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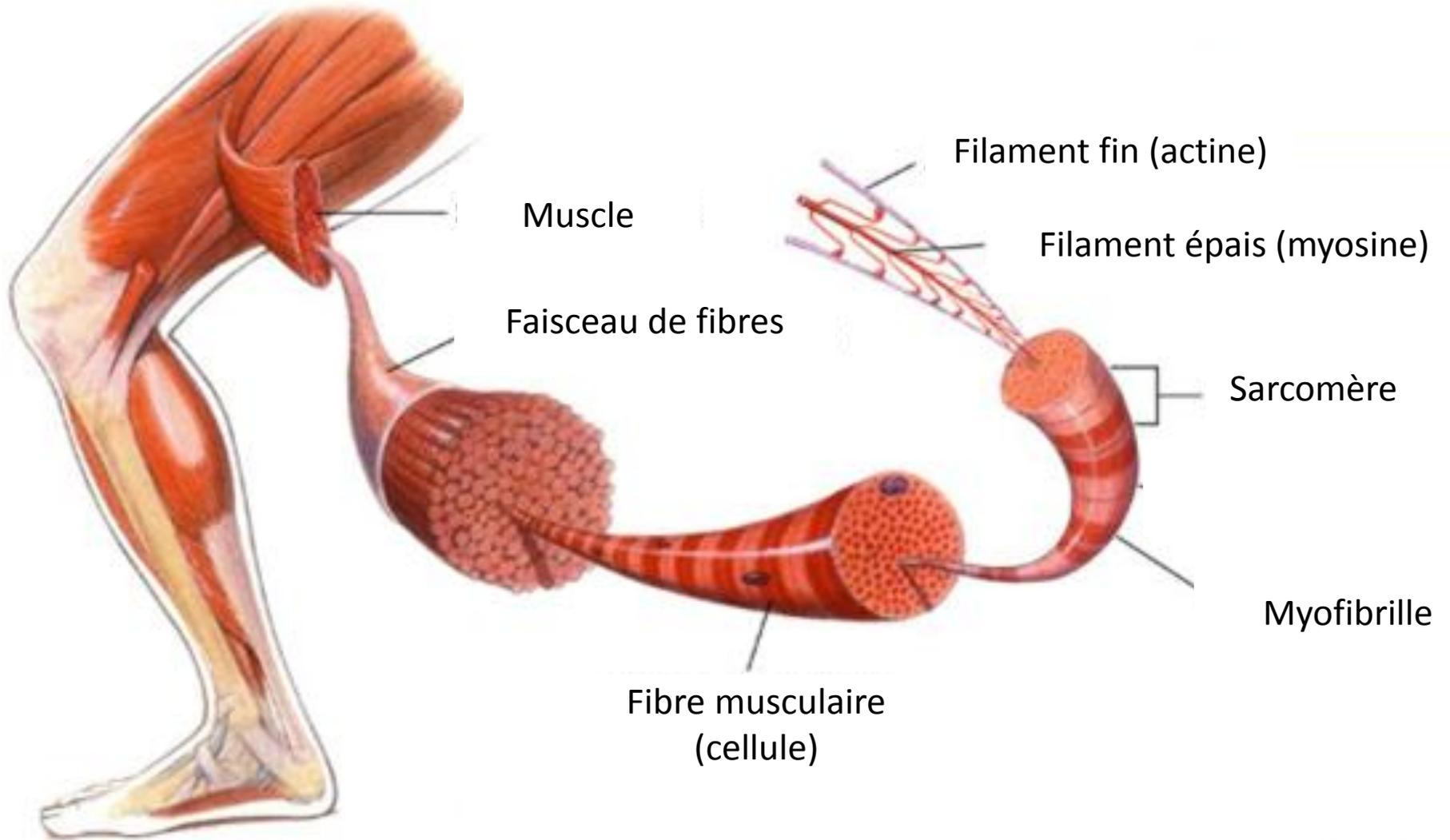


