

Facteurs limitant la performance en hypoxie. Interaction avec l'entraînement aérobie.



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« Réponses cellulaires et fonctionnelles à l'hypoxie »

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Interactions entre deux contraintes induisant des ajustements adaptatifs

Entraînement aérobie

Hypoxie

Modifications cardiovasculaires

Augmentation du volume cardiaque
Augmentation du débit cardiaque
Augmentation du transport maximal d'oxygène

Modifications ventilatoires

Hypoventilation relative

Modifications musculaires

Augmentation de la capillarisation
Augmentation des capacités oxydatives
Modifications métaboliques
Hypertrophie spécifique des fibres

Augmentation de $VO_2\text{max}$

Modifications cardiaques

Diminution du débit cardiaque maximal

Modifications ventilatoires

Hyperventilation, hypocapnie

Modifications hématologiques

Augmentation de la capacité de transport de l' O_2

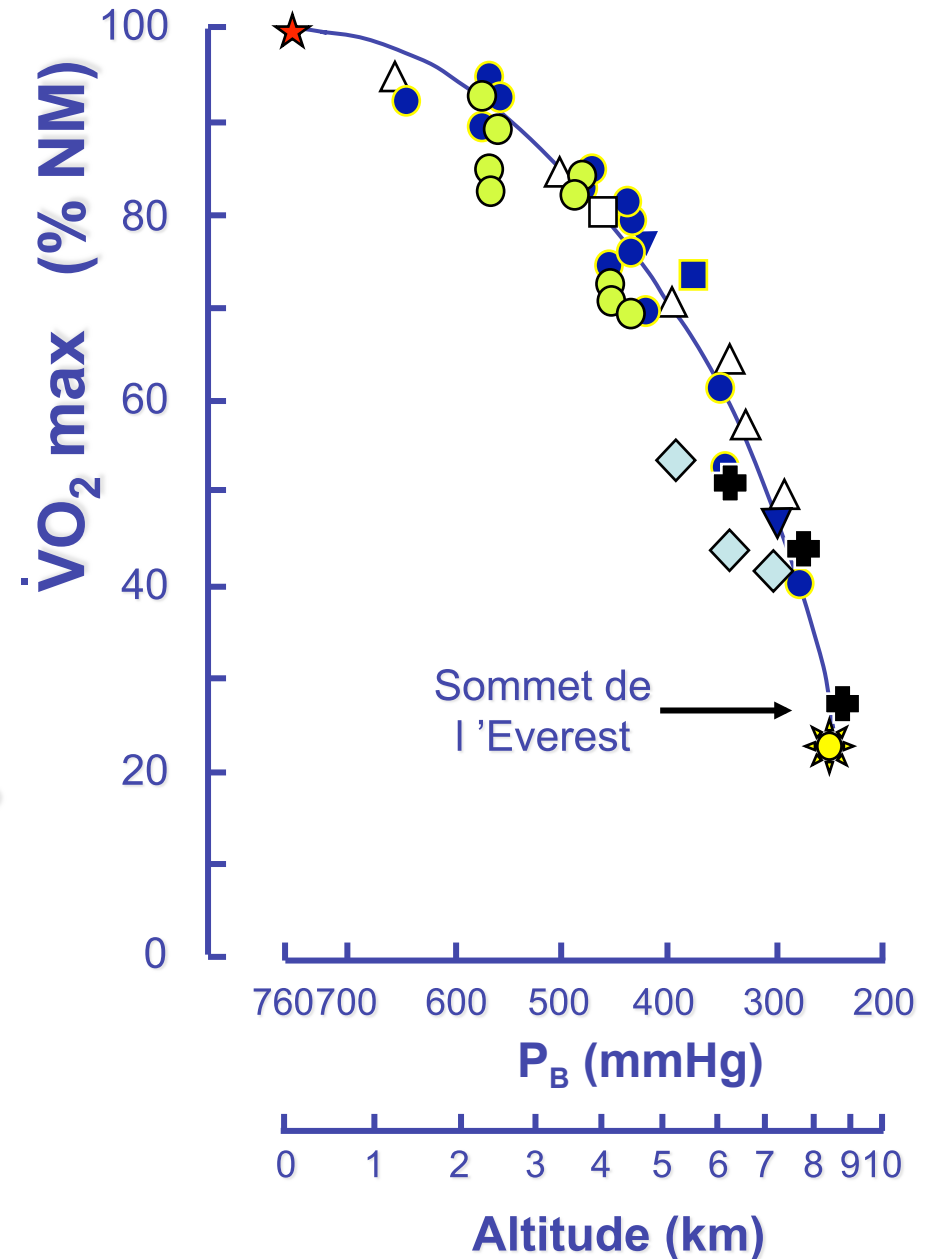
Modifications musculaires

Atrophie musculaire

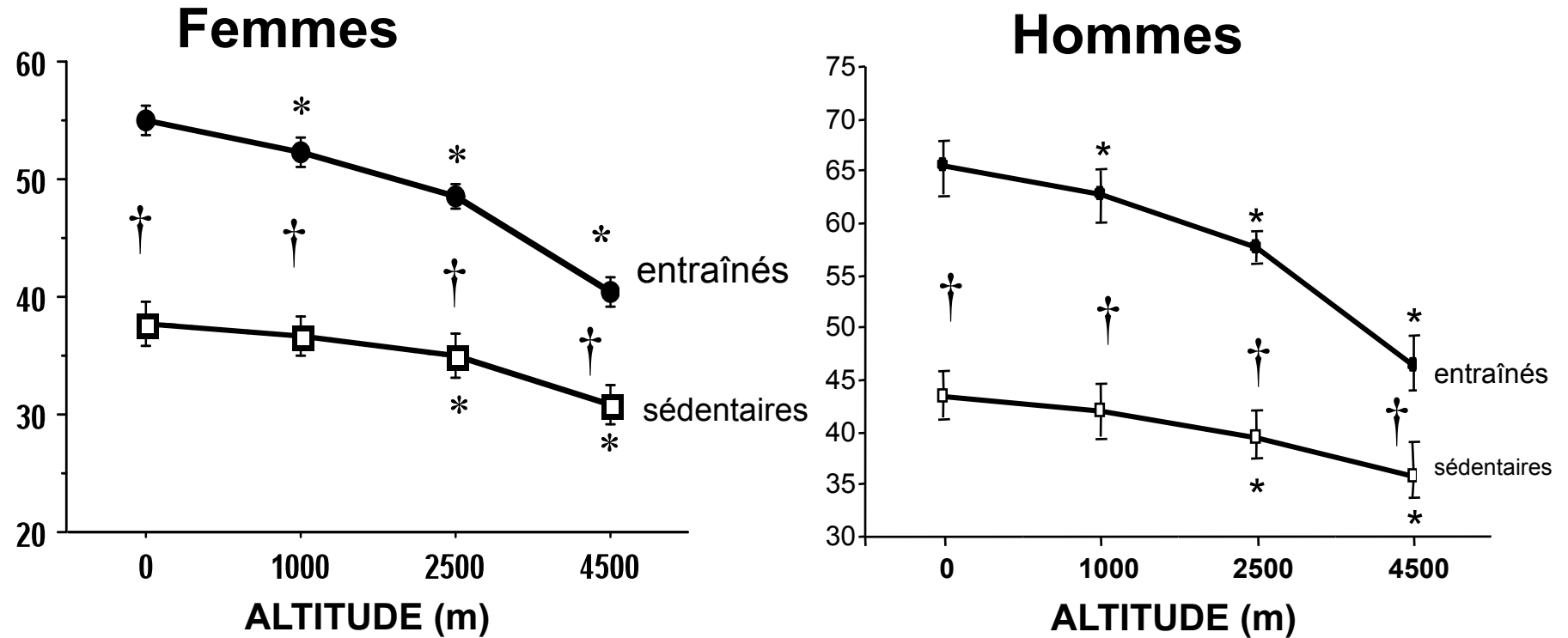
Diminution de $VO_2\text{max}$

La puissance maximale
aérobie ($\dot{V}O_2\text{max}$)
diminue avec l'altitude

*Quels sont les facteurs
limitants de la performance ?*



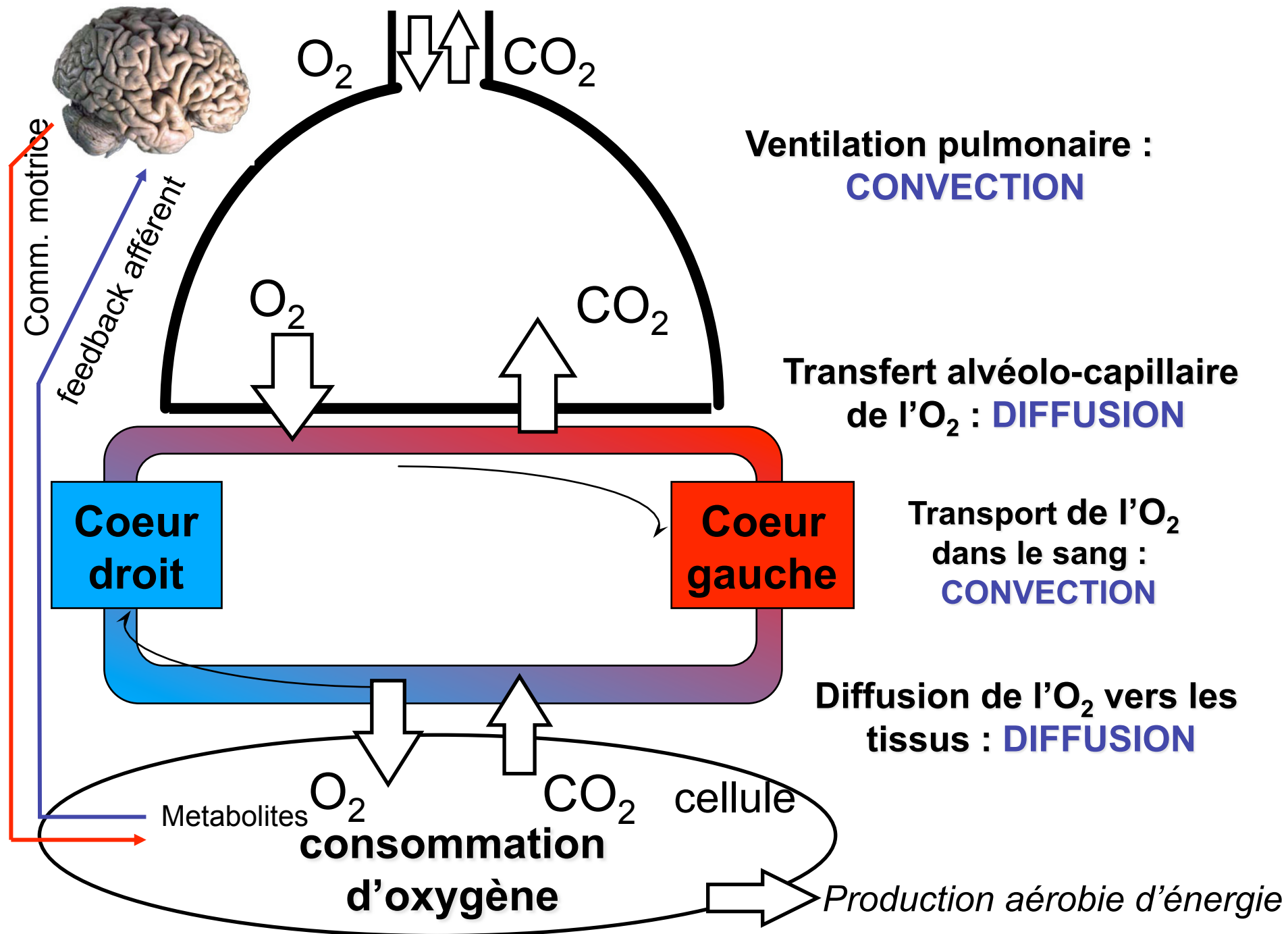
$\dot{V}O_{2\max}$ (ml/min/kg)



* hypoxie vs normoxie

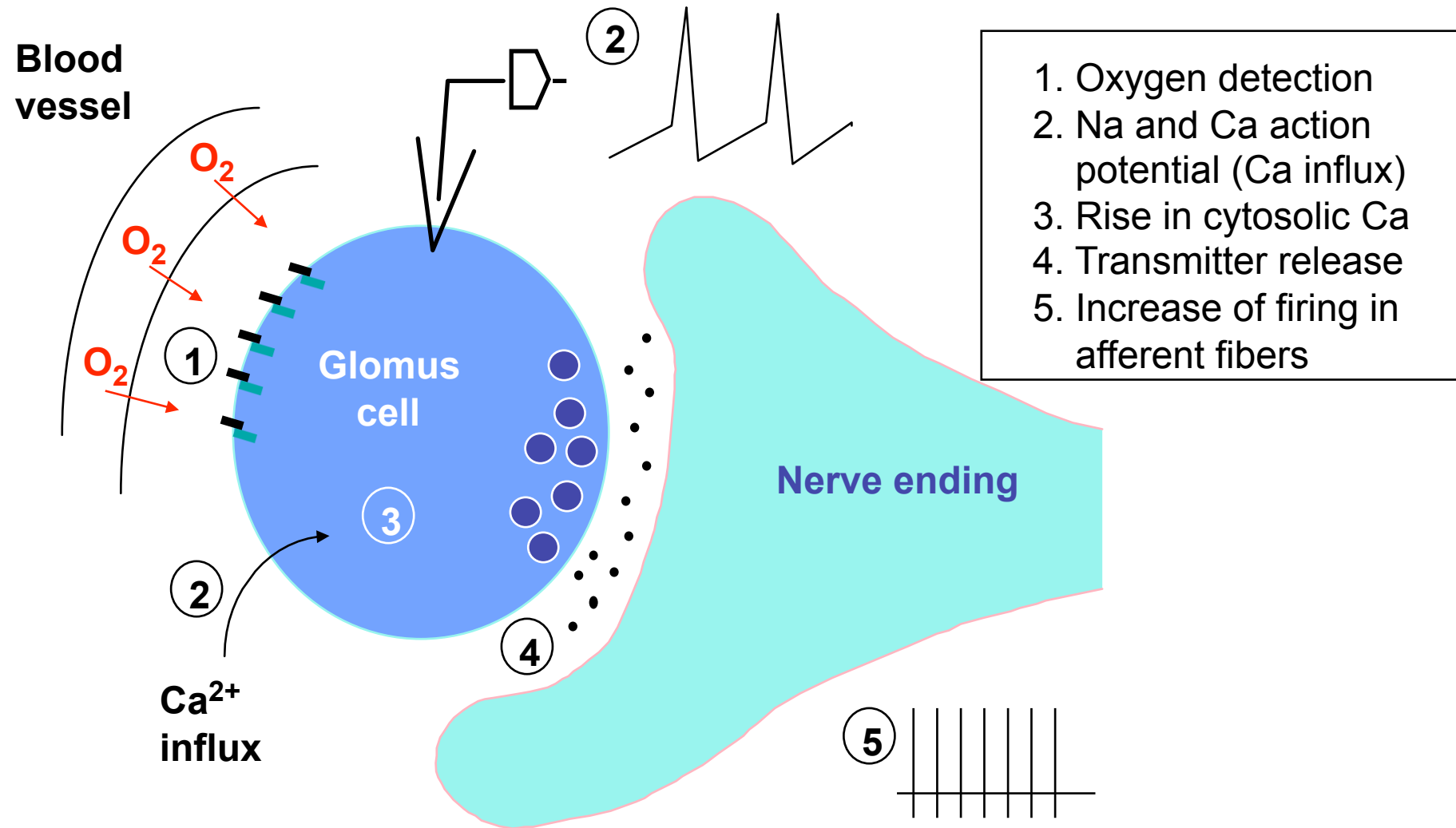
† entraîné vs sédentaire

Les sujets entraînés présentent une baisse de $\dot{V}O_{2\max}$ plus importante que les sédentaires en hypoxie aiguë



