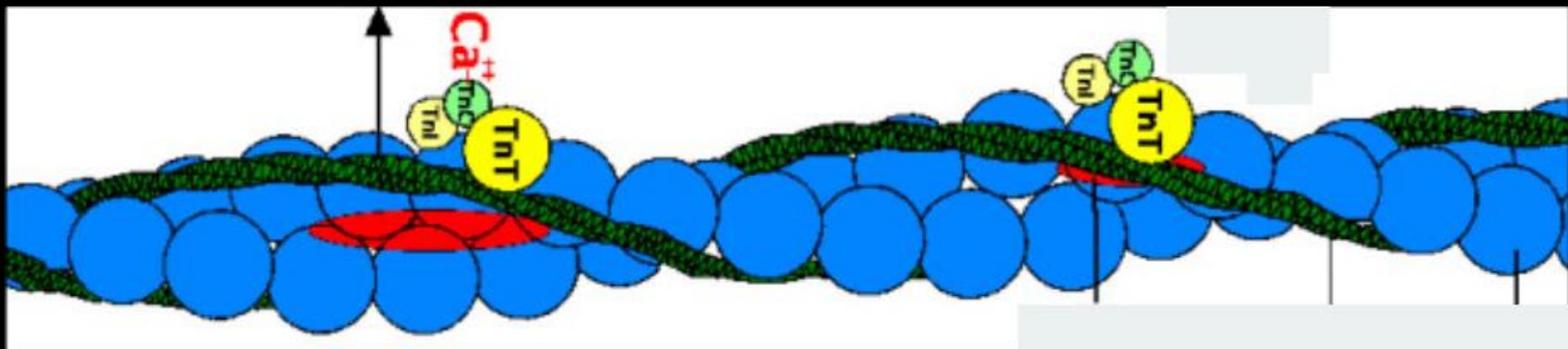
Transiente de Ca^{2+}



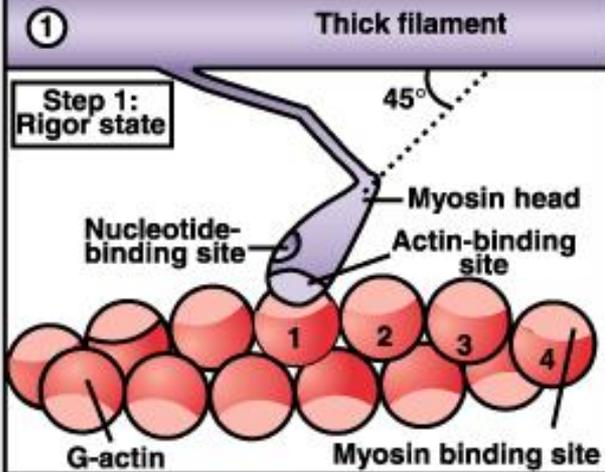
Teoria do deslizamento dos miofilamentos

Como se inicia a contração muscular?