DIU de la Pathologie Locomotrice
liée à la Pratique du Sport

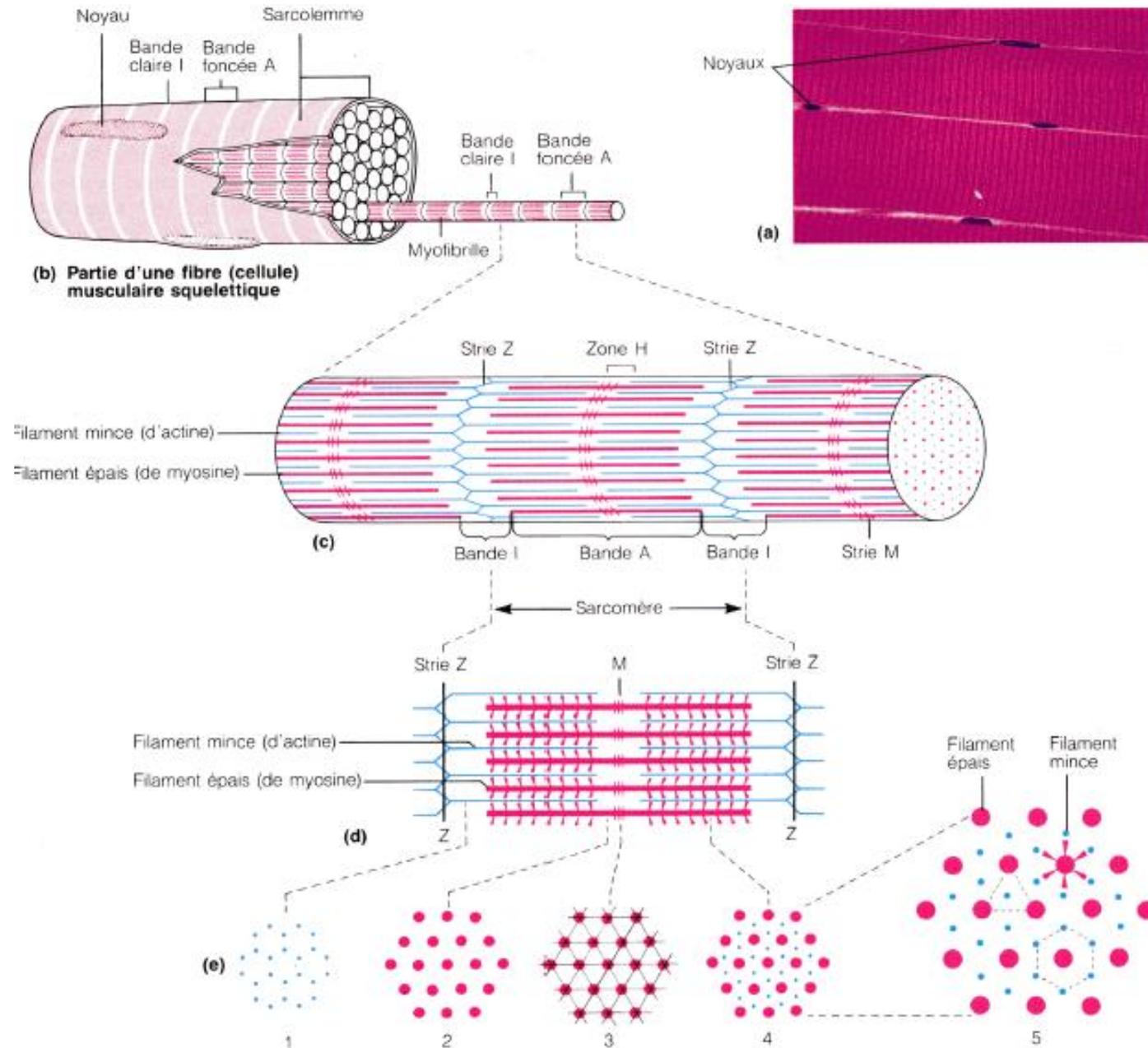
Physiologie du muscle

Pr. Laurent Messonnier

Chapitre 0. Structure et activation du muscle

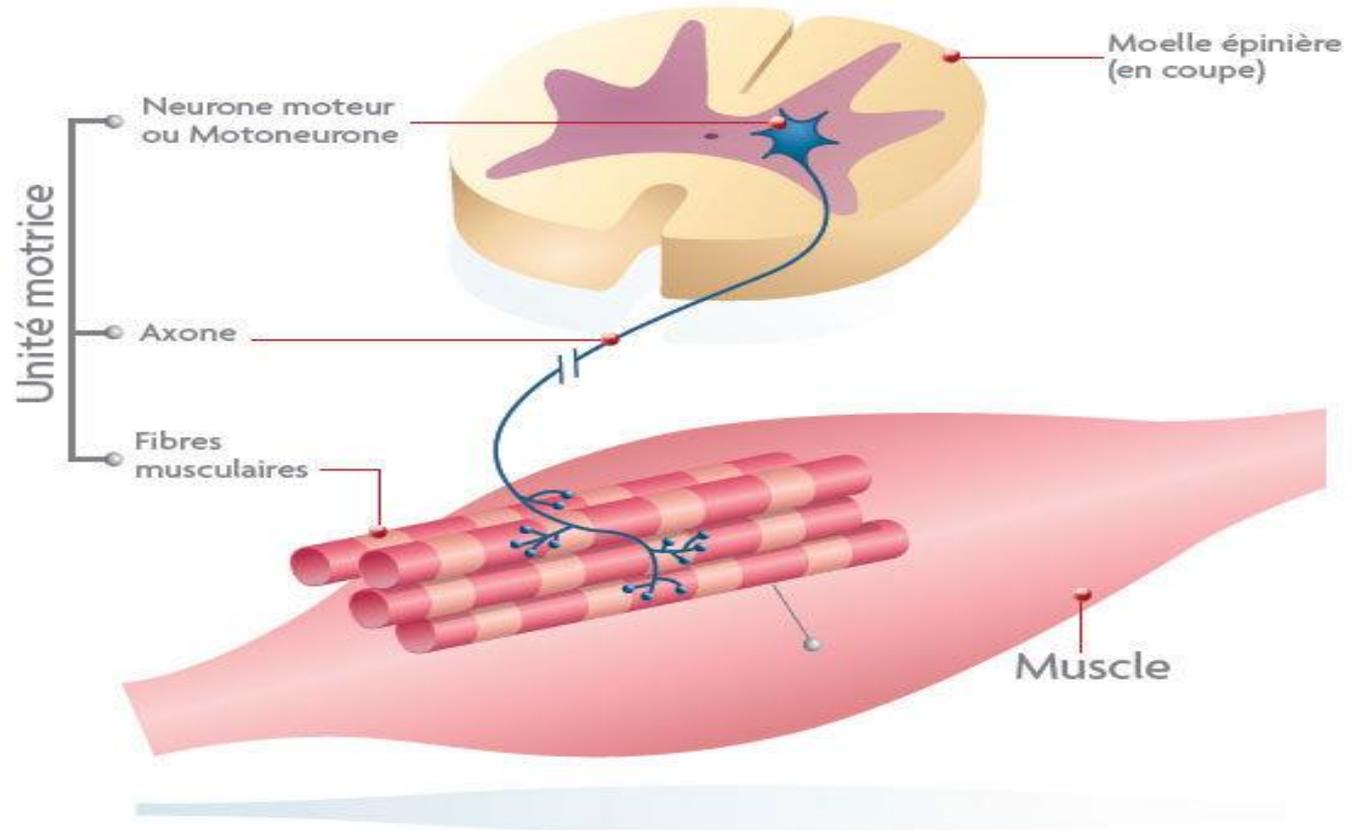


Chapitre 0. Structure et activation du muscle

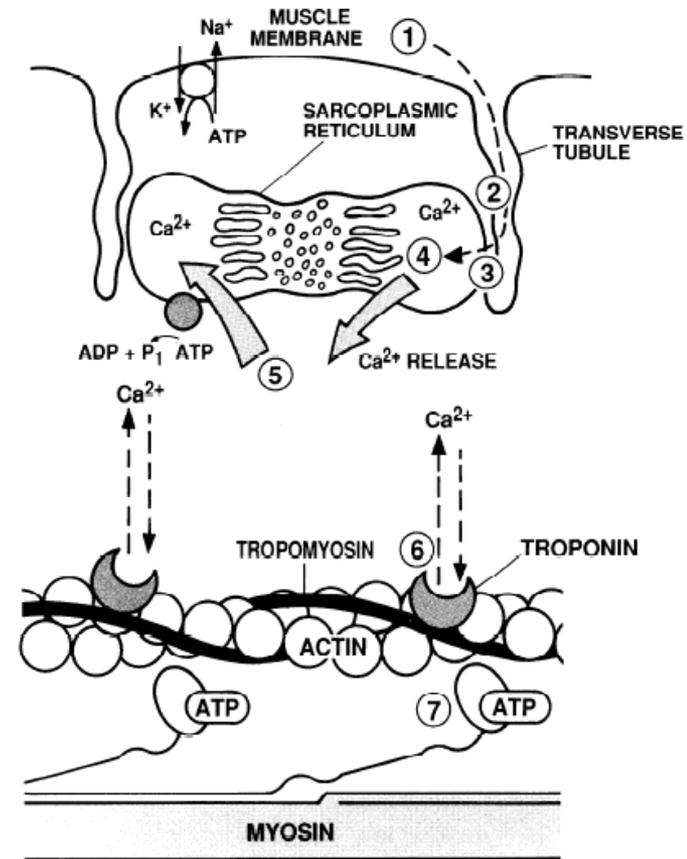
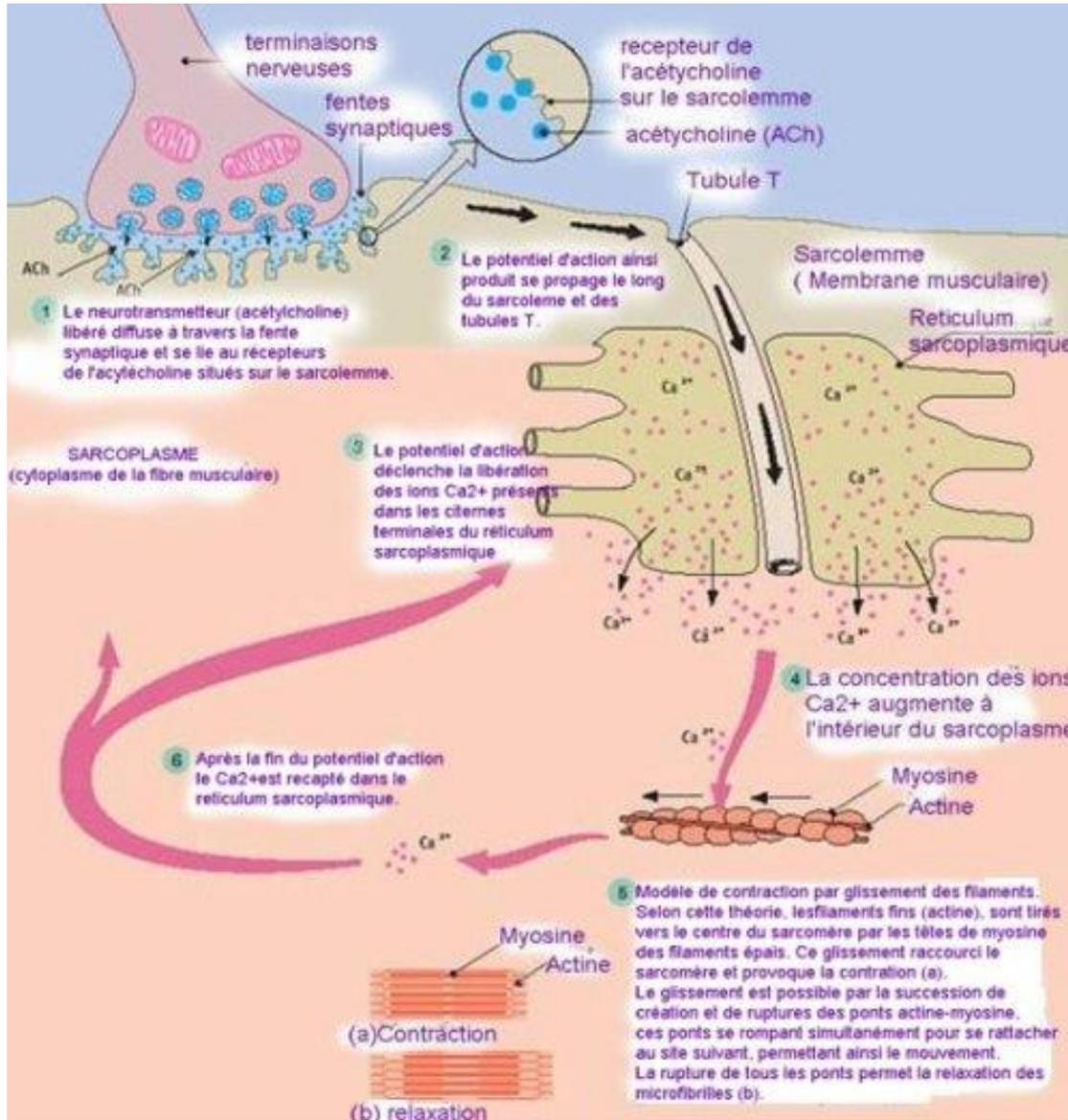


L'unité motrice :

