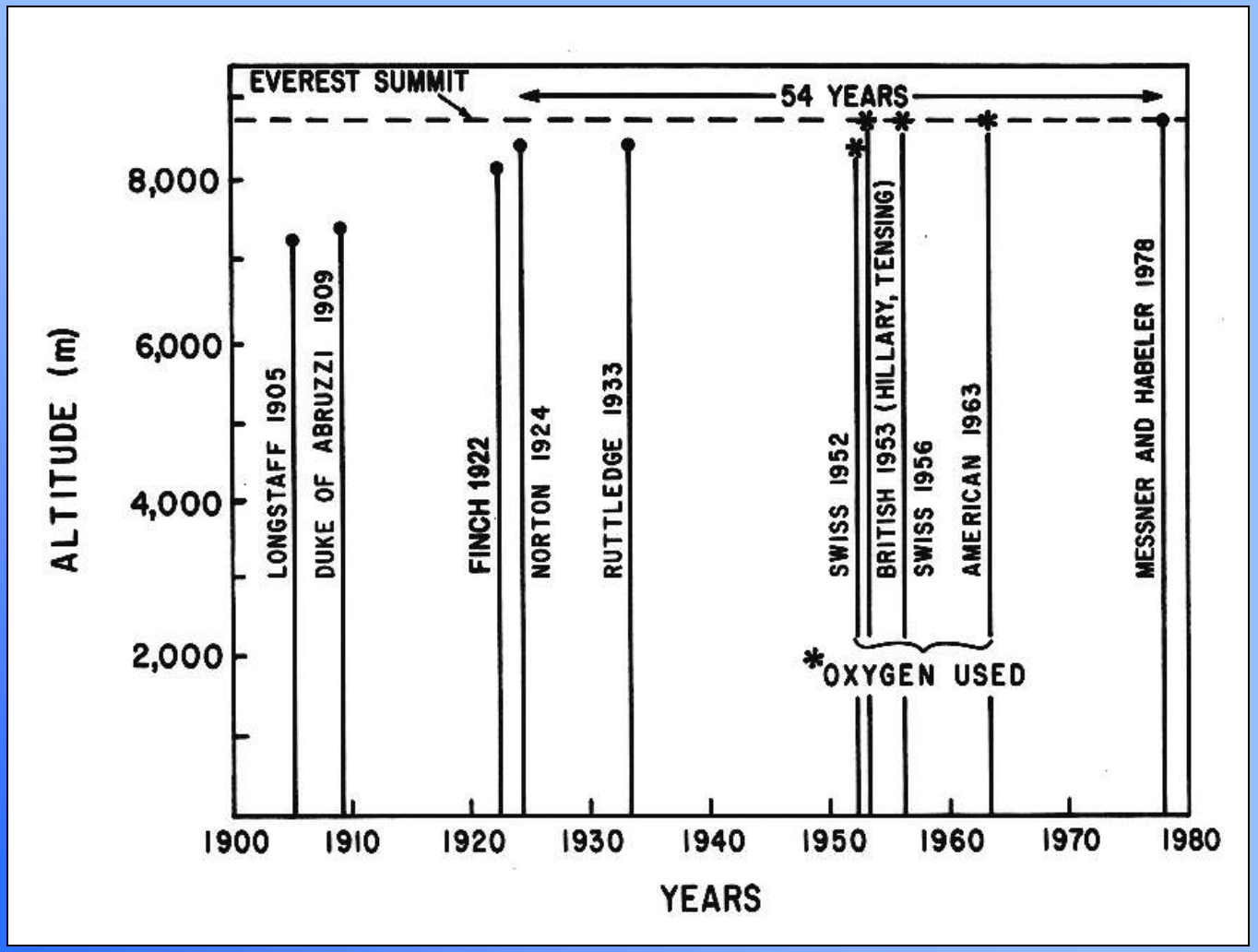
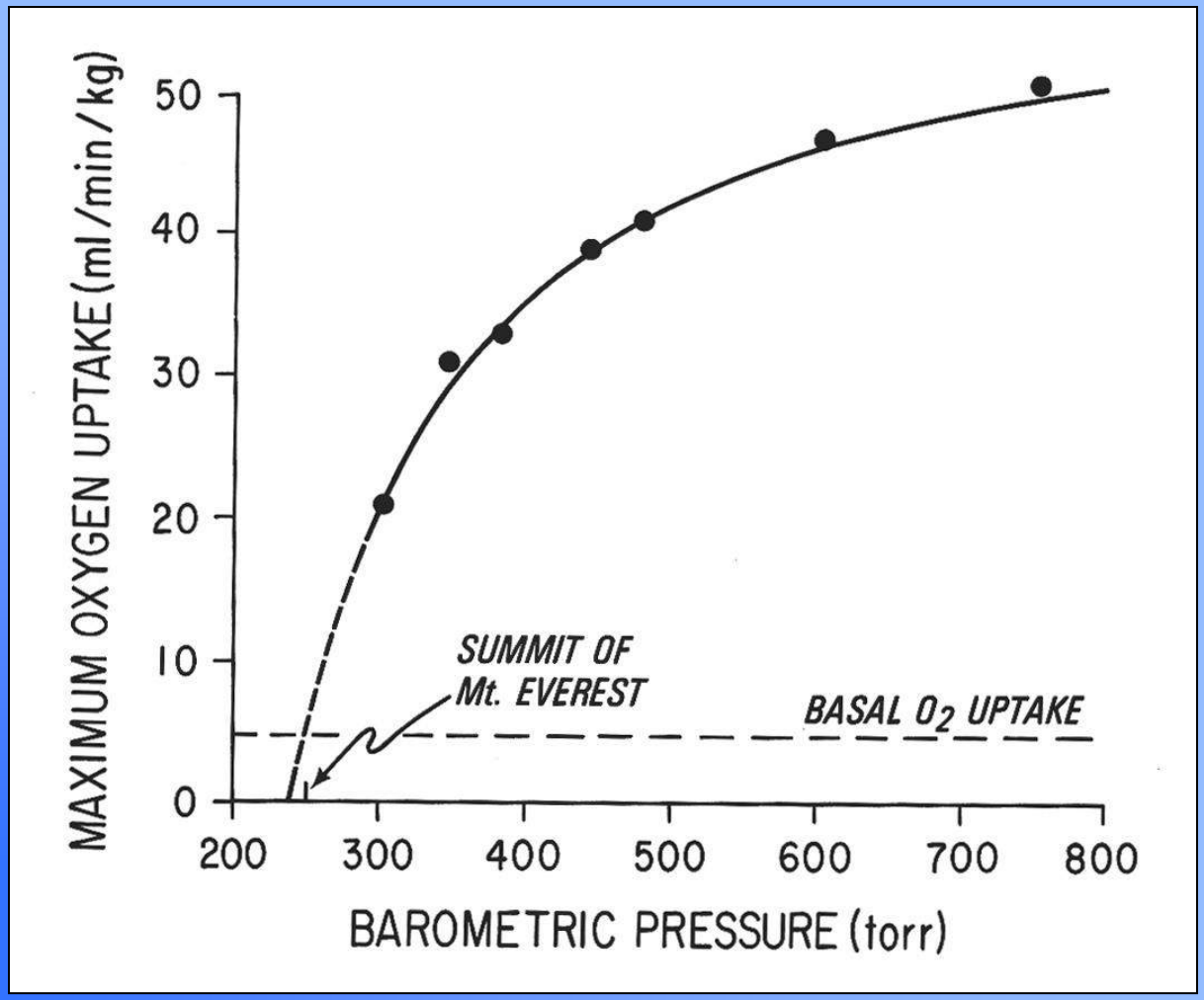
Lectures on respiratory physiology