Etape ventilatoire

Carotid chemoreceptors : hypoxic sensors

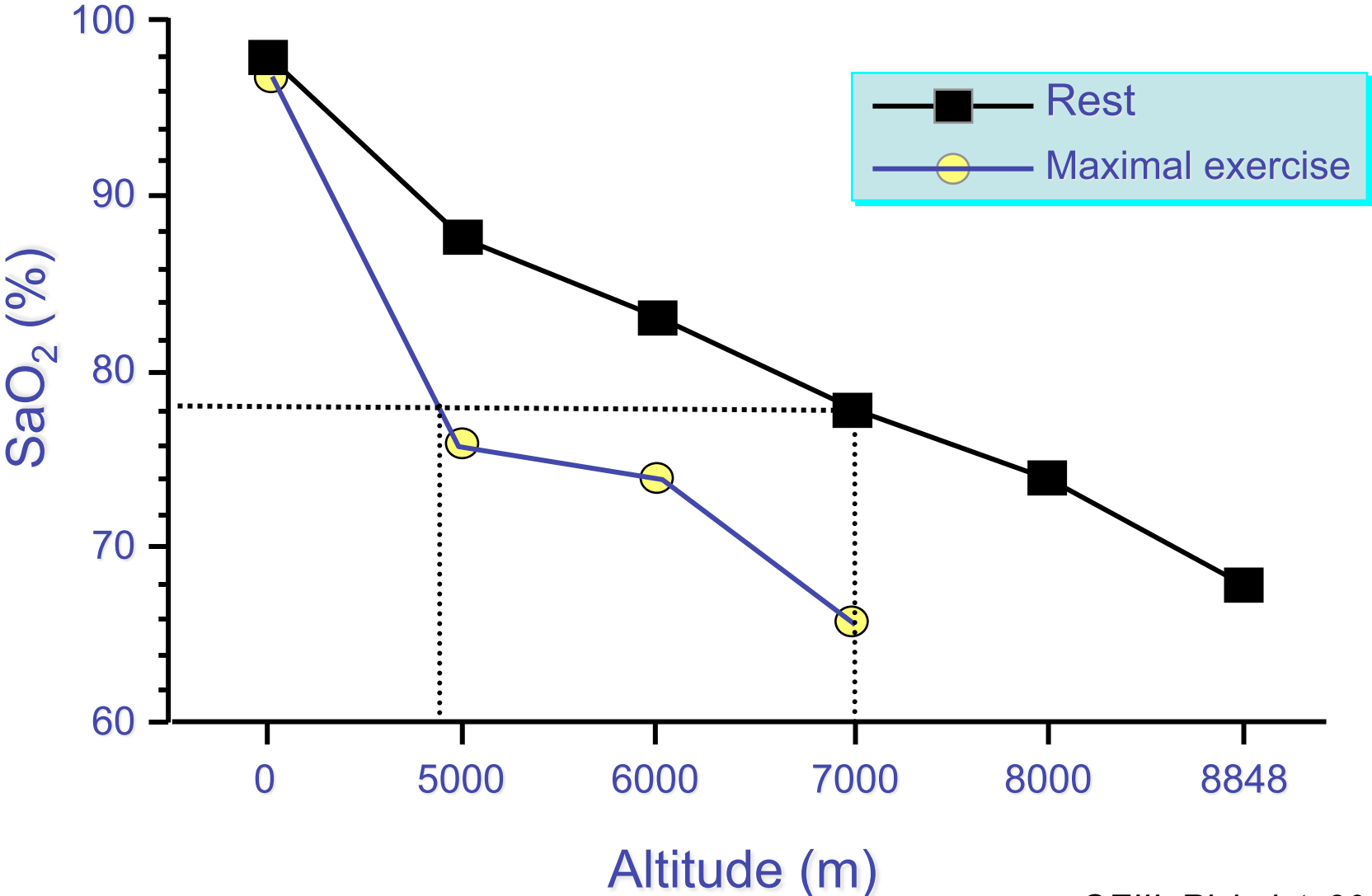


From Lopez-Barneo et al., NIPS, 1993

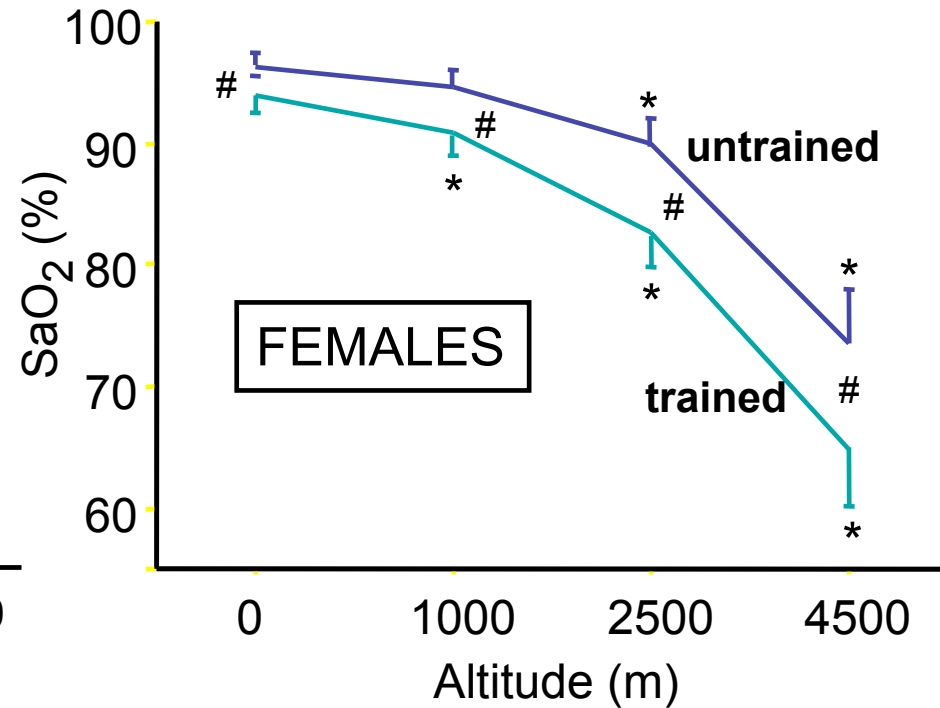
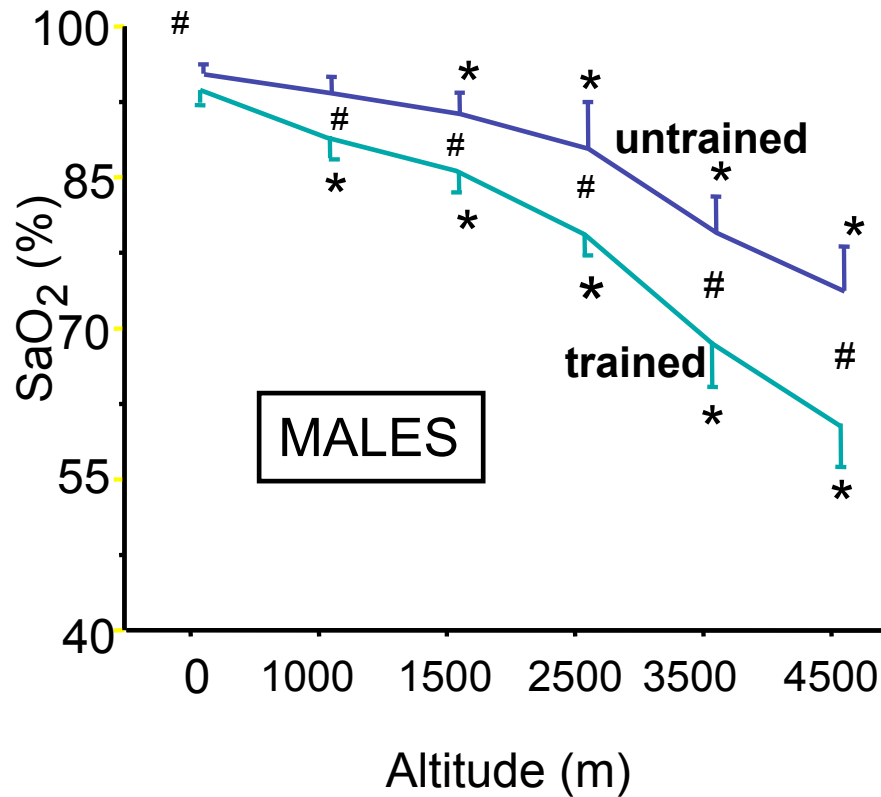
to CNS