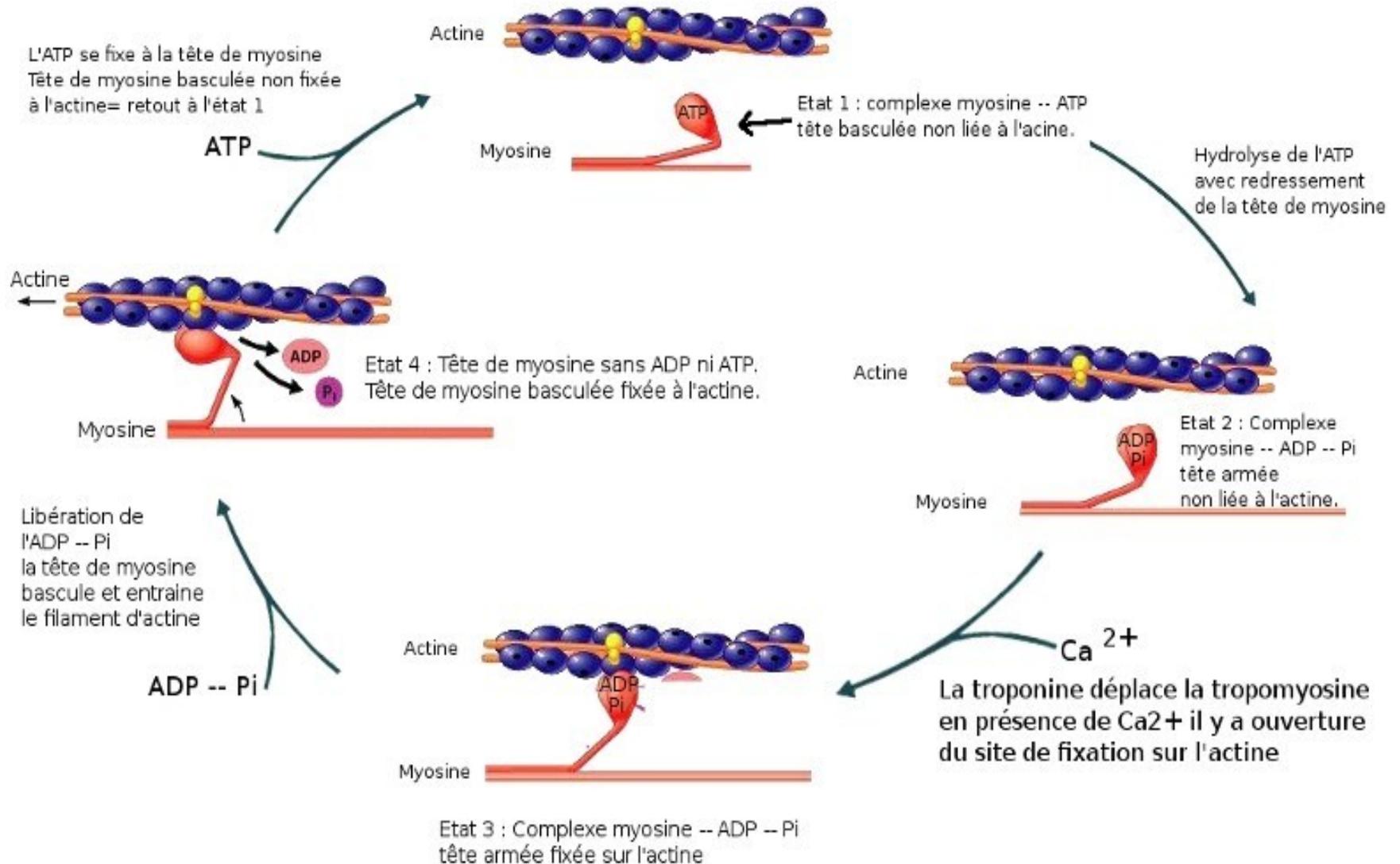
- Neurone moteur = **motoneurone**
- Toutes les fibres innervées par ce motoneurone



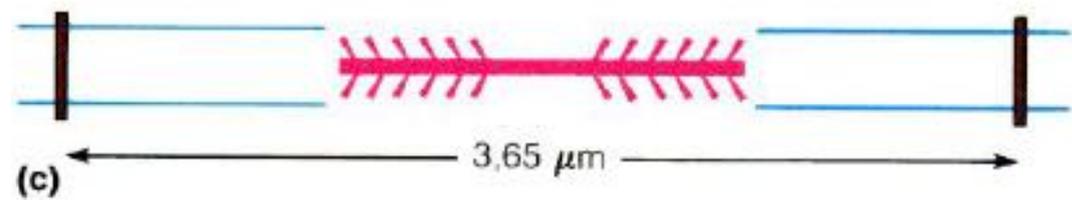
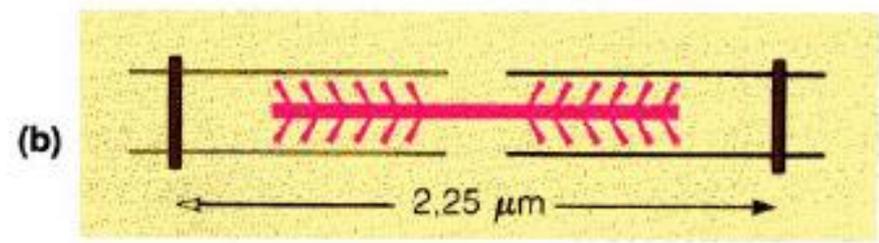
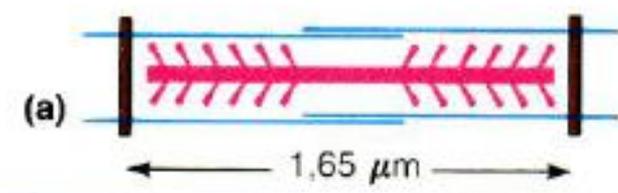
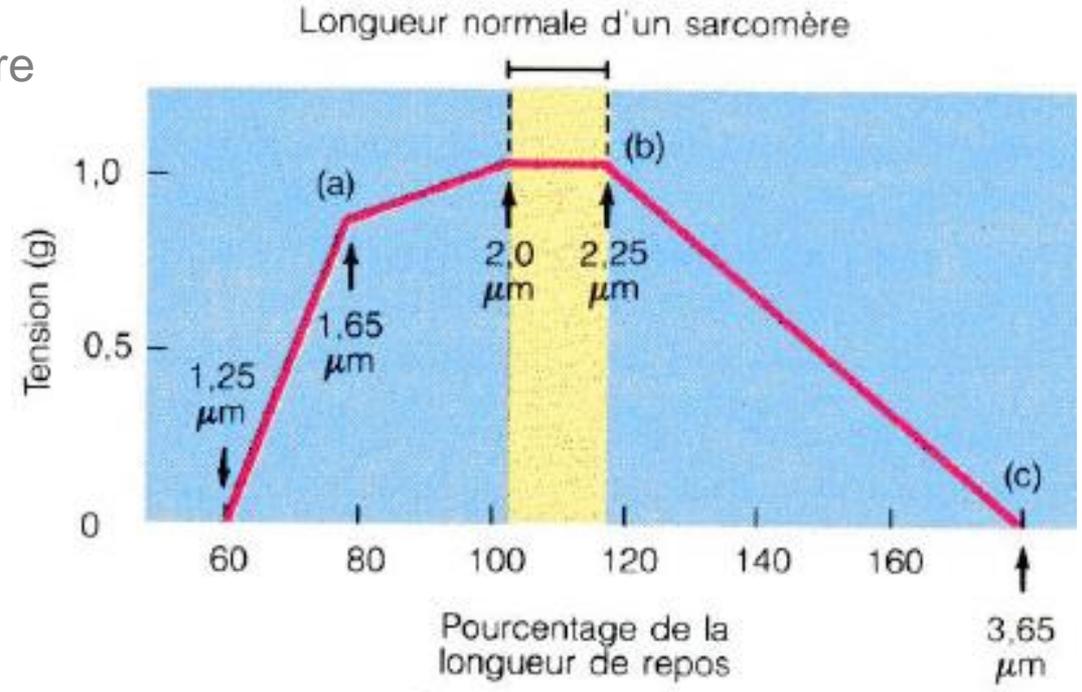
Chapitre 0. Structure et activation du muscle