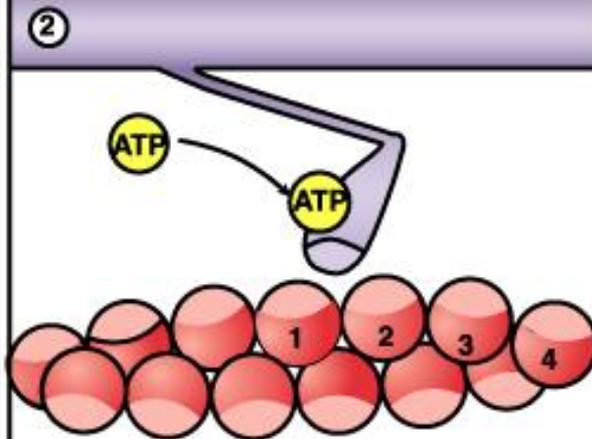




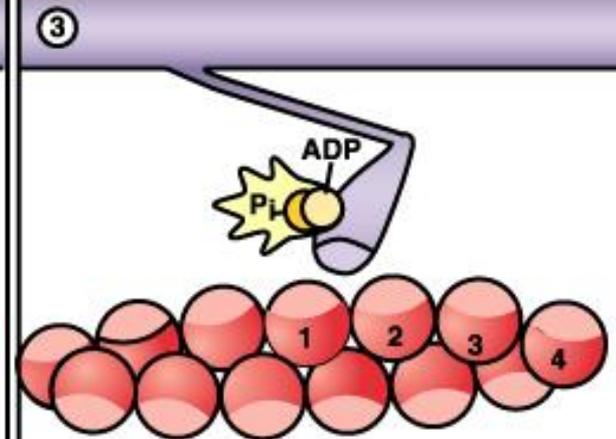
Tight binding in the rigor state. The crossbridge is at a 45° angle relative to the filaments.



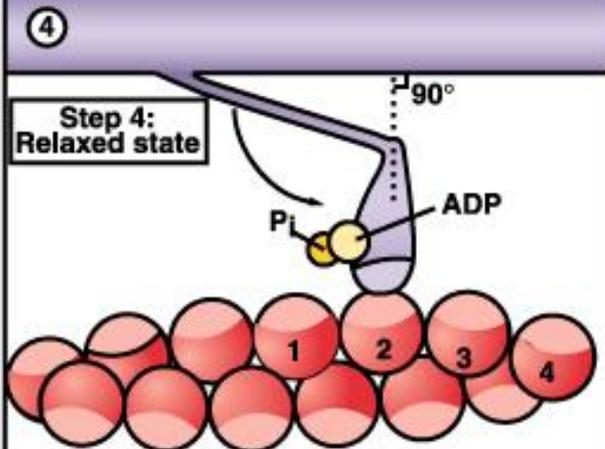
ATP binds to nucleotide-binding site on myosin. Myosin then dissociates from actin.



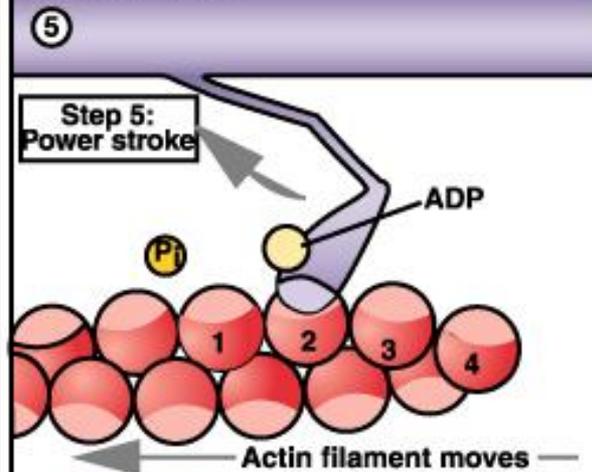
The ATPase activity of myosin hydrolyzes the ATP to ADP and inorganic phosphate. Both products remain bound to myosin.



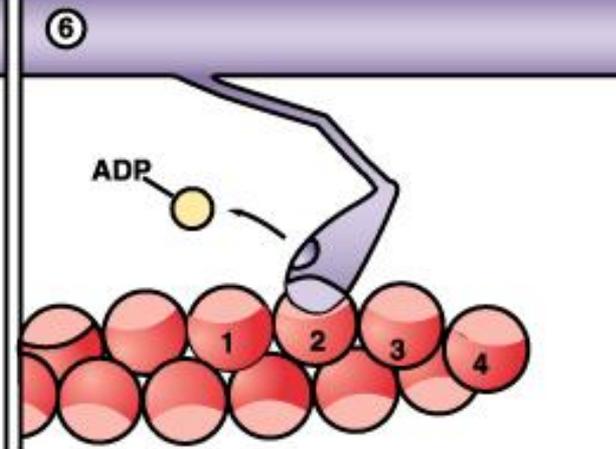
The myosin head swings over and binds weakly to a new actin molecule. The cross bridge is now at 90° relative to the filaments.