Respiration at the limit: surviving on the summit of Mt Everest

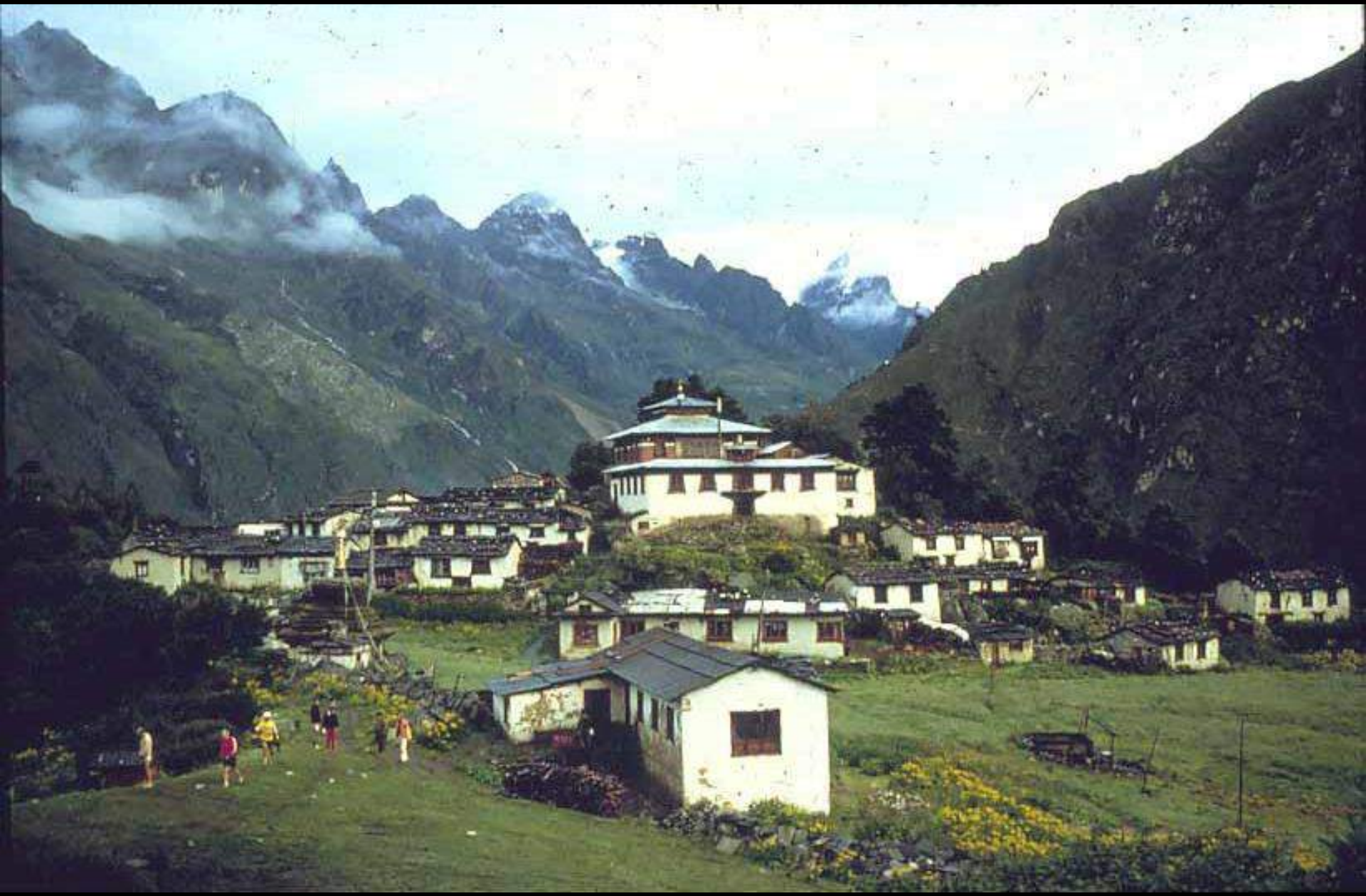