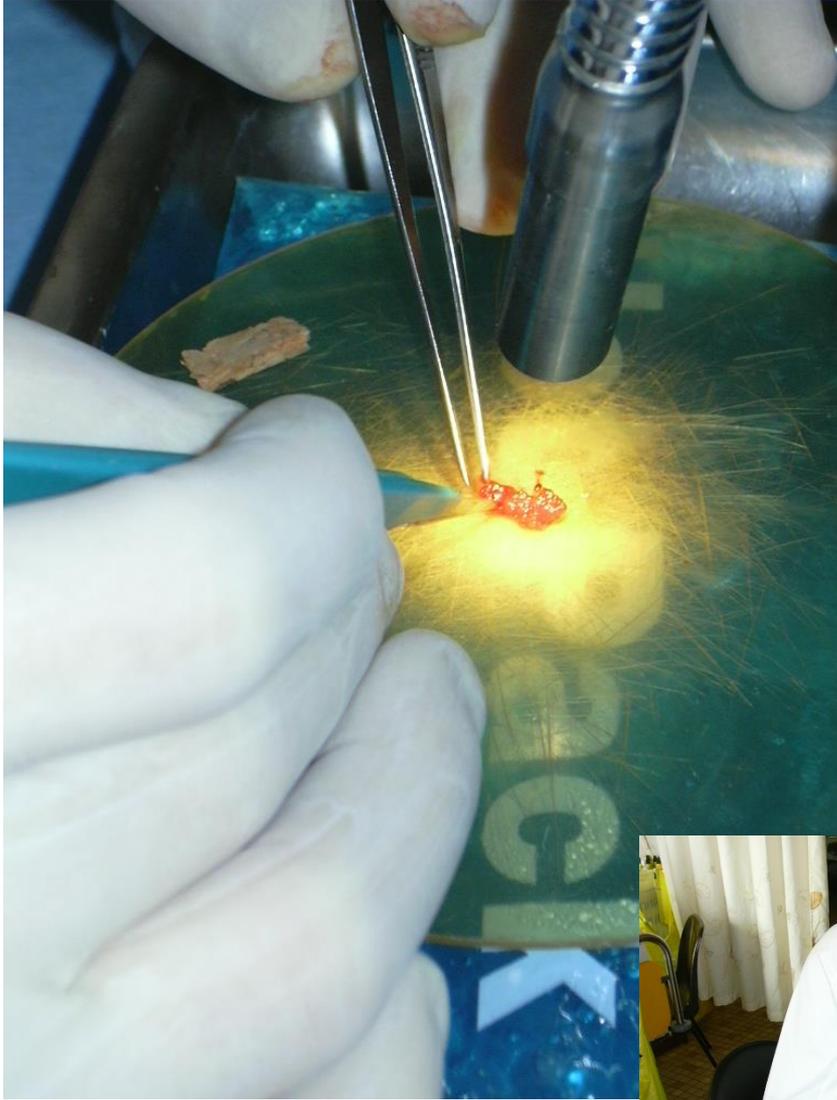
Chapitre 1. La contraction musculaire



Chapitre 1. La contraction musculaire



Chapitre 2. Les fibres musculaires



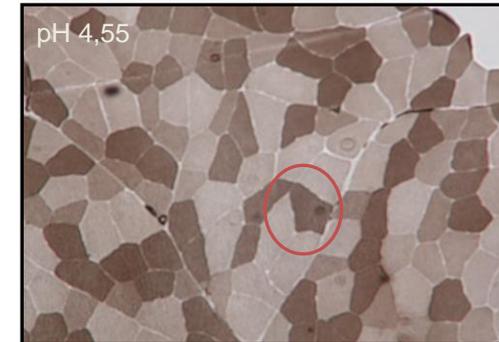
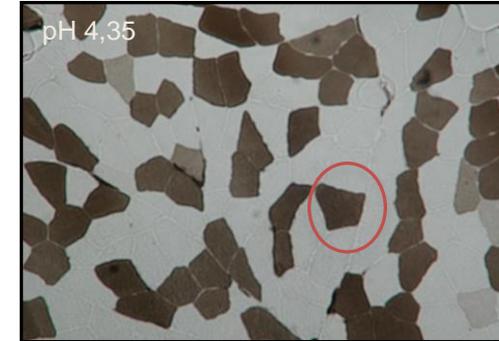
~80 mg



Chapitre 2. Les fibres musculaires

	<i>I. Fibres lentes</i>	<i>II. Fibres rapides</i>	
DUBOWITZ 1960 et PEARSE ENGEL 1962	I	II	
STEIN et PADYKULA 1962	B	C	A
PADYKULA et GAUTHIER 1966	ROUGE	INTERMÉDIAIRE	BLANCHE
YELLIN et GUTH 1970	β	$\alpha\beta$	α
BROOKE et KAISER 1970	I	II _A	II _B
BURKE et coll. 1971	S (<i>slow</i>)	FR (<i>fast resistant</i>)	FF (<i>fast fatiguable</i>)
PETER et coll. 1972	SO (<i>slow oxydative</i>)	FOG (<i>fast oxyd. glycol.</i>)	FG (<i>fast glycolitic</i>)
ESSEN et coll. 1975	ST (<i>slow twitch</i>)	FT _A (<i>fast twitch</i>)	FT _B (<i>fast twitch</i>)
SCHIAFFINO et coll. 1986	I	II _A	II _X II _B
Dénomination courante	I	II _A	II _A -II _X II _X II _X -II _B II _B