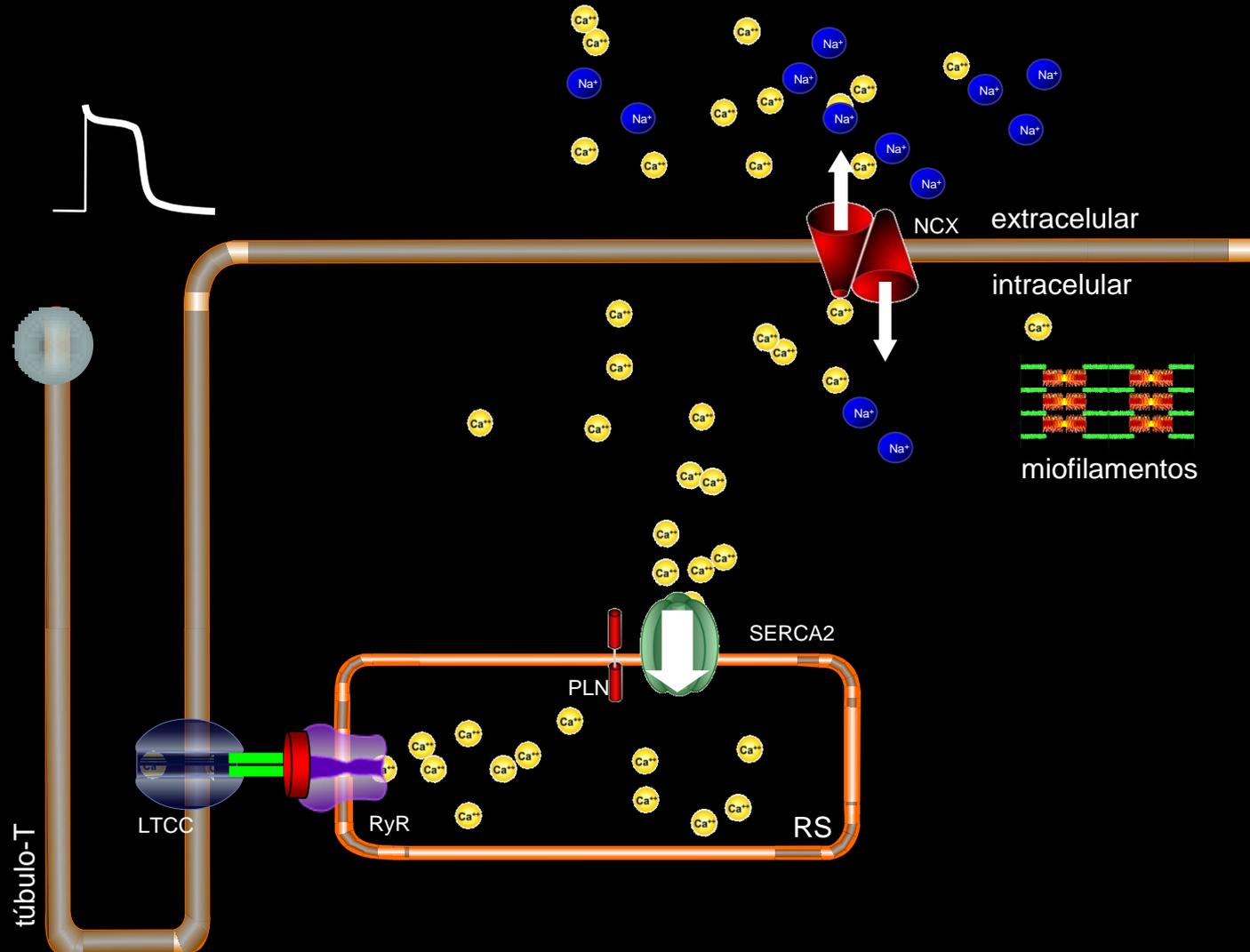
Release of P_i initiates the power stroke. In the power stroke, the myosin head rotates on its hinge, pushing the associated actin filament past it.



At the end of the power stroke, the myosin head releases the ADP and resumes the tightly bound rigor state.