Highest altitudes attained in the last century

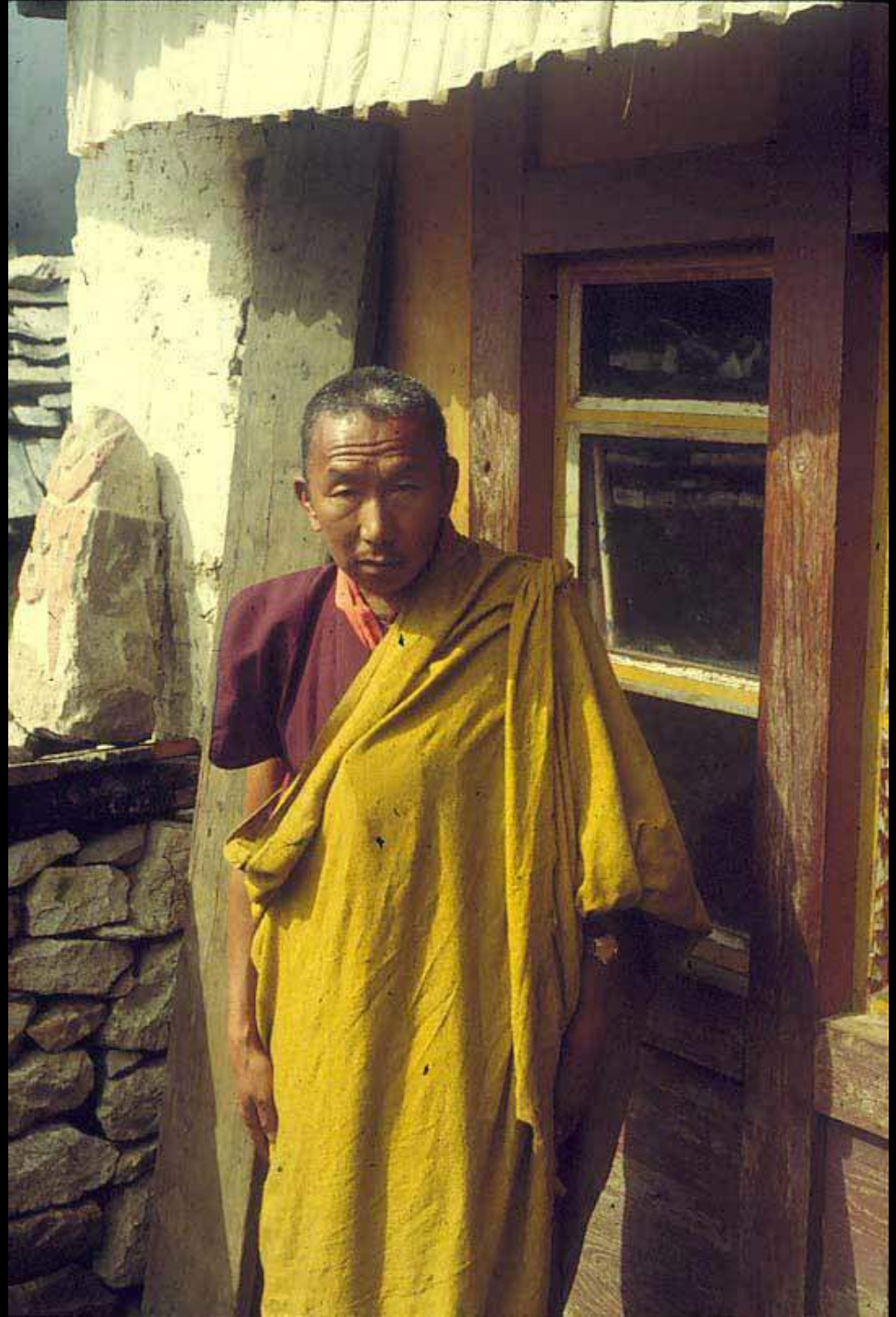


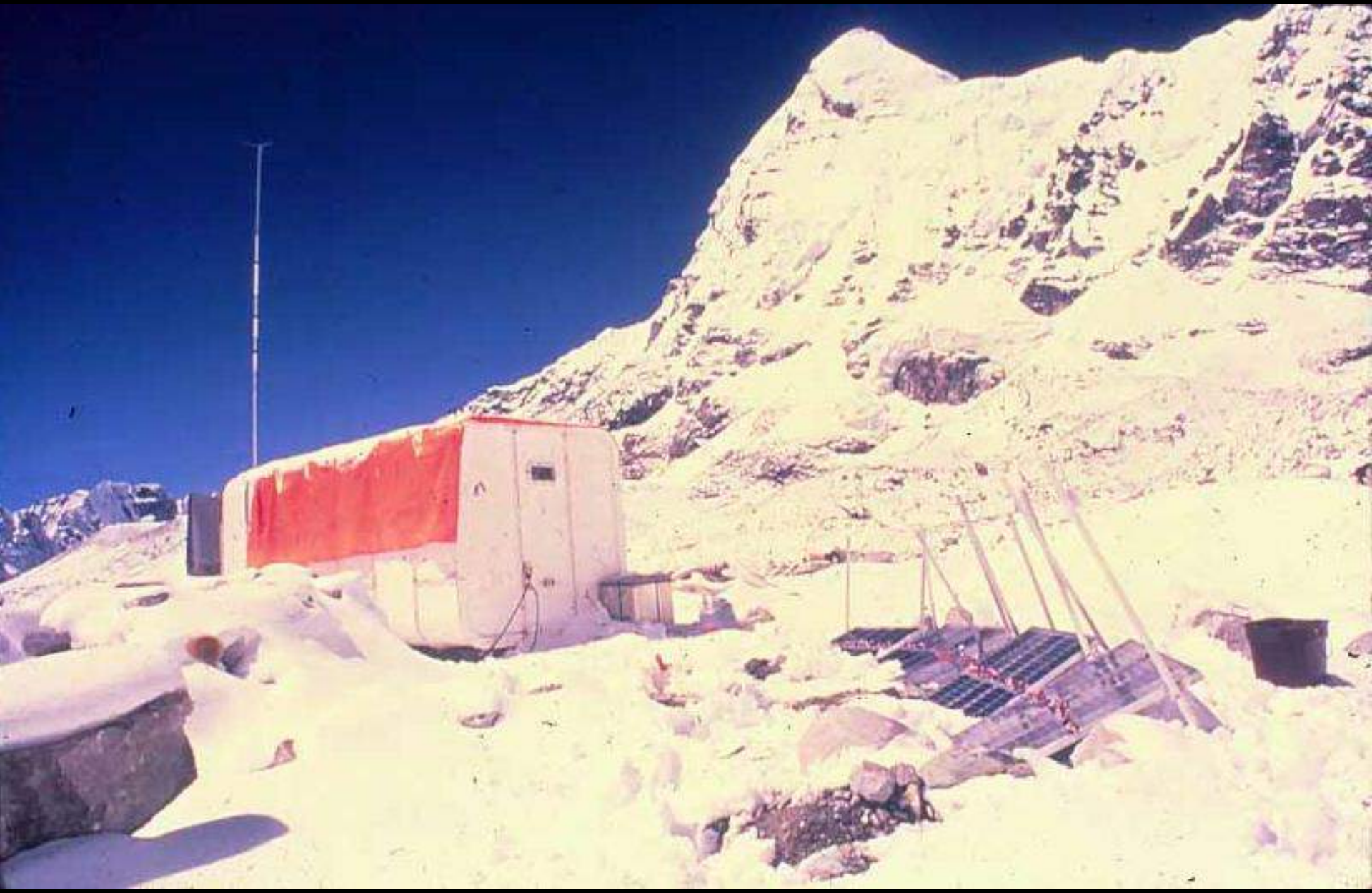