IIc

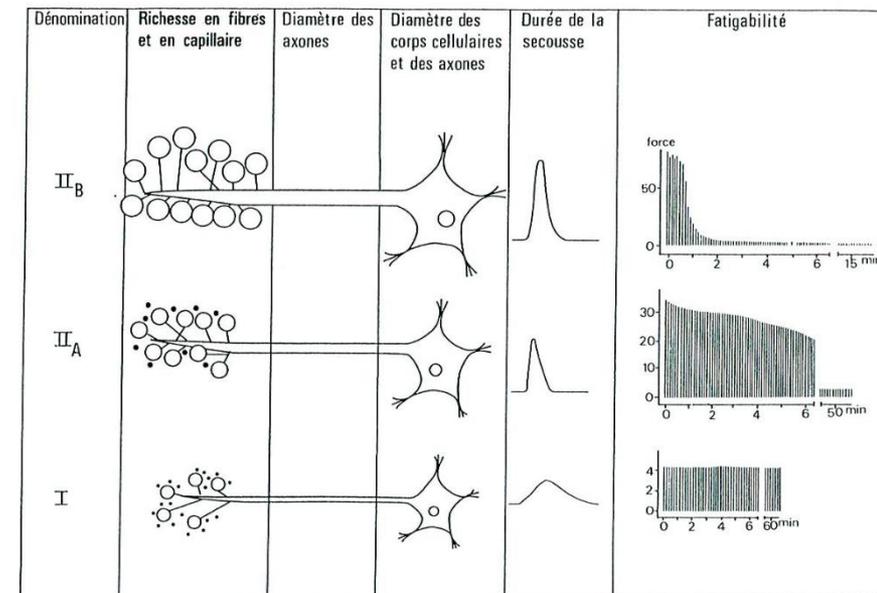


Chapitre 2. Les fibres musculaires

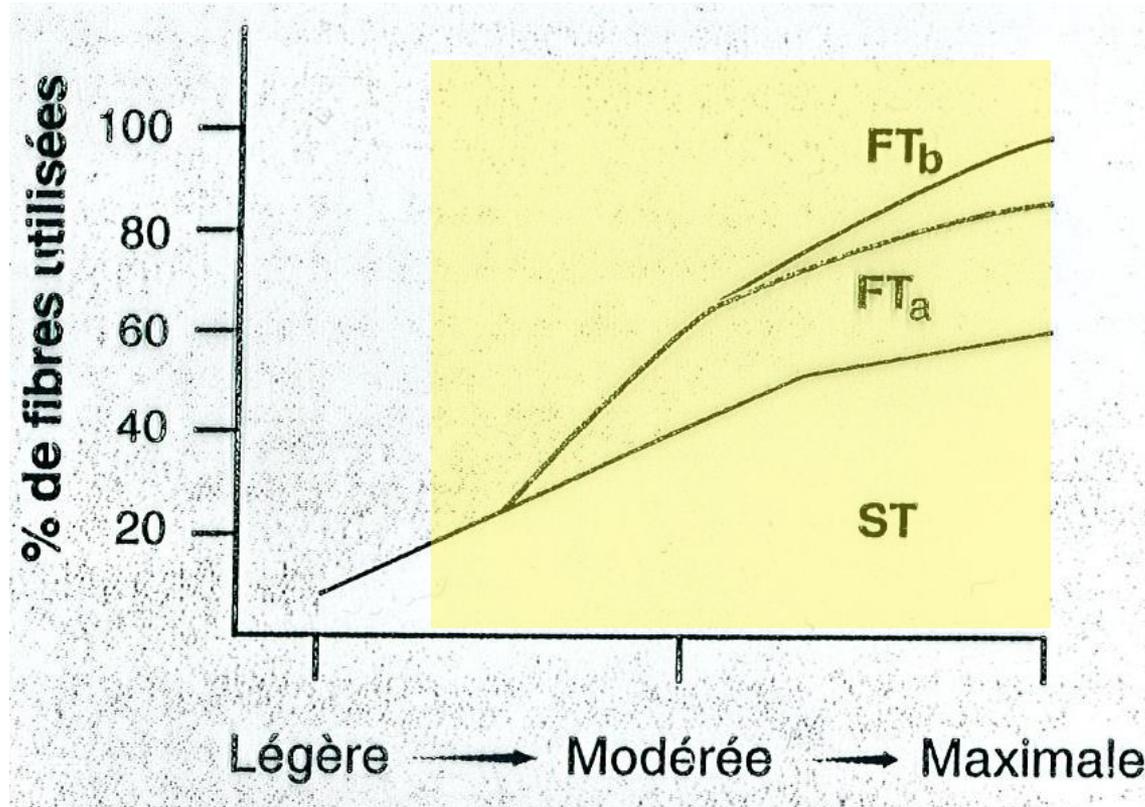
CARACTERISTIQUES HISTOLOGIQUES DES PRINCIPAUX GROUPES DE FIBRES MUSCULAIRES

Type de fibres	I	II	
		A	B
PROPRIÉTÉS CONTRACTILES Myosine ATP-ase			
POTENTIELS MÉTABOLIQUES			
Glycolyse			
Oxydation			
SUBSTRATS			
Glycogène			
Triglycérides			
VASCULARISATION CAPILLAIRE			
SURFACE DES FIBRES			

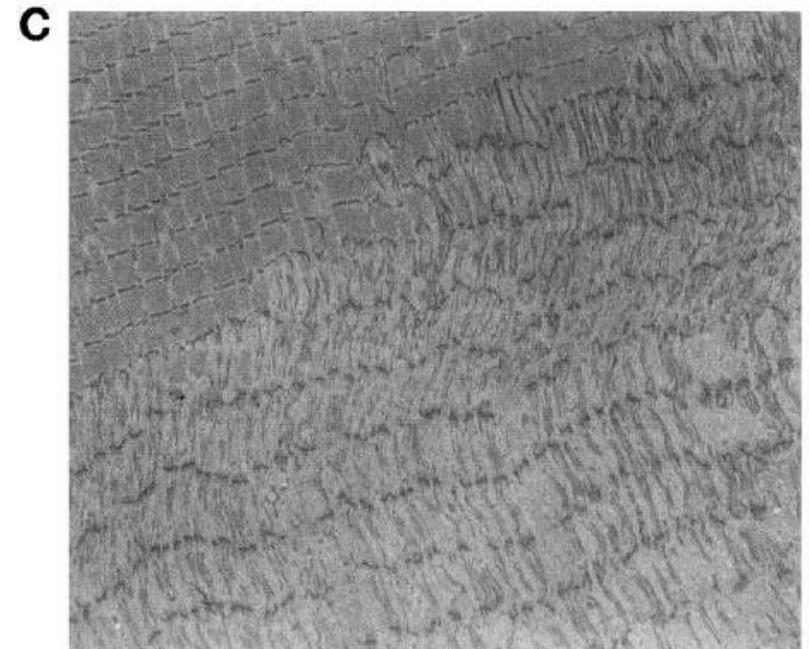
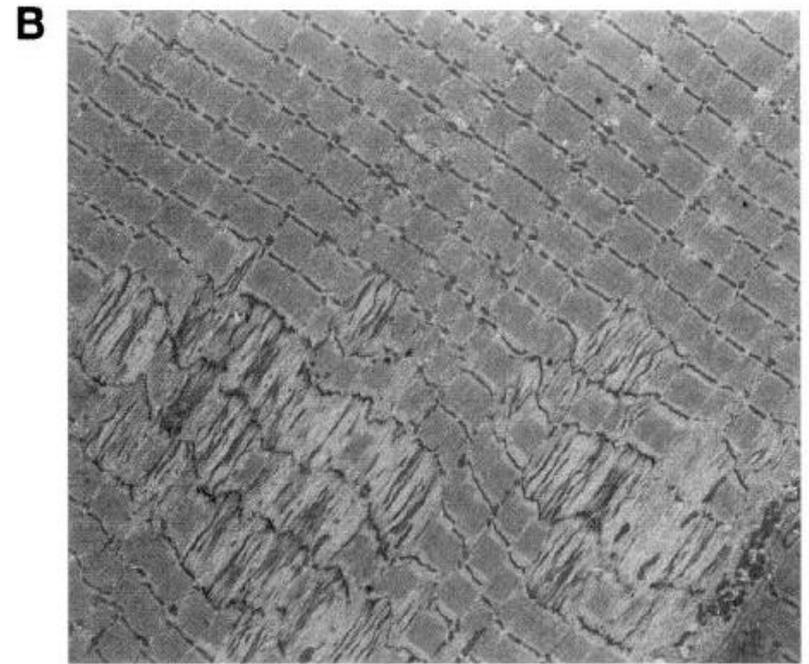
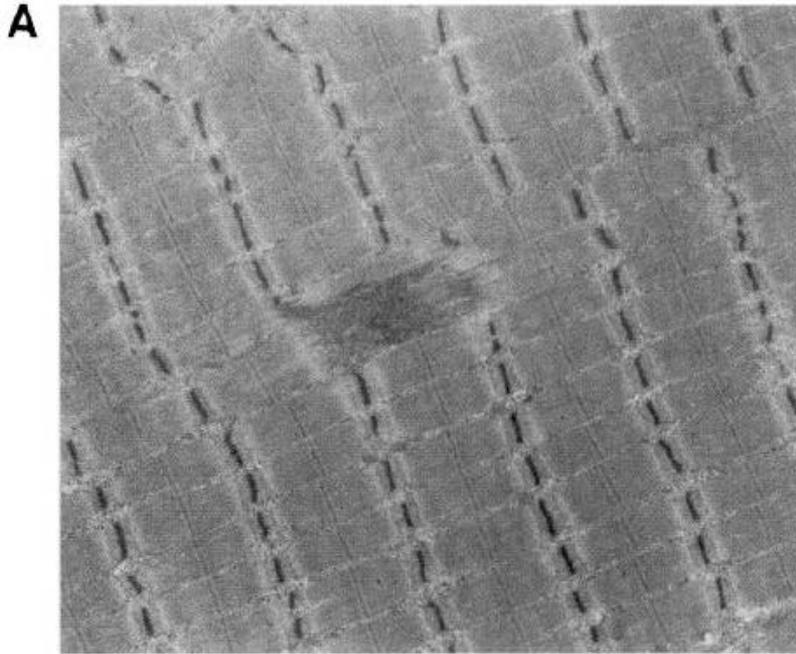
	TYPE 1	TYPE 2A	TYPE 2B
Myoglobine	+++	++	-
Nombre de capillaires	très important	important	faible
Contenu en mitochondries et enzymes mitochondriales	fortement oxydatives	oxydatives	faiblement oxydatives
enzymes glycolytiques	faible	moyen	fort
Teneur en lipides	fort	moyen	faible
réticulum sarcoplasmique	peu développé	important	important
diamètre moyen des fibres	petit	grand	grand



Chapitre 2. Les fibres musculaires



Chapitre 3. Les dommages musculaires



DOMS
(delayed onset of muscle soreness)
=
Courbatures

Contraintes mécaniques élevées
(ex : la course en descente)

Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

Étude longitudinale

Parameter	Pre-training			Post-training		
	HT	NT	HT+NT	HT	NT	HT+NT
Fiber type distribution (%)						
ST	39.2 (6.2)	40.4 (2.9)	39.9 (2.8)	40.9 (6.2)	38.1 (3.9)	39.2 (3.2)
FTa	31.4 (5.8)	31.9 (3.4)	31.8 (2.9)	28.5 (2.3)	34.6 (2.7)	32.2 (2.0)
FTb	27.7 (4.7)	25.1 (3.5)	26.1 (2.7)	25.1 (4.1)	23.5 (1.9)	24.1 (1.9)
FTc	1.7 (0.8)	2.6 (1.3)	2.2 (0.8)	5.4 (3.3)	3.8 (2.0)	4.5 (1.7)
Fiber cross-sectional area (μm^2)						
ST	3977 (201)	5025 (373)	4622 (277)	4530 (225)	5494 (329)	5123 (252)**
FTa	5359 (482)	5375 (363)	5369 (277)	6110 (667)	5863 (479)	5958 (375)*
FTb	4208 (506)	4159 (237)	4178 (230)	5160 (707)	4018 (253)	4457 (336)
FTc	603 (603)	1061 (709)	885 (481)	2237 (1525)	745 (745)	1319 (736)
Capillaries in contact per fiber, and capillary density						
ST	4.16 (0.17)	4.45 (0.19)	4.34 (0.14)	5.64 (0.15)	6.11 (0.36)	5.93 (0.23)**
FTa	4.54 (0.28)	4.36 (0.17)	4.43 (0.14)	5.78 (0.32)	5.78 (0.28)	5.78 (0.22)**
FTb	3.34 (0.16)	3.38 (0.21)	3.36 (0.14)	4.34 (0.32)	4.18 (0.28)	4.24 (0.20)**
Density (mm^2)	328 (27)	367 (16)	351 (15)	431 (37)	475 (27)	459 (22)**
Enzyme activities ($\mu\text{mol}\cdot\text{min}^{-1}\cdot\text{g}^{-1}$ dry muscle)						
PFK	158 (13)	139 (7)	147 (7)	152 (22)	134 (17)	141 (13)
CS	18.2 (1.24)	18.2 (1.28)	18.19 (0.88)	25.1 (0.96)	28.1 (3.13)	26.92 (1.95)**
LDH	896 (196)	1009 (134)	965 (108)	780 (193)	765 (101)	771 (92)**
Proportion of LDH isozymes (%)						
H-LDH	18.2 (3.6)	20.6 (2.8)	19.7 (2.1)	22.1 (4.8)	25.8 (3.0)	24.4 (2.5)*
M-LDH	81.8 (3.6)	79.4 (2.8)	80.3 (2.1)	77.9 (4.8)	74.2 (3.0)	75.6 (2.5)*