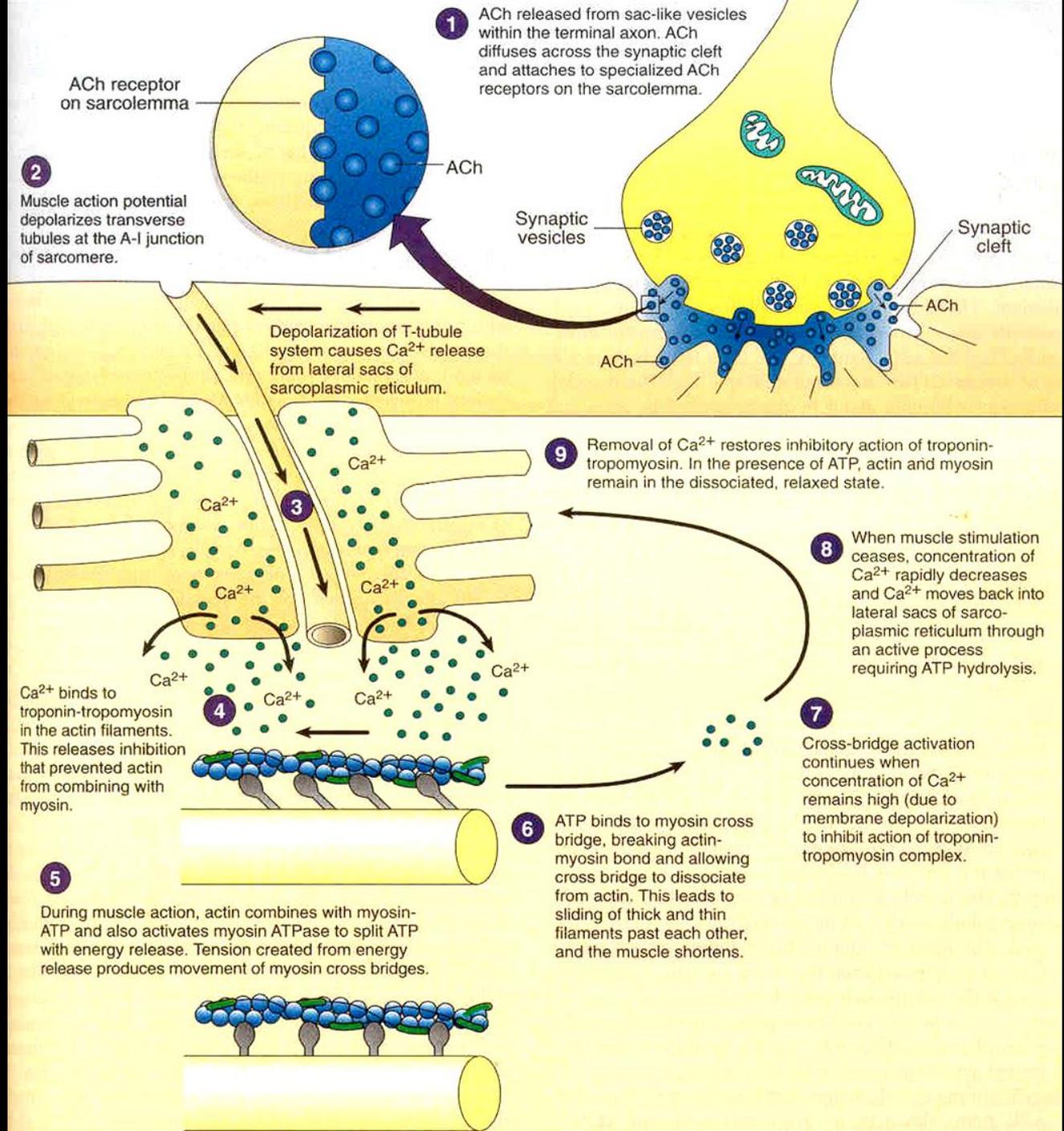
Transiente de Ca^{2+}



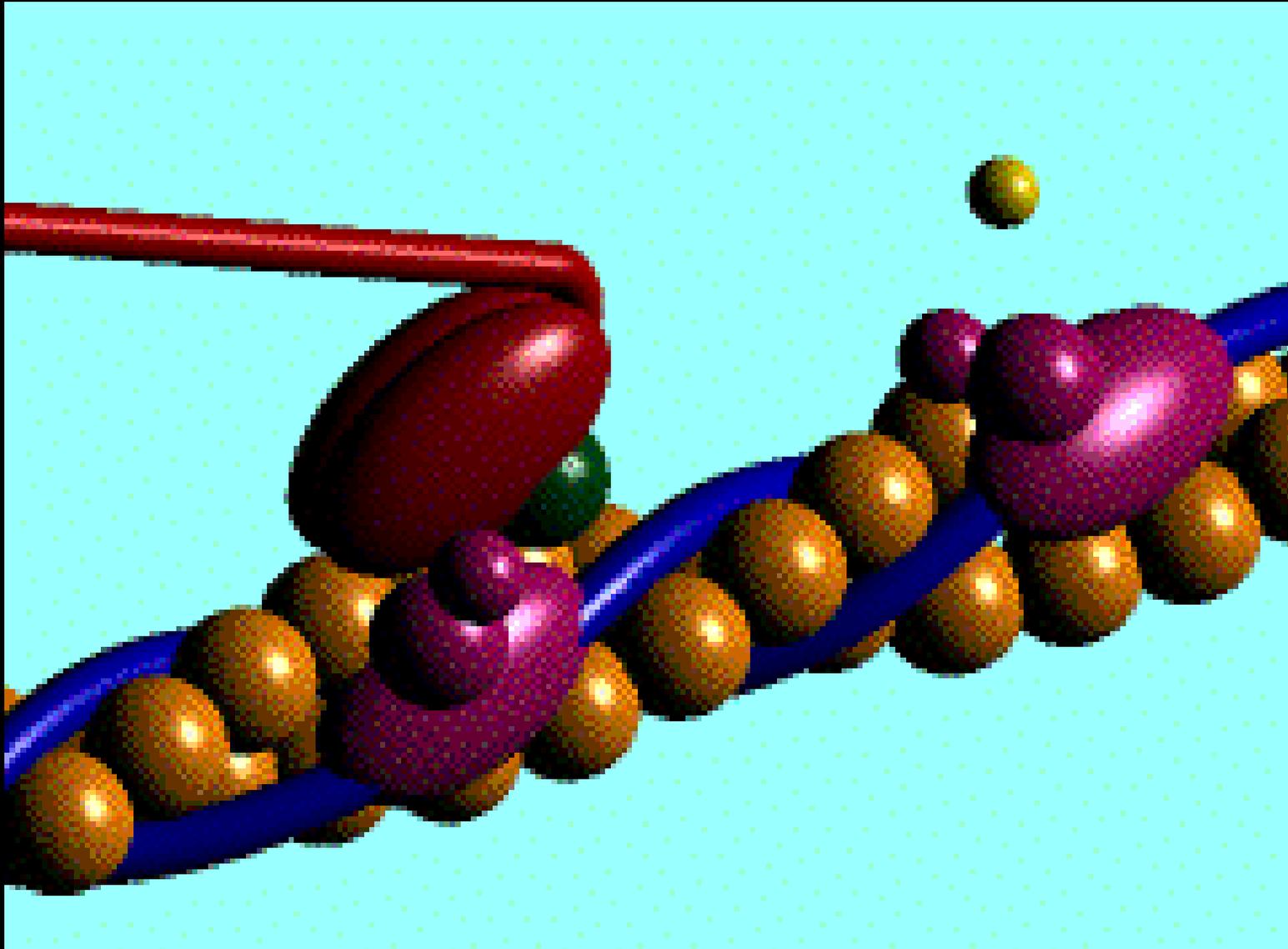