Maximum oxygen uptake at increasing altitudes

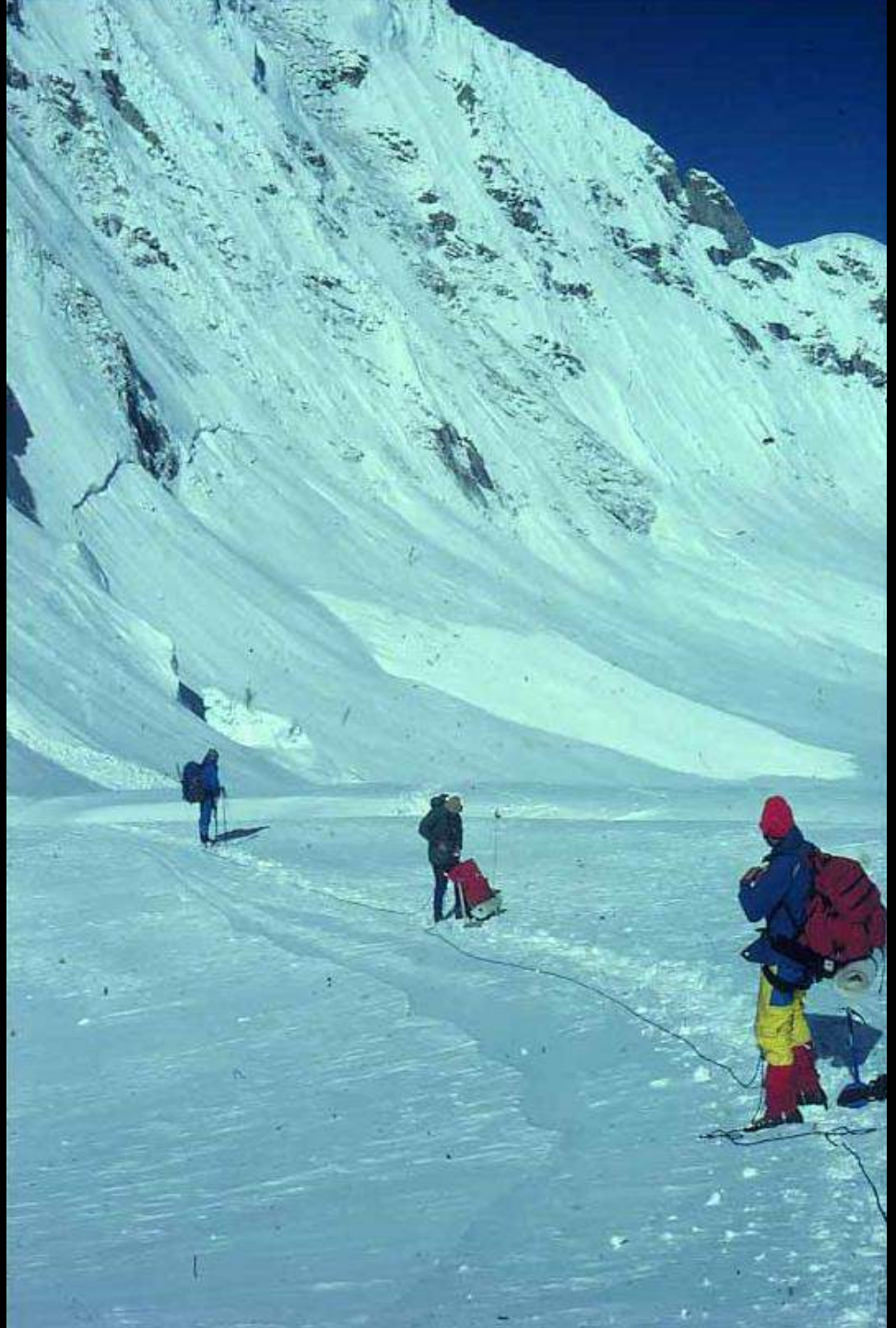