Etape diffusionnelle pulmonaire

Decrease in arterial O₂ saturation at rest and exercise with increasing altitude



SaO₂ at maximal exercise

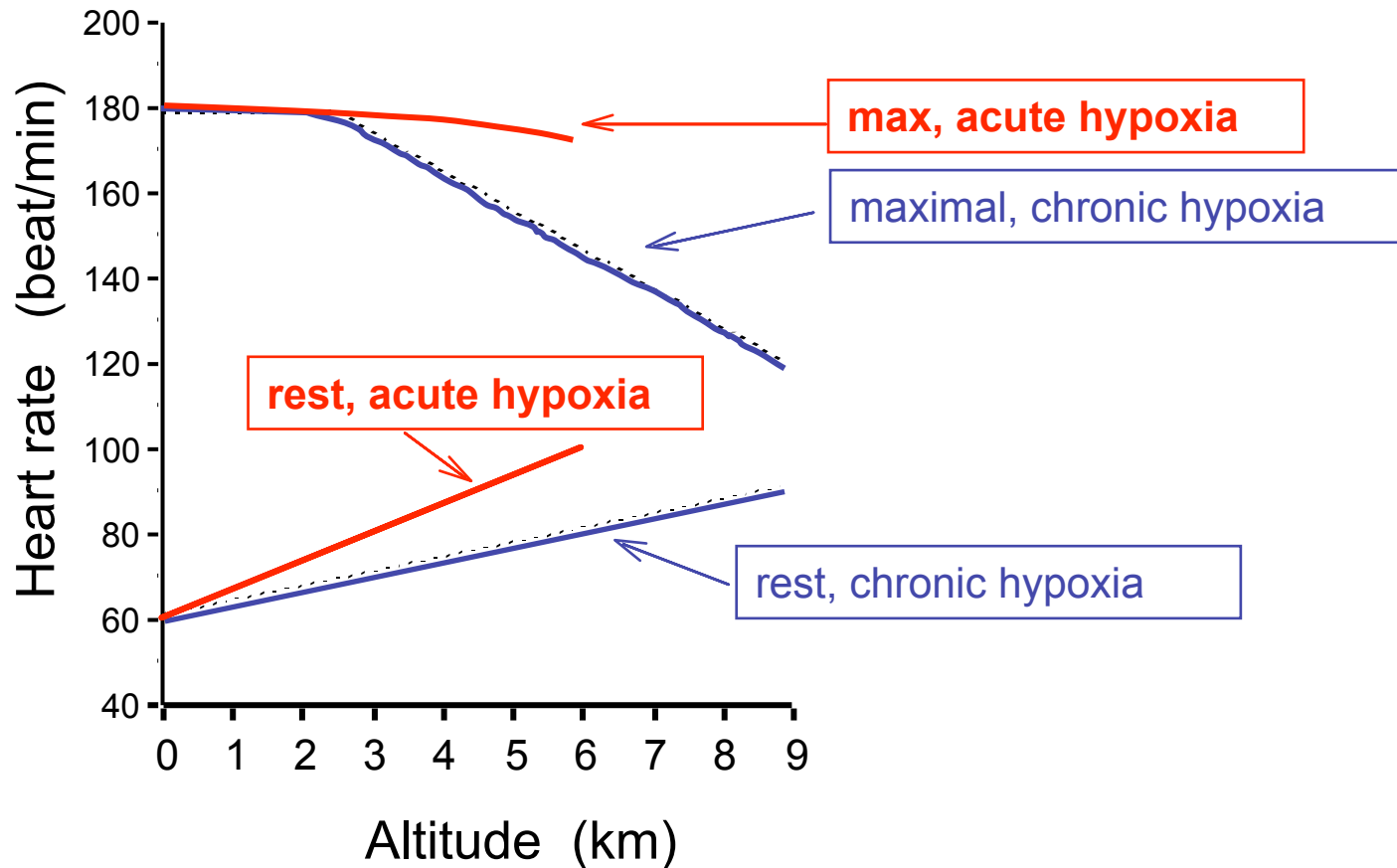


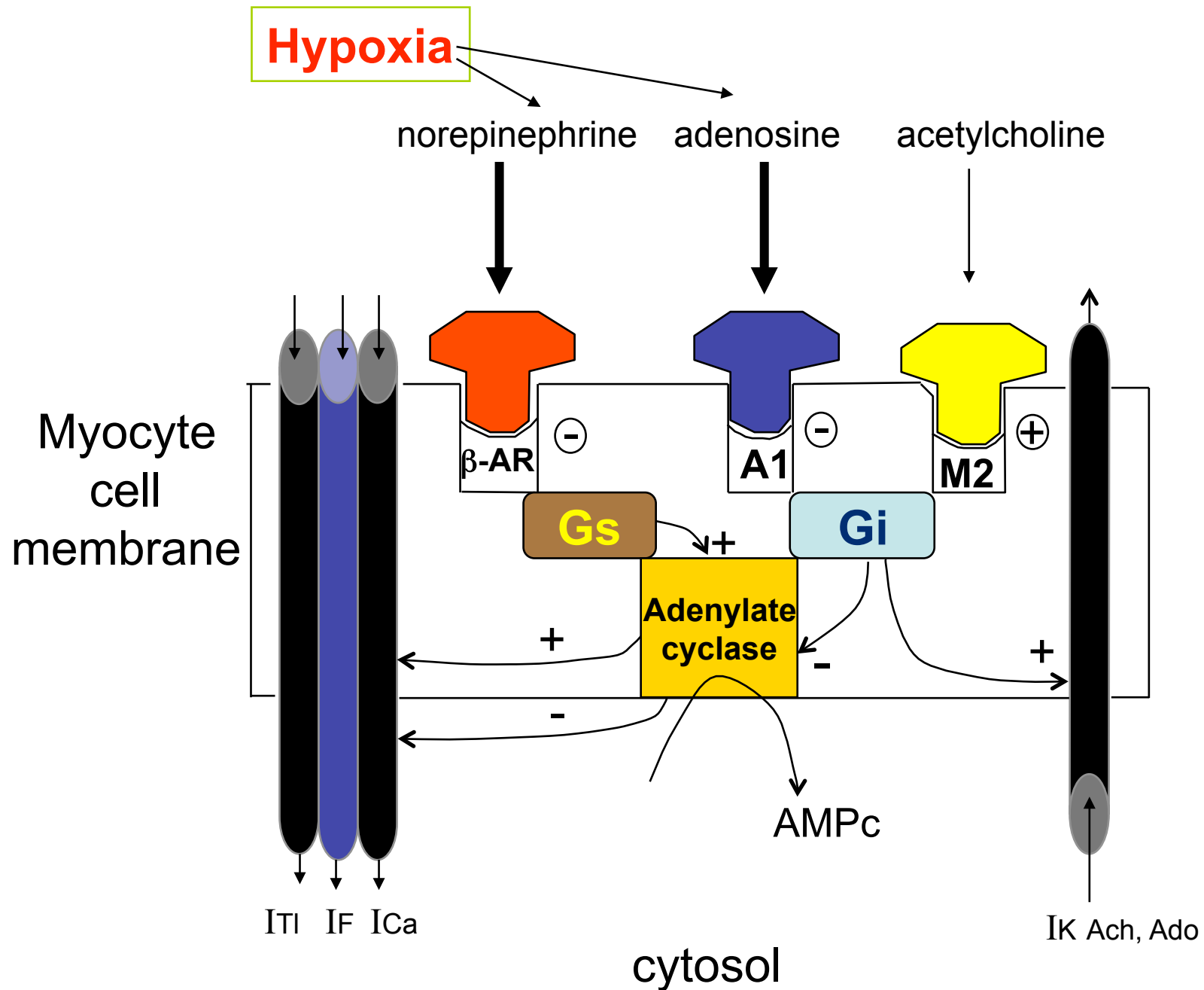
* hypoxia vs normoxia # trained vs untrained

Trained subjects show a greater desaturation at exercise in acute hypoxia

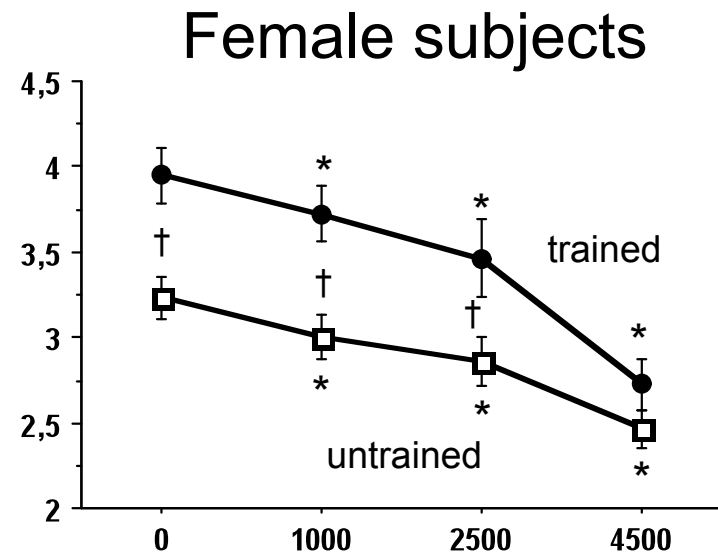
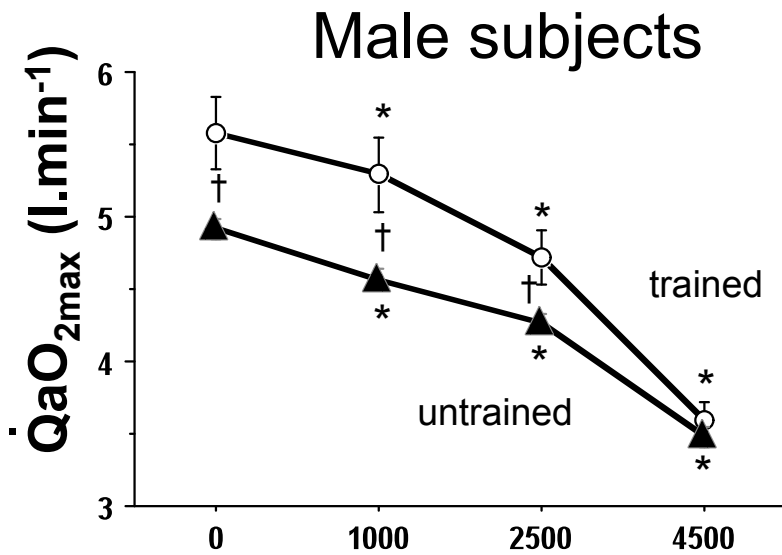
Etape cardiovasculaire