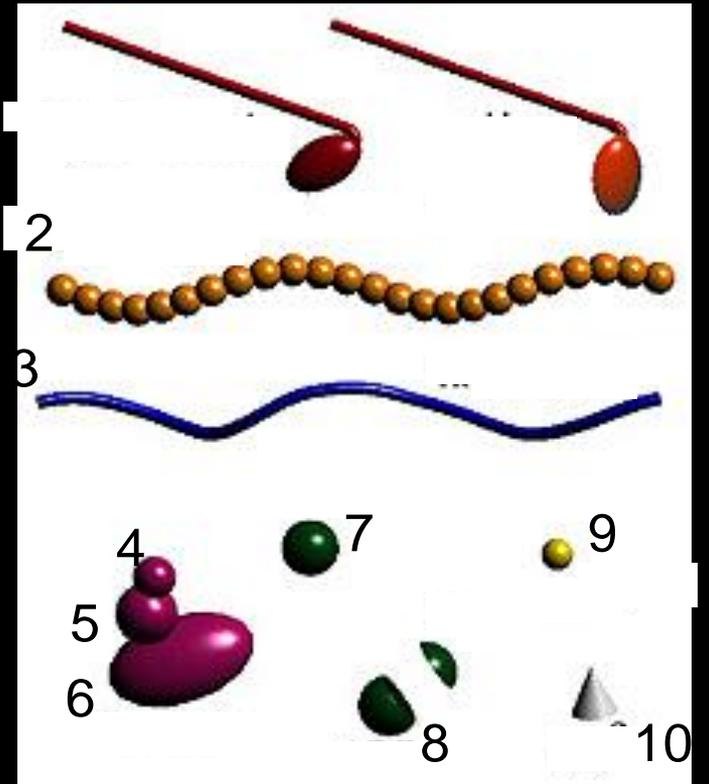
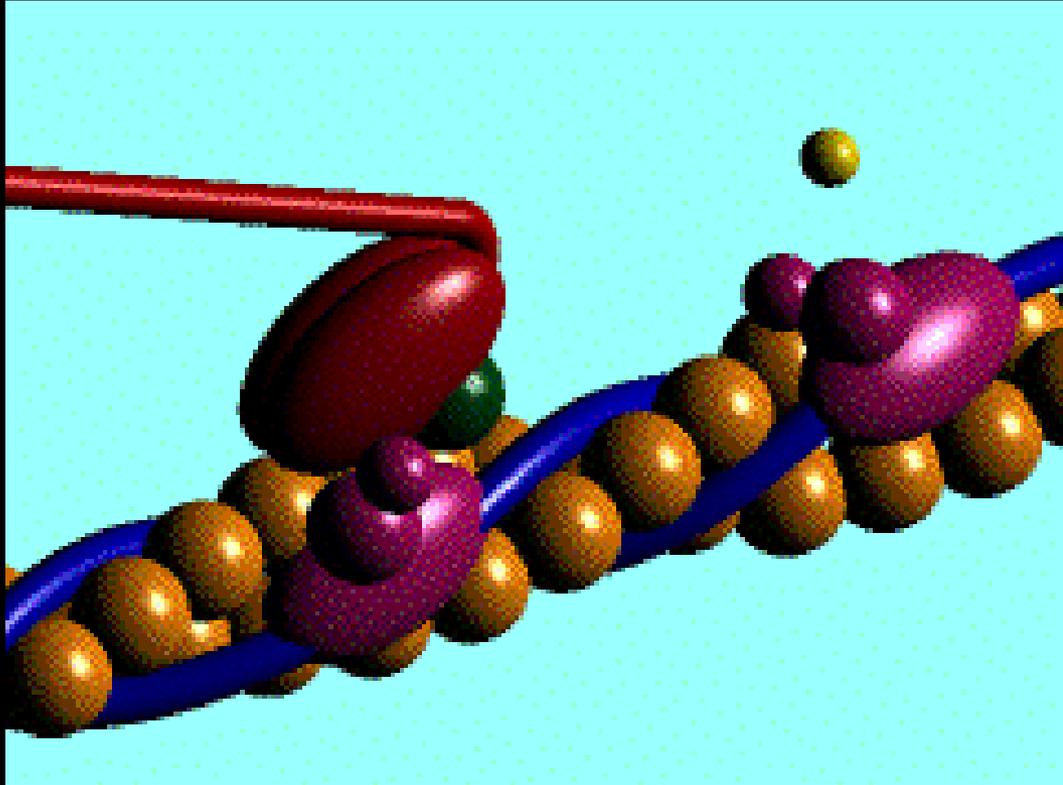
1. Downloaded from <https://www.researchgate.net/publication/326111111>

Resumo



Contração muscular





Contração muscular