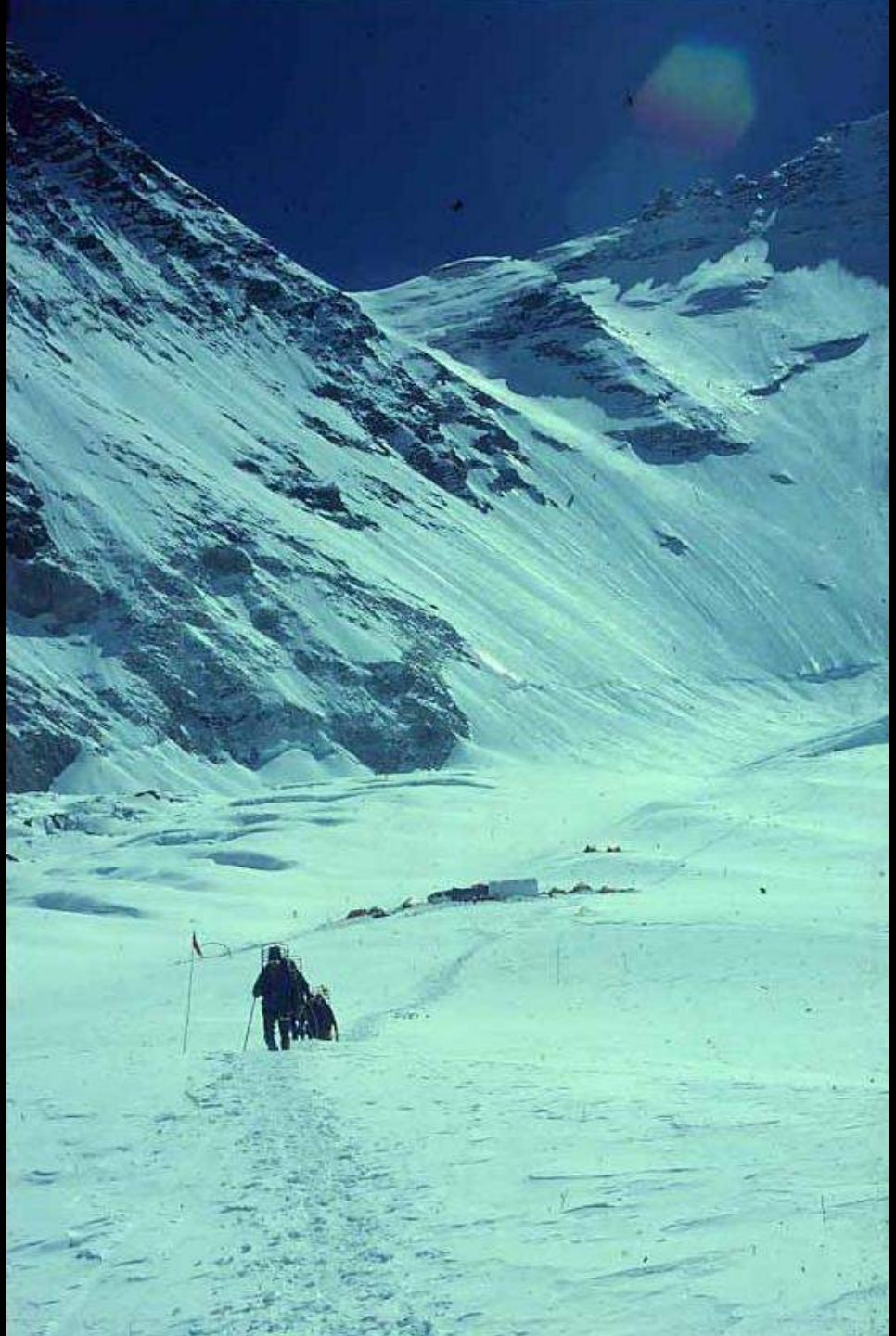

FGHANISTAN
O° N.
PAKISTAN
TIBET
Lhasa
Delhi
NEPAL
Katmandu
Everest
ASSAM
Karachi