Adaptation of heart rate in acute and chronic hypoxia

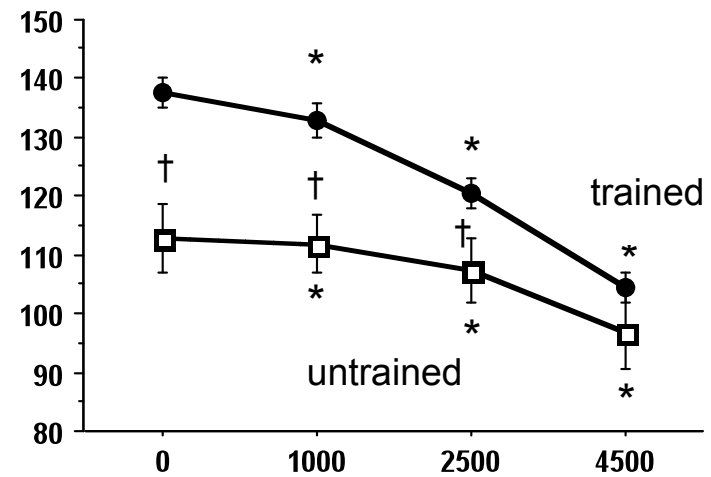
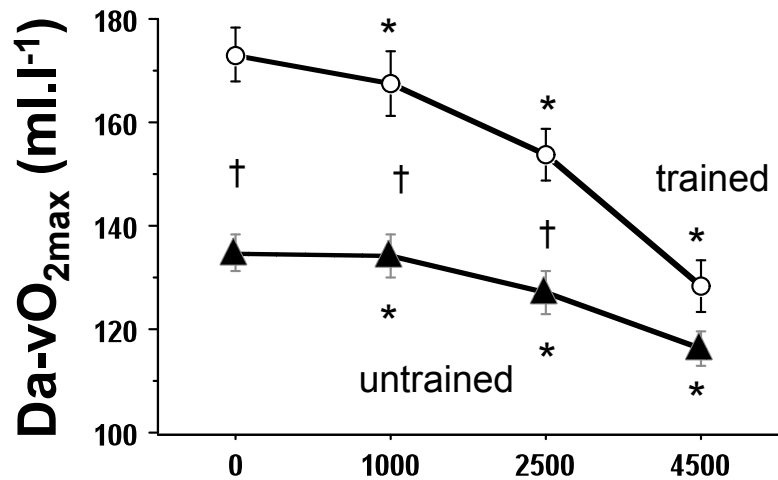




From: Lerman and Belardinelli, *Circulation*, 1991 ; Richalet et al. 1990; Favret and Richalet, 2007



O₂ transport and extraction of trained and untrained subjects converge at 4500m



ALTITUDE (m)

Etape diffusionnelle tissulaire

Subjects

5 endurance trained athletes (59.6 ± 2.8 ml/min/kg) and 6 physically active men (46.2 ± 2.8 ml/min/kg).

NIRS

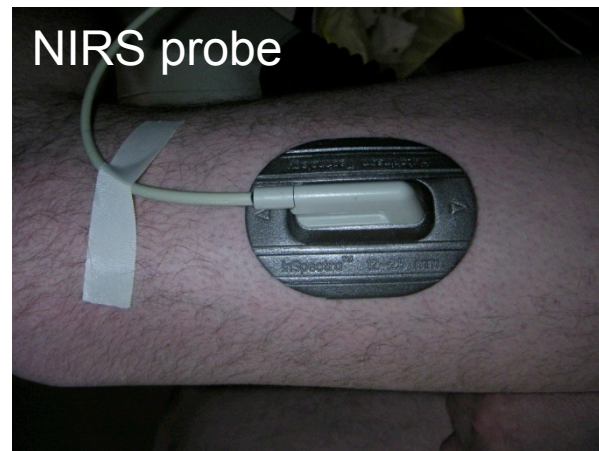
Protocol

Each subject performed VO_2 peak tests on a cyclo-ergometer at 4 different simulated altitudes: 0m, 1000m, 2500m and 4000m

Measurements

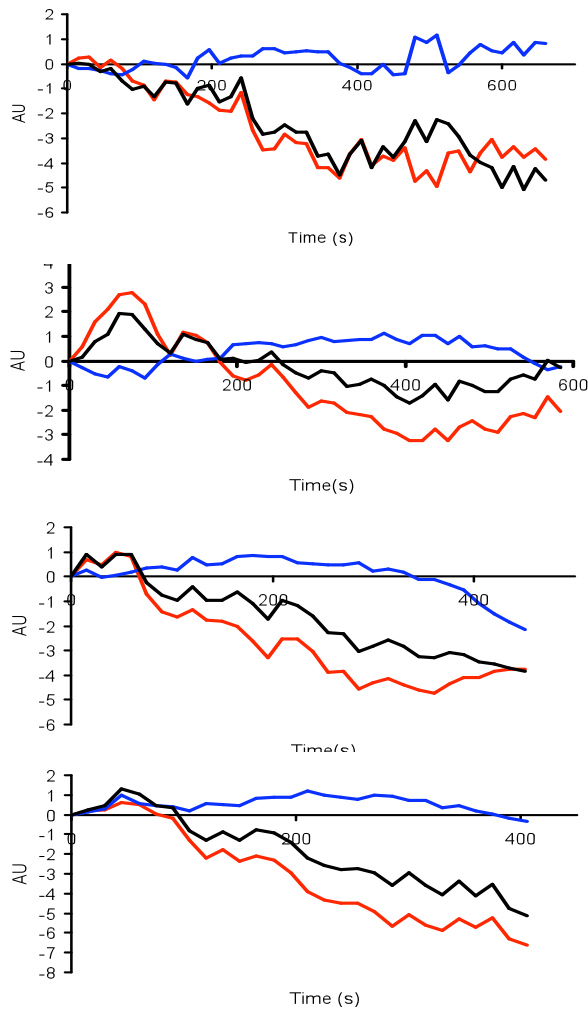
Usual ventilatory and cardiovascular parameters
Cardiac output using transthoracic bio-impedance

Muscle tissue HbO_2 and HHb using Near InfraRed Spectroscopy (NIRS: InSpectra Tissue Spectrometer Model 325, Hutchinson Technology, MN, USA).