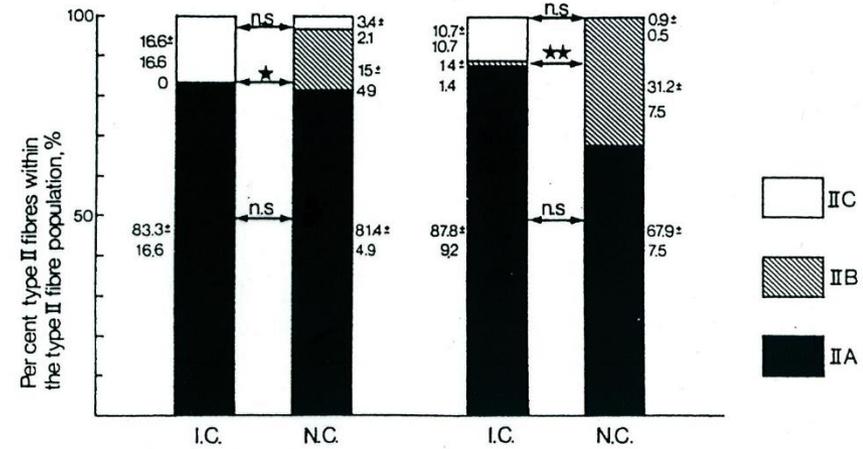
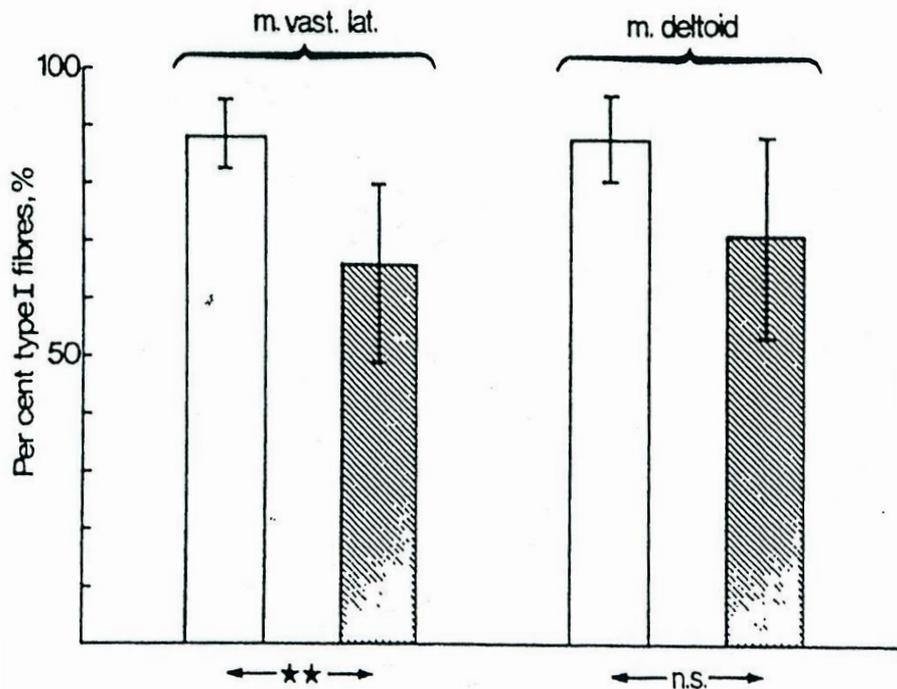
Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

Group n	Percent type I fibers		Mean fiber areas		Capillary density	
	m.v.l. %	m.d. %	m.v.l. ($\mu\text{m}^2 \times 10^2$)	m.d. ($\mu\text{m}^2 \times 10^2$)	m.v.l. (cap $\times \text{mm}^{-2}$)	m.d. (cap $\times \text{mm}^{-2}$)
Rowers 12	70.1 \pm 3.6	74.0 \pm 3.9	39.7 \pm 3.1	35.8 \pm 2.8	598 \pm 62	599 \pm 39
Sedentary 11	40.5 \pm 3.9 ¹	—	33.3 \pm 2.3 ¹	—	329 \pm 11 ²	—

¹Larsson et al. 1979

²Andersen and Henriksson 1977 (n = 5)

Étude transversale



I.C. rowers
 N.C. rowers

Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

Étude longitudinale

Parameter	Pre-training			Post-training		
	HT	NT	HT + NT	HT	NT	HT + NT
Fiber type distribution (%)						
ST	39.2 (6.2)	40.4 (2.9)	39.9 (2.8)	40.9 (6.2)	38.1 (3.9)	39.2 (3.2)
FTa	31.4 (5.8)	31.9 (3.4)	31.8 (2.9)	28.5 (2.3)	34.6 (2.7)	32.2 (2.0)
FTb	27.7 (4.7)	25.1 (3.5)	26.1 (2.7)	25.1 (4.1)	23.5 (1.9)	24.1 (1.9)
FTc	1.7 (0.8)	2.6 (1.3)	2.2 (0.8)	5.4 (3.3)	3.8 (2.0)	4.5 (1.7)
Fiber cross-sectional area (μm^2)						
ST	3977 (201)	5025 (373)	4622 (277)	4530 (225)	5494 (329)	5123 (252)**
FTa	5359 (482)	5375 (363)	5369 (277)	6110 (667)	5863 (479)	5958 (375)*
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Capillaries in contact per fiber, and capillary density						
ST	4.16 (0.17)	4.45 (0.19)	4.34 (0.14)	5.64 (0.15)	6.11 (0.36)	5.93 (0.23)**
FTa	4.54 (0.28)	4.36 (0.17)	4.43 (0.14)	5.78 (0.32)	5.78 (0.28)	5.78 (0.22)**
FTb	3.34 (0.16)	3.38 (0.21)	3.36 (0.14)	4.34 (0.32)	4.18 (0.28)	4.24 (0.20)**
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H-LDH	18.2 (3.6)	20.6 (2.8)	19.7 (2.1)	22.1 (4.8)	25.8 (3.0)	24.4 (2.5)*
M-LDH	81.8 (3.6)	79.4 (2.8)	80.3 (2.1)	77.9 (4.8)	74.2 (3.0)	75.6 (2.5)*

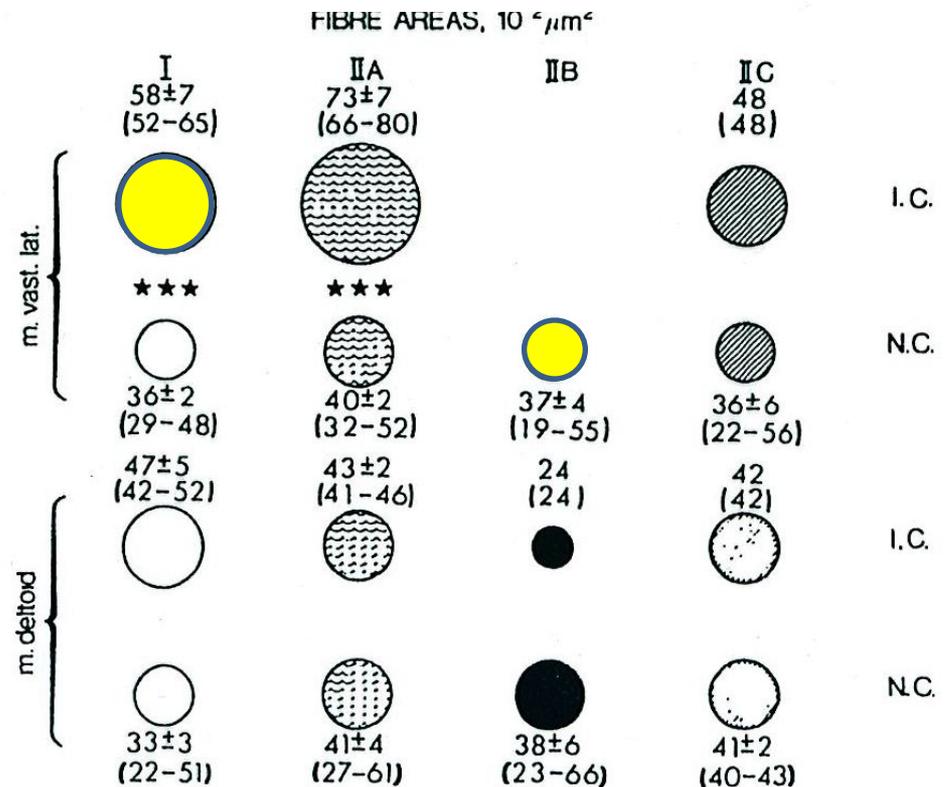
Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