Calcutta
BURMA
INDIA
Bombay
Arabian Sea
Madras
Bay of Bengal

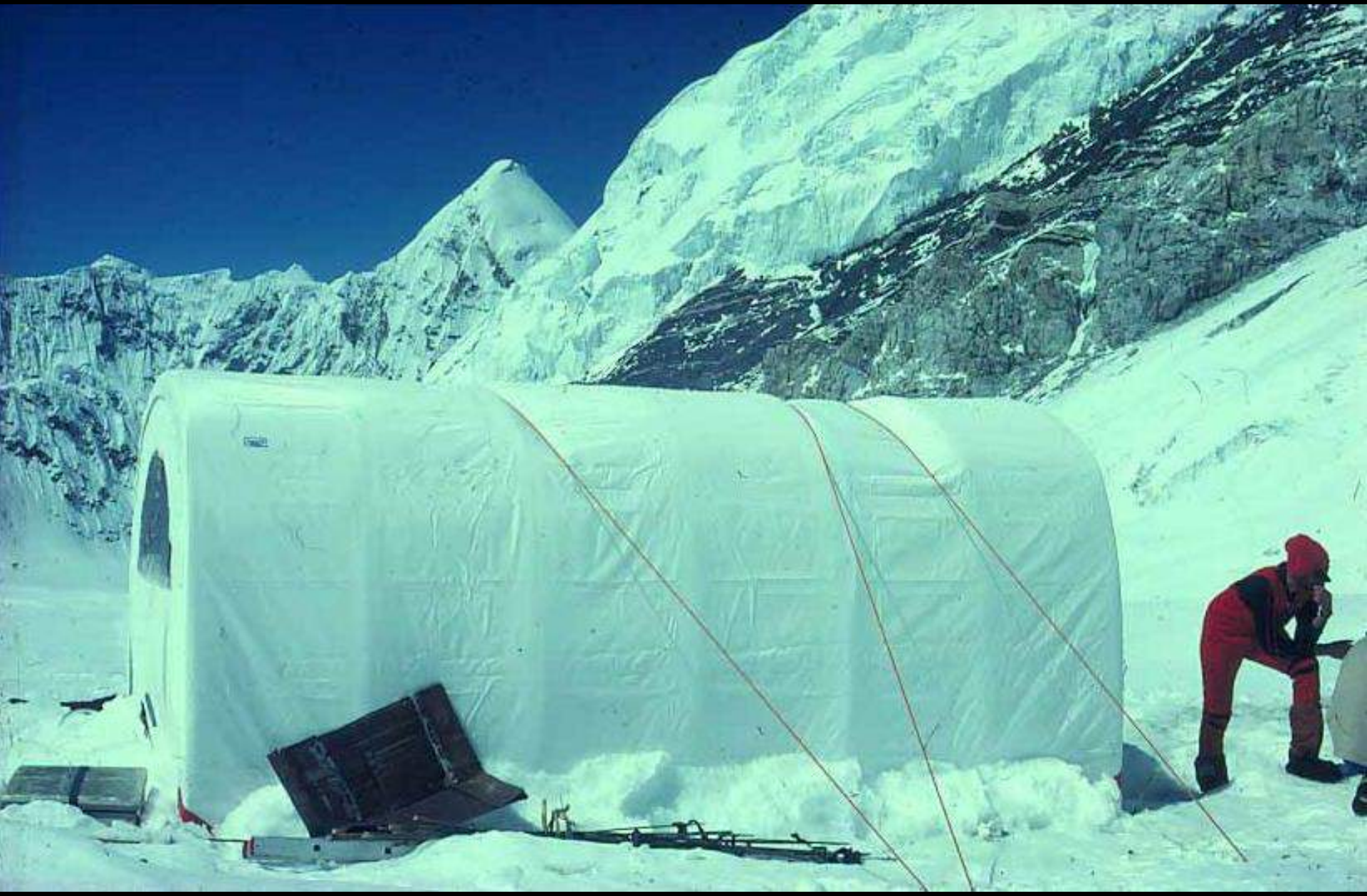