NIRS Vastus lateralis

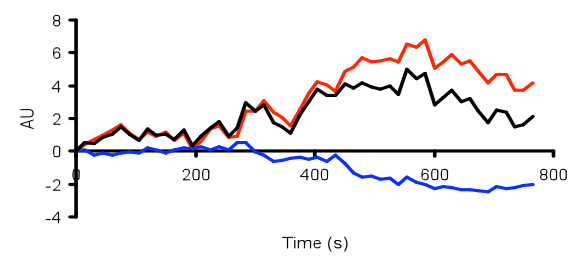
Sédentaires



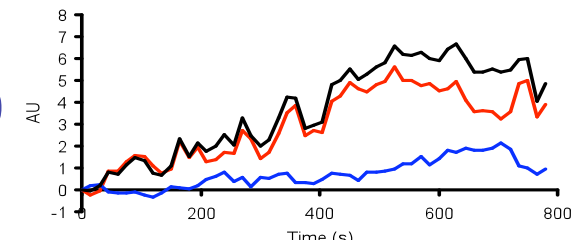
HbO₂
HHb
Hbtot

Entraînés

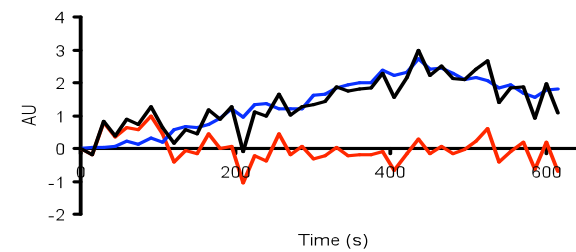
0m



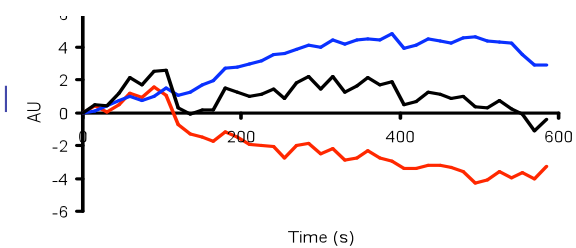
1000



2500



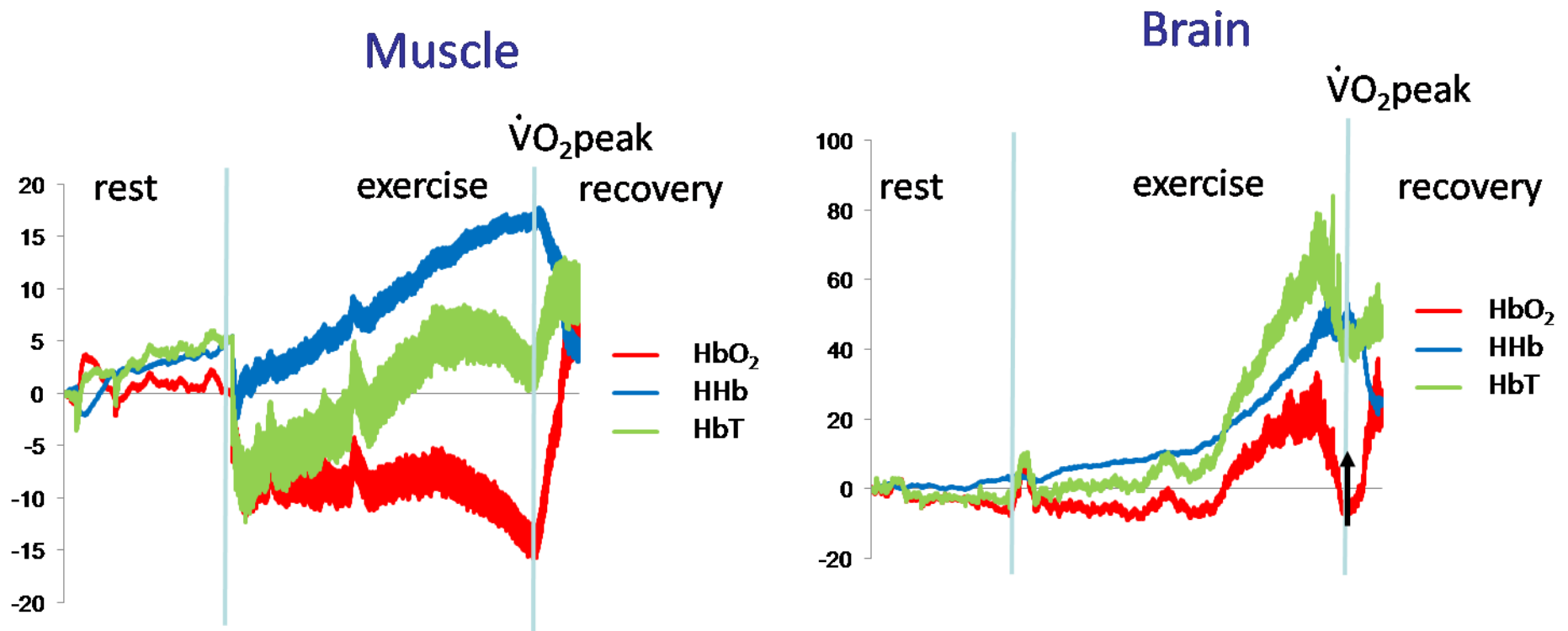
4000



Variations des paramètres du NIRS: HbO₂, HHb et Hbtot en fonction du temps chez les athlètes et chez les sédentaires à différentes altitudes simulées

La commande cérébrale

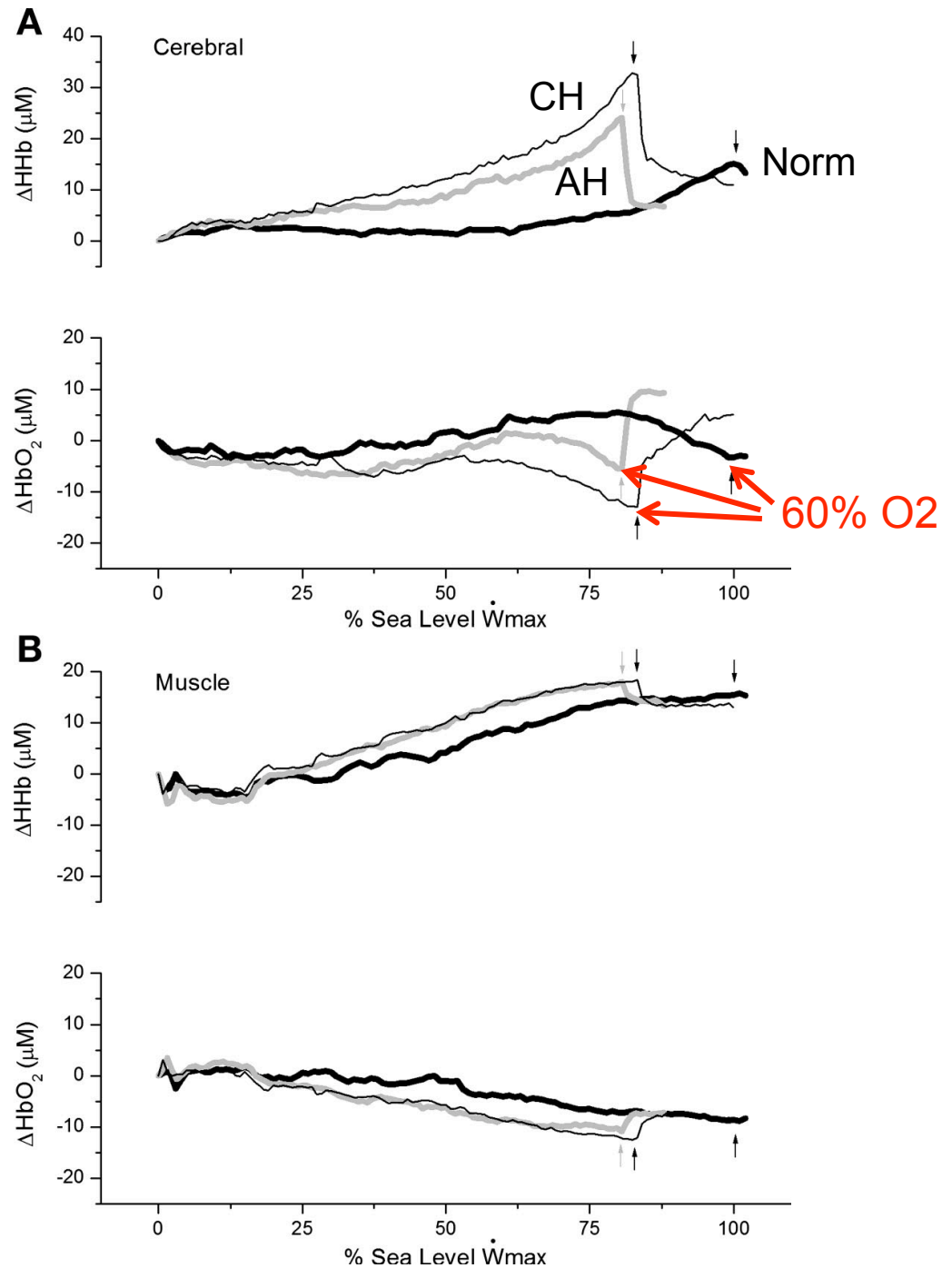
Acute hypoxia (3500m)



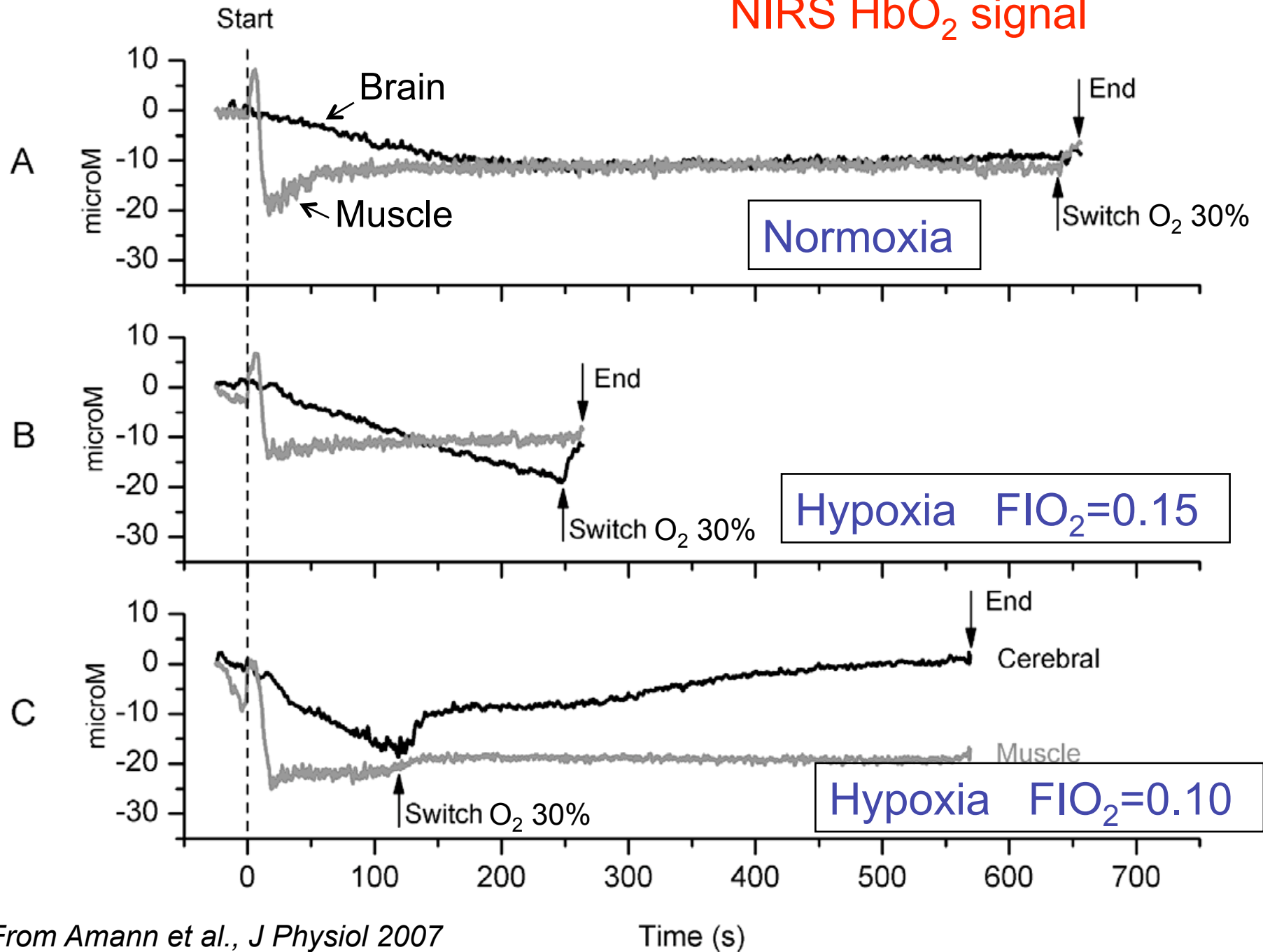
NIRS signals in a trained subject exercising at 3500m