Group n	Percent type I fibers		Mean fiber areas		Capillary density	
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Rowers 12	70.1 ± 3.6	74.0 ± 3.9	39.7 ± 3.1	35.8 ± 2.8	598 ± 62	599 ± 39
Sedentary 11	40.5 ± 3.9 ¹	—	33.3 ± 2.3 ¹	—	329 ± 11 ²	—

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Étude transversale



Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

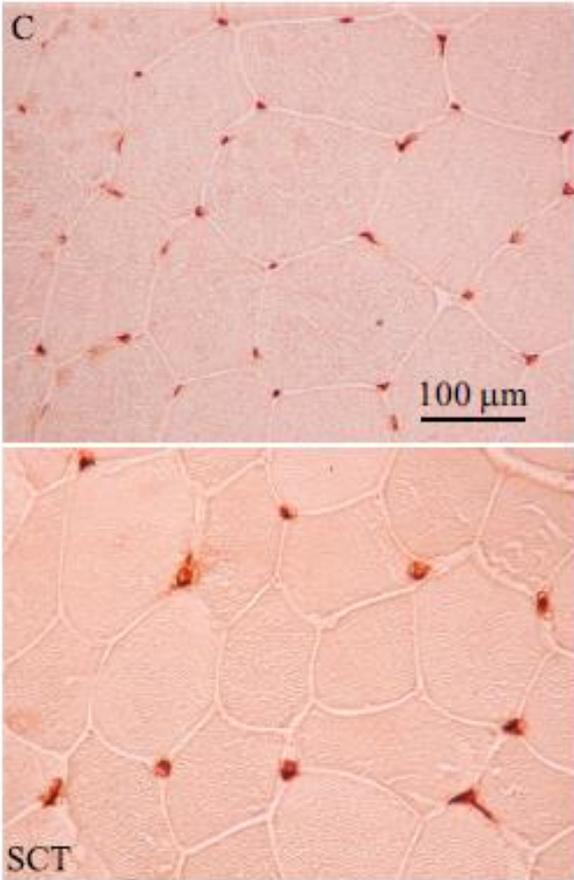
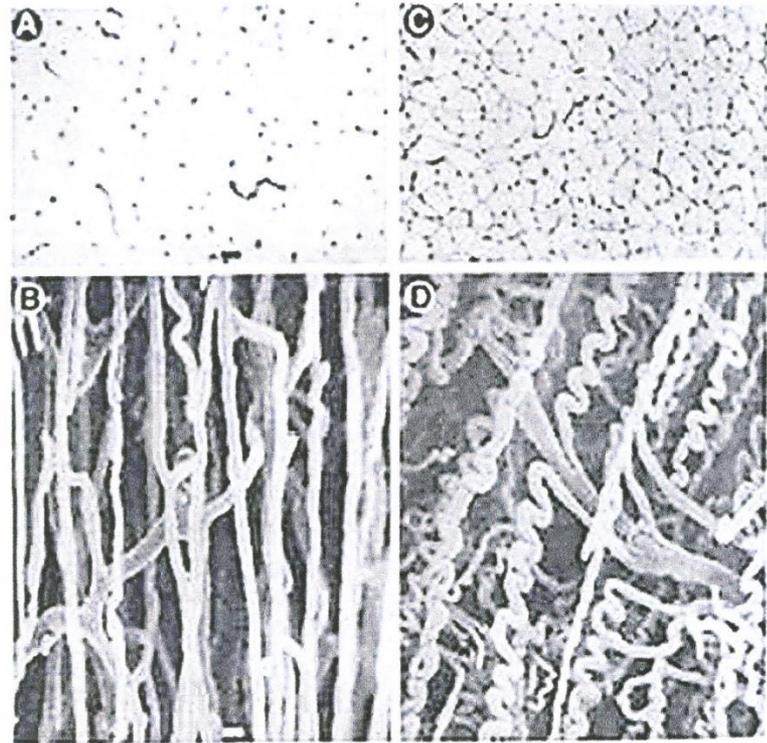
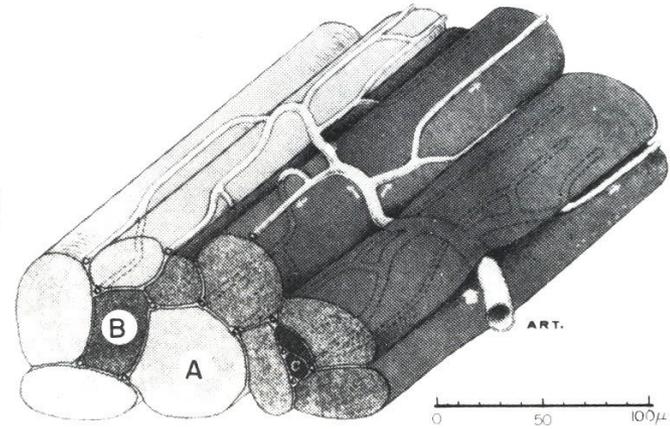


FIG. 2. Capillaries branch from small arteriole to supply blood to muscle fibers. [From Eriksson and Myrhage (21).]



Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

Parameter	Pre-training			Post-training		
	HT	NT	HT+NT	HT	NT	HT+NT
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Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

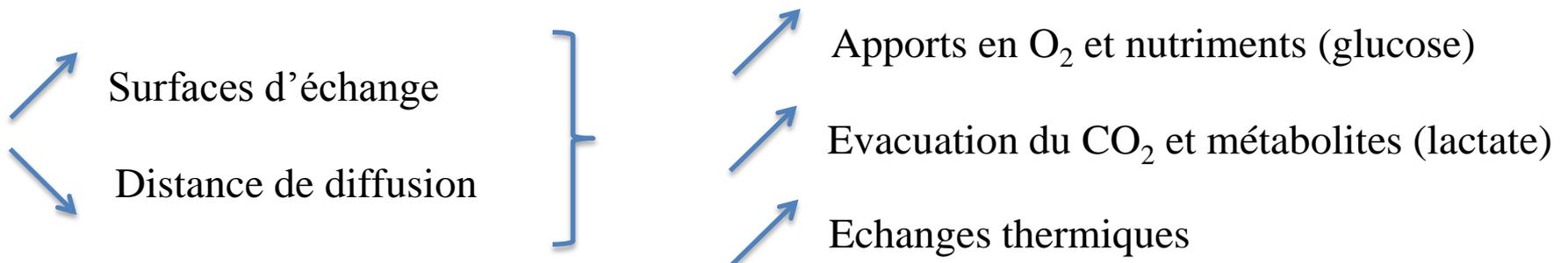
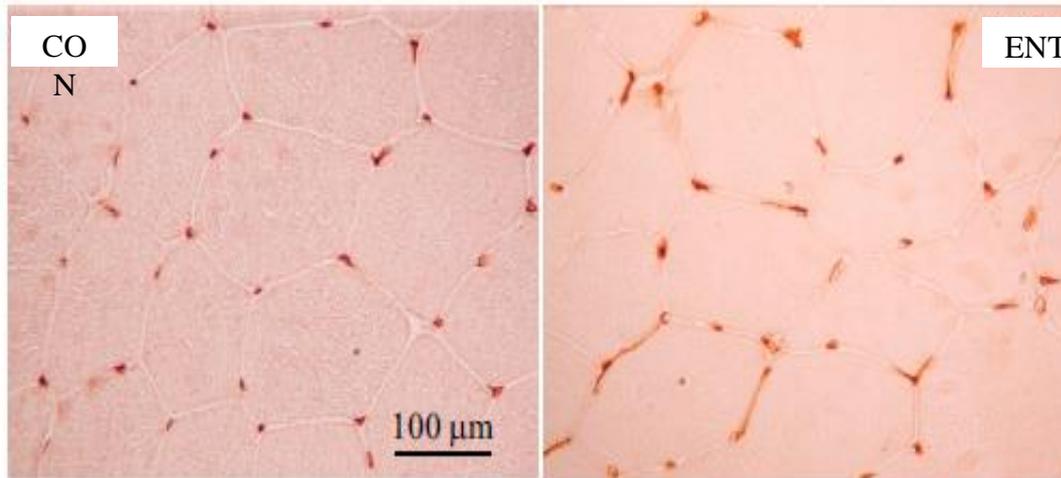
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Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