« L'hypoxie cérébrale paraît imposer une limite à l'exercice maximal en hypoxie ($PIO_2=86$ Torr) puisque la restauration de la normoxie permet une augmentation de la performance... »

From: Subudhi et al., AJP, 2008



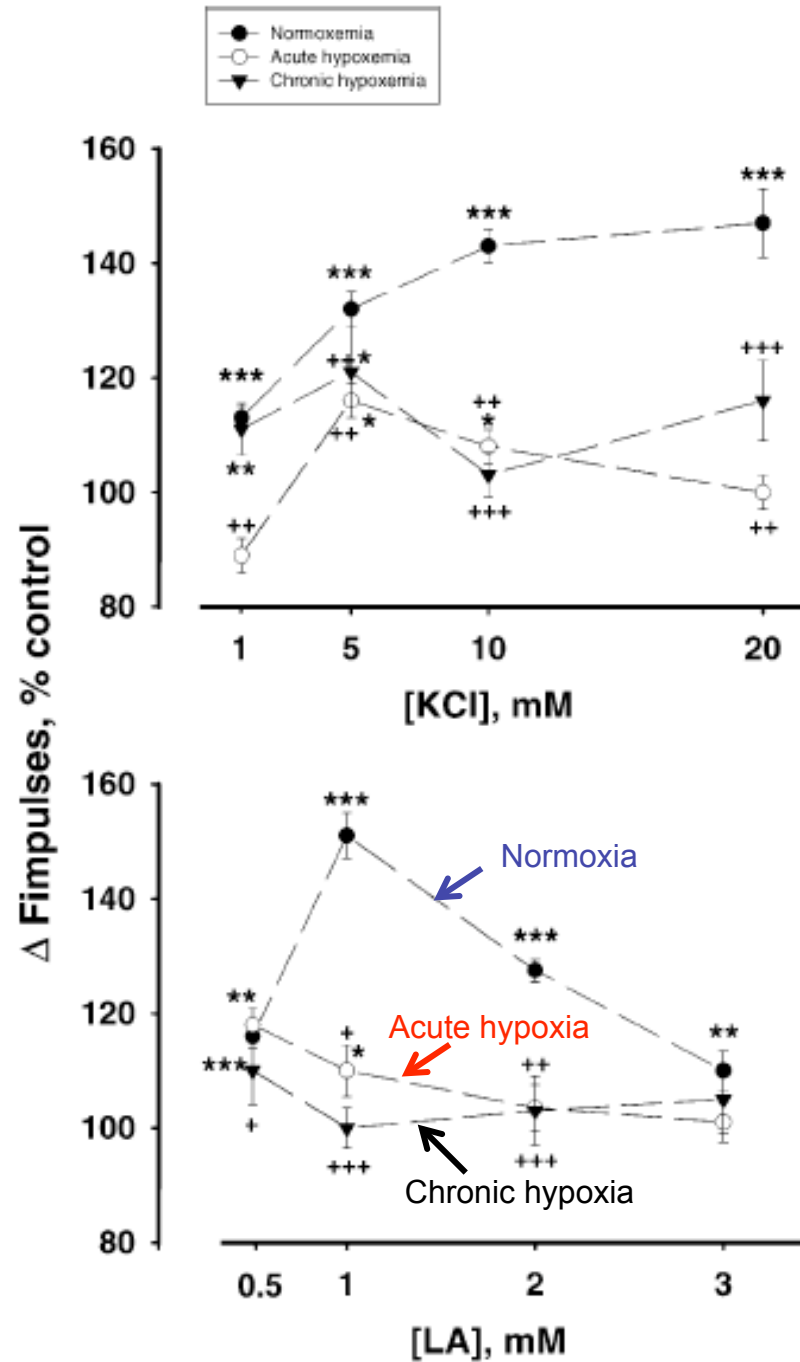
NIRS HbO₂ signal

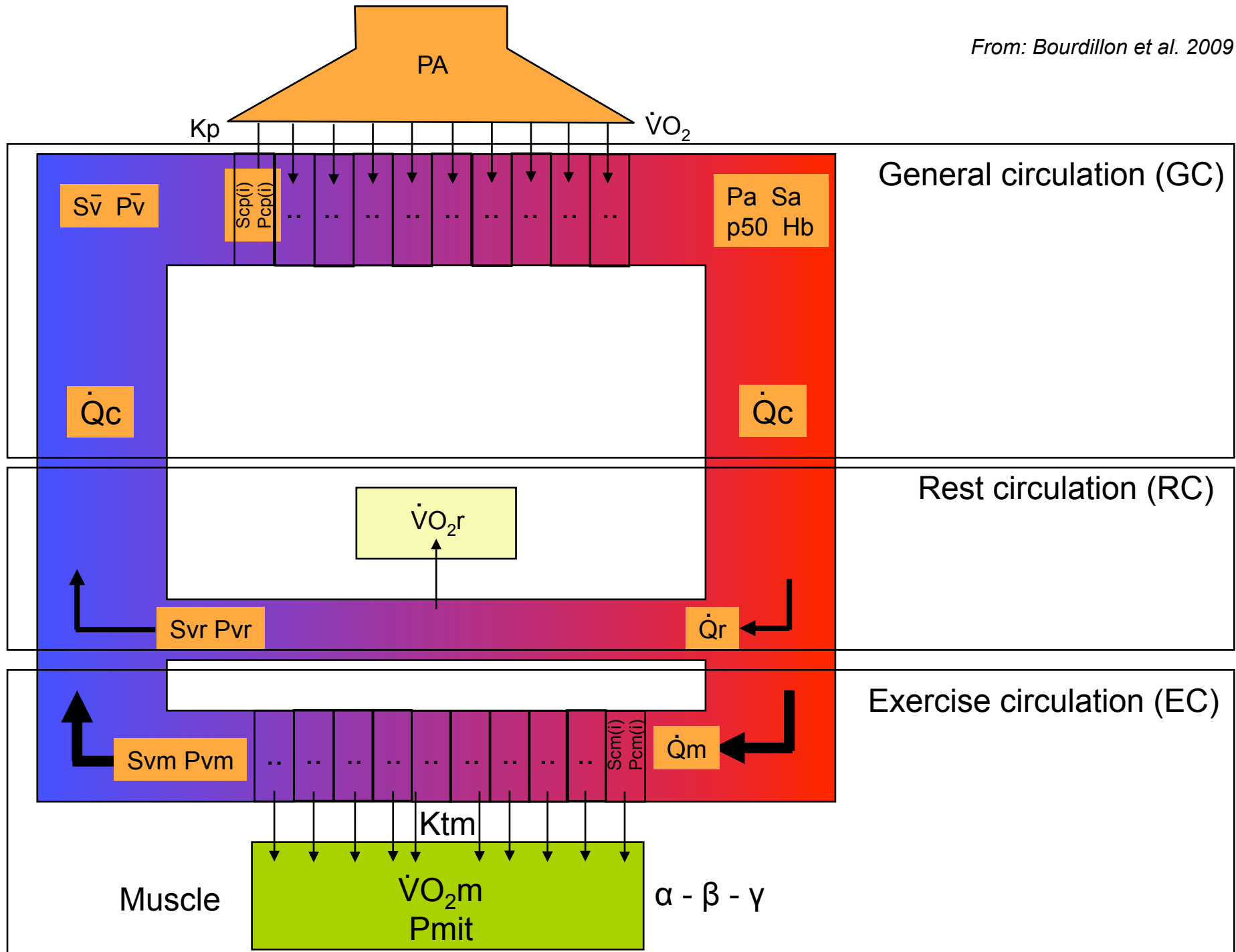


From Amann et al., J Physiol 2007

Rats, 1h (acute) and 45 days (chronic) exposure to $FIO_2=0.1$