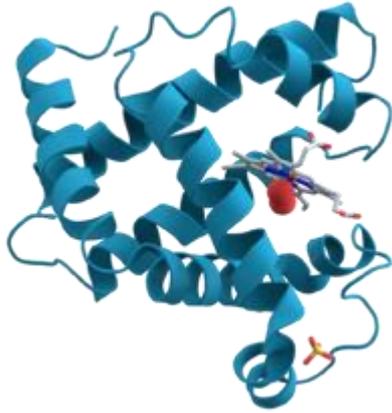
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¹Larsson et al. 1979

²Andersen and Henriksson 1977 (n = 5)



Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)



Contenu en myoglobine **+75 à 80%**

Apports d'O₂ à la mitochondrie

Nombre

Taille

Efficacité



1. Group	2. DPNH dehydrogenase	3. Mitochondrial protein	4. DPNH dehydrogenase
	<i>μmoles/min/g muscle</i>	<i>mg/g muscle</i>	<i>μmoles/min/mg protein</i>
Sedentary.....	5.6 ± 0.6	2.97 ± 0.20	1.96 ± 0.30
Exercising . . .	11.8 ± 1.5 ^a	4.67 ± 0.30 ^a	2.54 ± 0.26 ^b

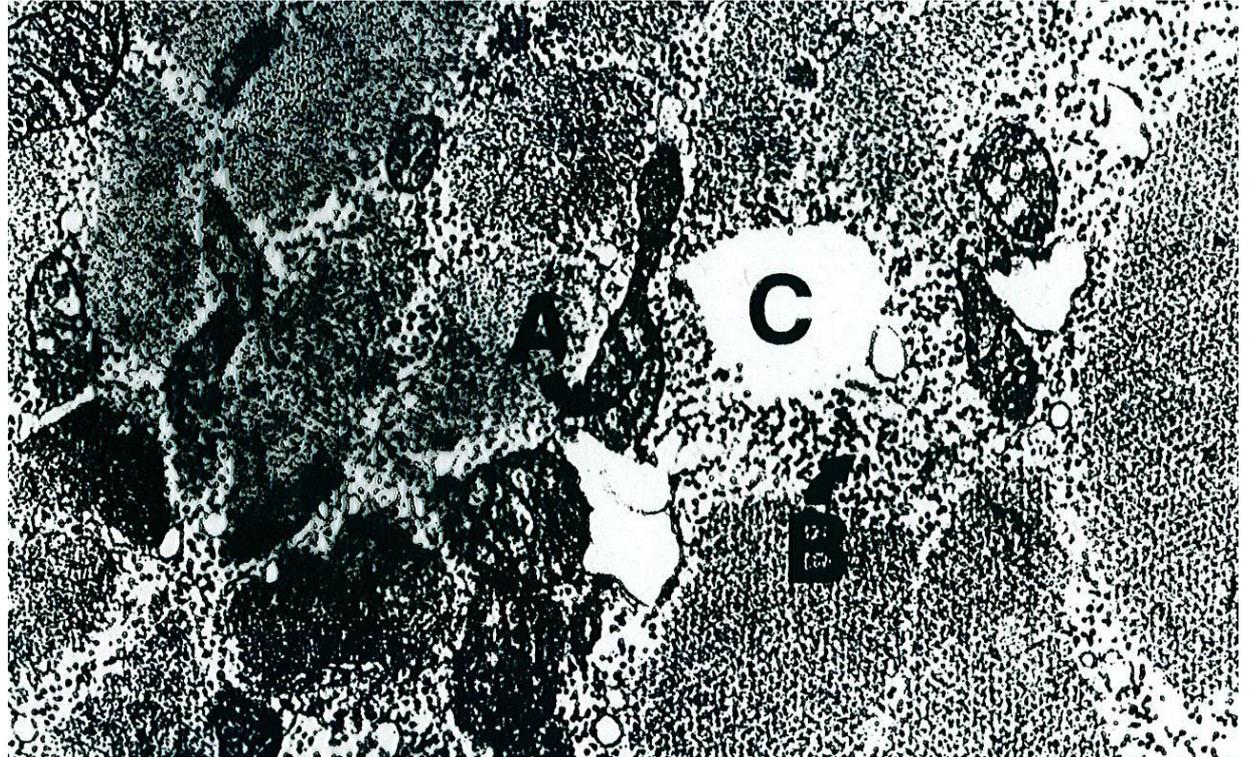
Chapitre 4. Plasticité musculaire (ex: adaptations à l'entraînement en endurance)

Parameter	Pre-training			Post-training		
	HT	NT	HT+NT	HT	NT	HT+NT
Fiber type distribution (%)						
ST	39.2 (6.2)	40.4 (2.9)	39.9 (2.8)	40.9 (6.2)	38.1 (3.9)	39.2 (3.2)
FTa	31.4 (5.8)	31.9 (3.4)	31.8 (2.9)	28.5 (2.3)	34.6 (2.7)	32.2 (2.0)
FTb	27.7 (4.7)	25.1 (3.5)	26.1 (2.7)	25.1 (4.1)	23.5 (1.9)	24.1 (1.9)
FTc	1.7 (0.8)	2.6 (1.3)	2.2 (0.8)	5.4 (3.3)	3.8 (2.0)	4.5 (1.7)
Fiber cross-sectional area (μm^2)						
ST	3977 (201)	5025 (373)	4622 (277)	4530 (225)	5494 (329)	5123 (252)**
FTa	5359 (482)	5375 (363)	5369 (277)	6110 (667)	5863 (479)	5958 (375)*
FTb	4208 (506)	4159 (237)	4178 (230)	5160 (707)	4018 (253)	4457 (336)
FTc	603 (603)	1061 (709)	885 (481)	2237 (1525)	745 (745)	1319 (736)
Capillaries in contact per fiber, and capillary density						
ST	4.16 (0.17)	4.45 (0.19)	4.34 (0.14)	5.64 (0.15)	6.11 (0.36)	5.93 (0.23)**
FTa	4.54 (0.28)	4.36 (0.17)	4.43 (0.14)	5.78 (0.32)	5.78 (0.28)	5.78 (0.22)**
FTb	3.34 (0.16)	3.38 (0.21)	3.36 (0.14)	4.34 (0.32)	4.18 (0.28)	4.24 (0.20)**
Density (mm^2)	328 (27)	367 (16)	351 (15)	431 (37)	475 (27)	459 (22)**
Enzyme activities ($\mu\text{mol}\cdot\text{min}^{-1}\cdot\text{g}^{-1}$ dry muscle)						
PFK	158 (13)	139 (7)	147 (7)	152 (22)	134 (17)	141 (13)
CS	18.2 (1.24)	18.2 (1.28)	18.19 (0.88)	25.1 (0.96)	28.1 (3.13)	26.92 (1.95)**
LDH	896 (196)	1009 (134)	965 (108)	780 (193)	765 (101)	771 (92)**
Proportion of LDH isozymes (%)						
H-LDH	18.2 (3.6)	20.6 (2.8)	19.7 (2.1)	22.1 (4.8)	25.8 (3.0)	24.4 (2.5)*
M-LDH	81.8 (3.6)	79.4 (2.8)	80.3 (2.1)	77.9 (4.8)	74.2 (3.0)	75.6 (2.5)*

	Fibre type distribution (%)				Enzymes activities ($\mu\text{mol}\cdot\text{min}^{-1}\cdot\text{g}^{-1}$ dry muscle)					
	ST	FTa	FTb	FTc	PFK	LDH	M-LDH	CS	HAD	PFK/CS
Pre-training	40.4 ± 2.9	31.9 ± 3.4	25.1 ± 3.5	2.6 ± 1.3	139 ± 7	1009 ± 134	815 ± 125	18.2 ± 1.3	43.6 ± 1.7	8.05 ± 0.86
Post-training	38.1 ± 3.9	34.6 ± 2.7	23.5 ± 1.9	3.8 ± 2.0	134 ± 17	765 ± 101	586 ± 92	28.1 ± 3.1	50.5 ± 2.7	5.05 ± 0.69

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↗ Glycogène
↗ Lipides



A. Mitochondrie, B. granule de glycogène, C. vacuole de lipides



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DIU de la Pathologie Locomotrice
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Physiologie du muscle

Pr. Laurent Messonnier