Activity of type III/IV fibres in the Tibialis anterior

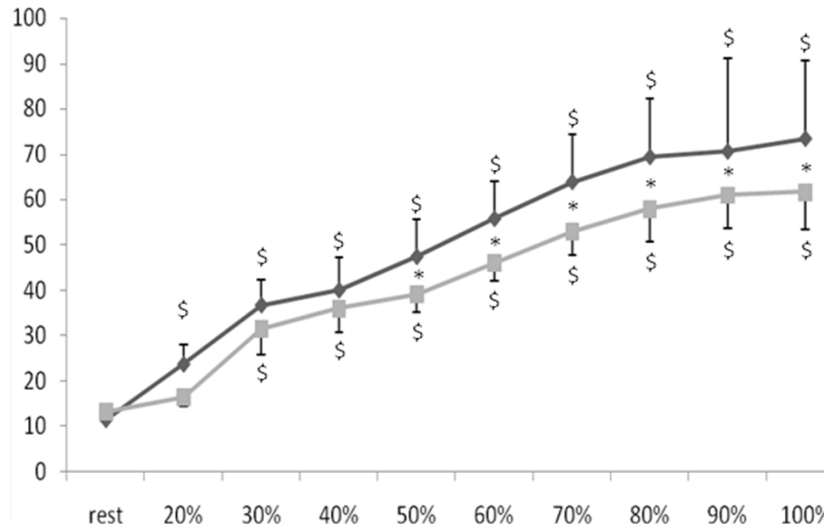




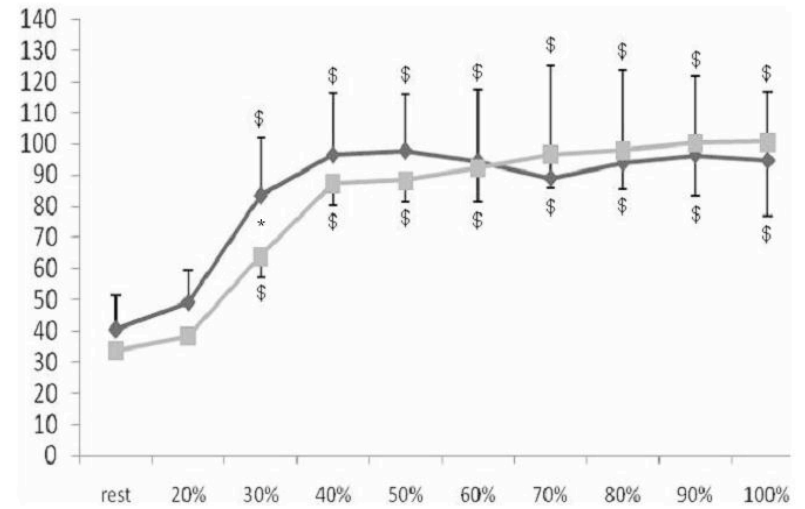
From: Bourdillon et al. 2009

normoxia

K_p
Pulmonary
diffusion
coefficient



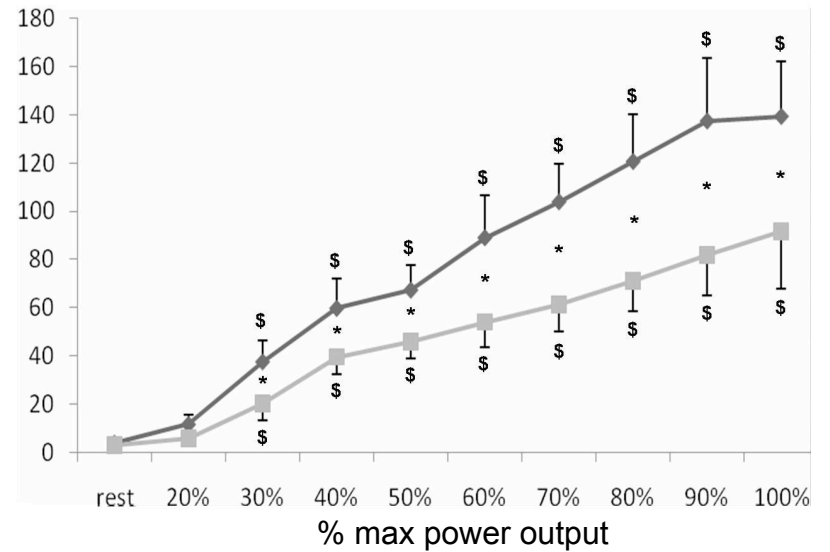
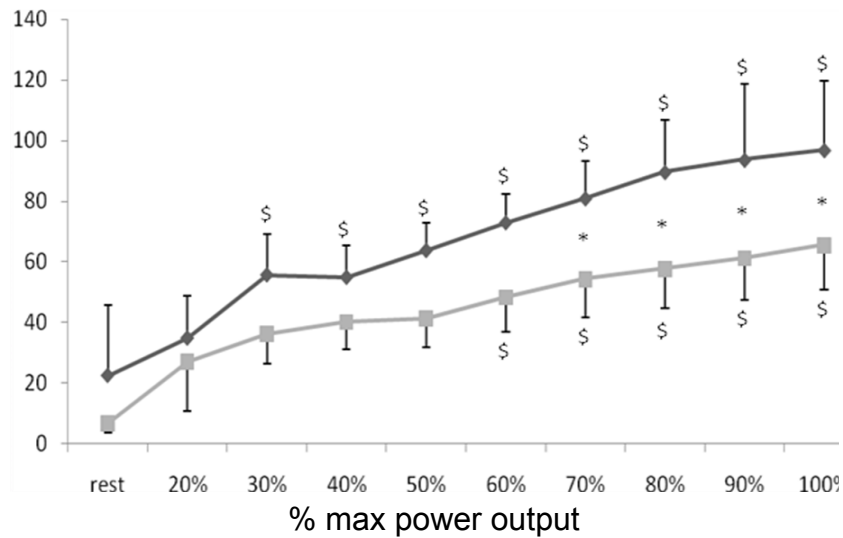
4000m

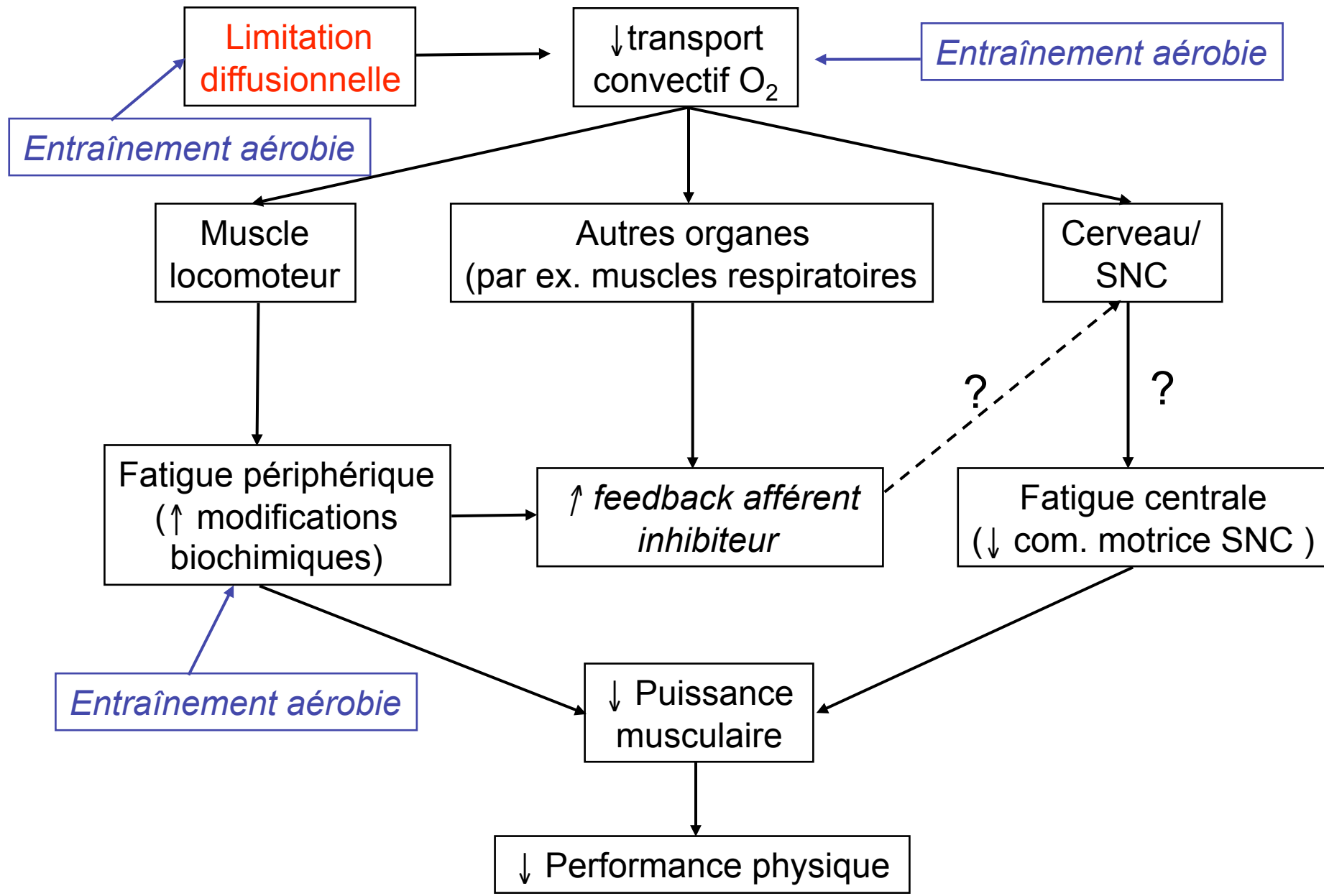


— Trained

— Untrained

K_t
Tissue
diffusion
coefficient







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