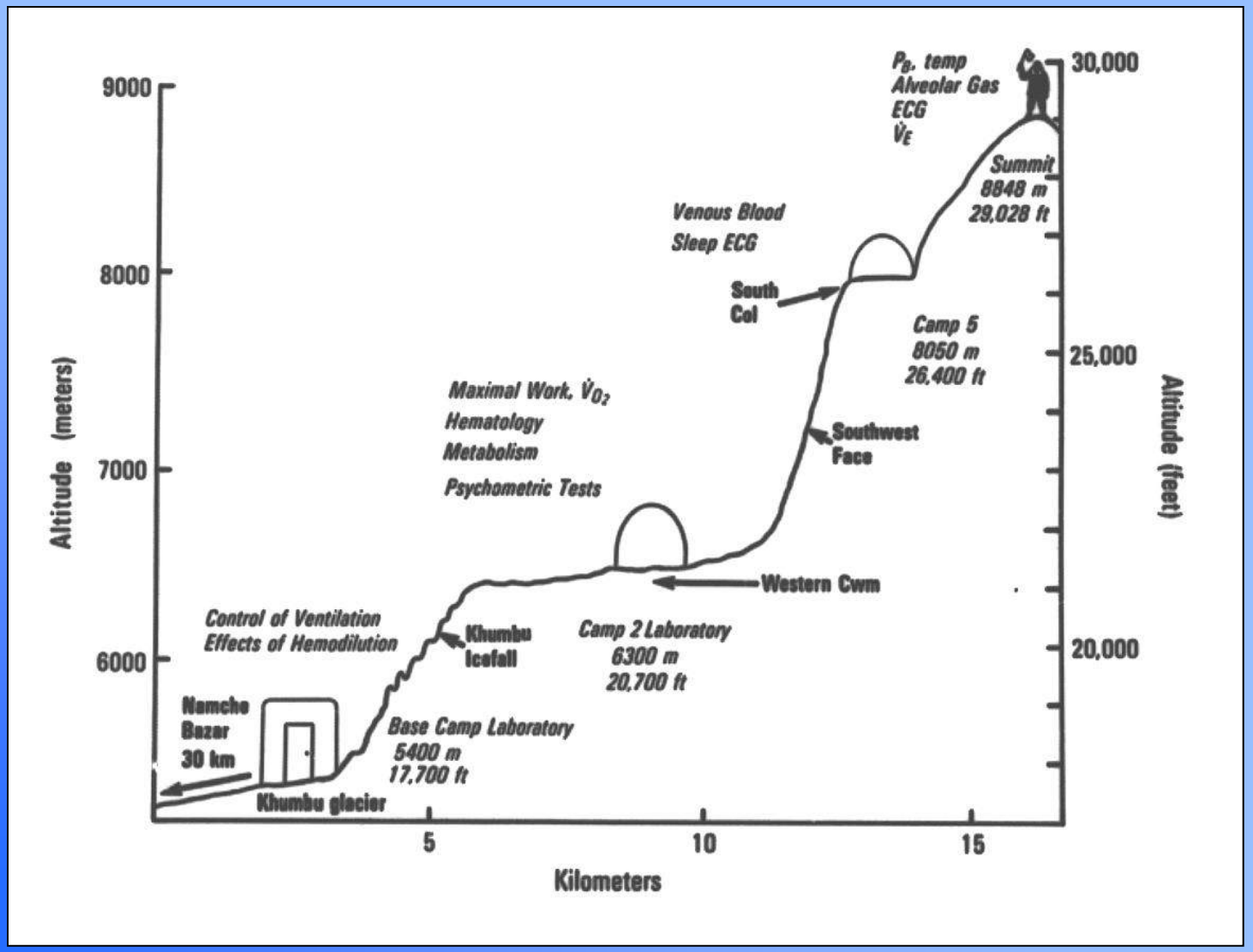




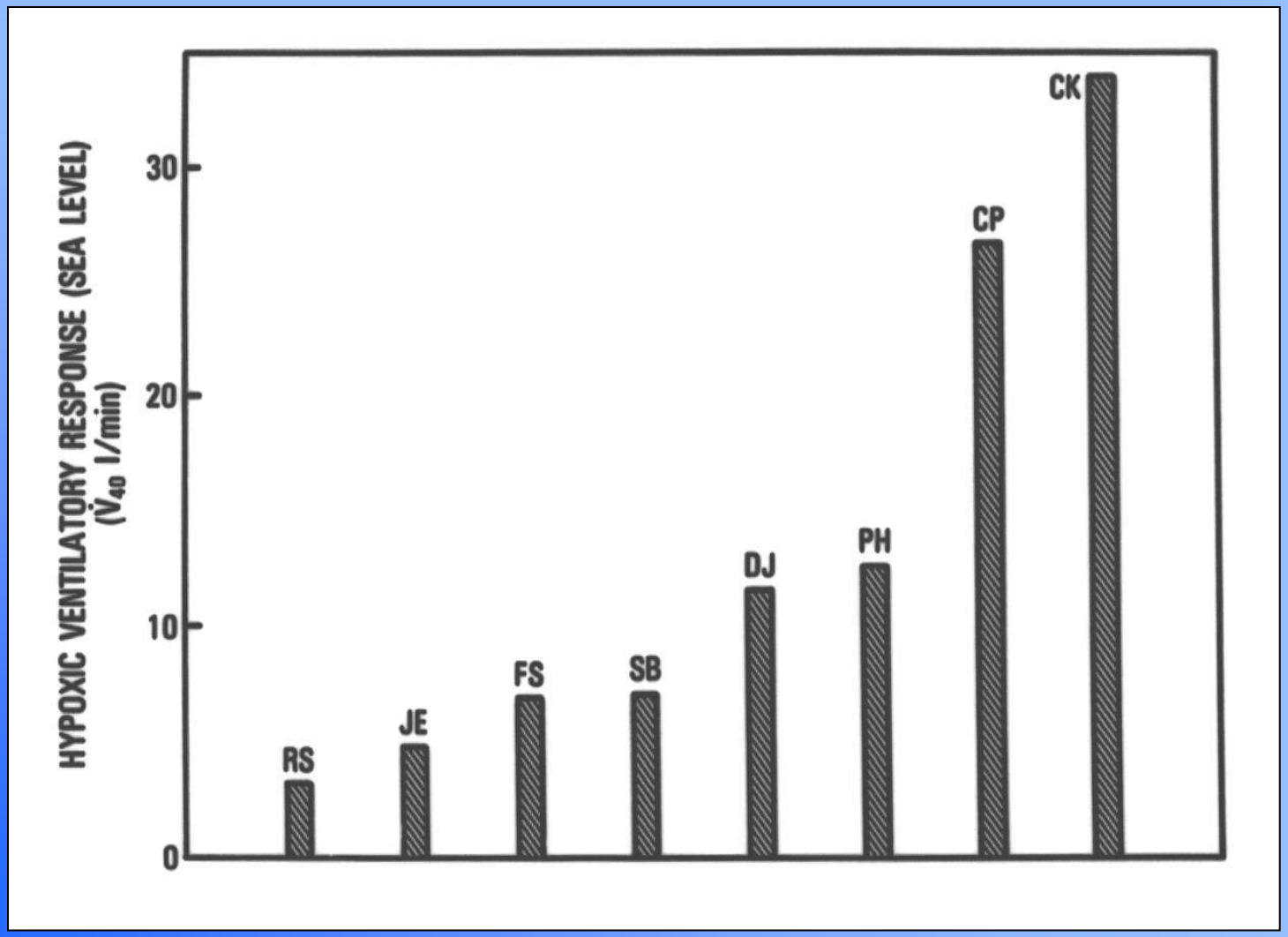




Sites where experiments were done



Climbers Ranked by their Hypoxic Ventilatory Response



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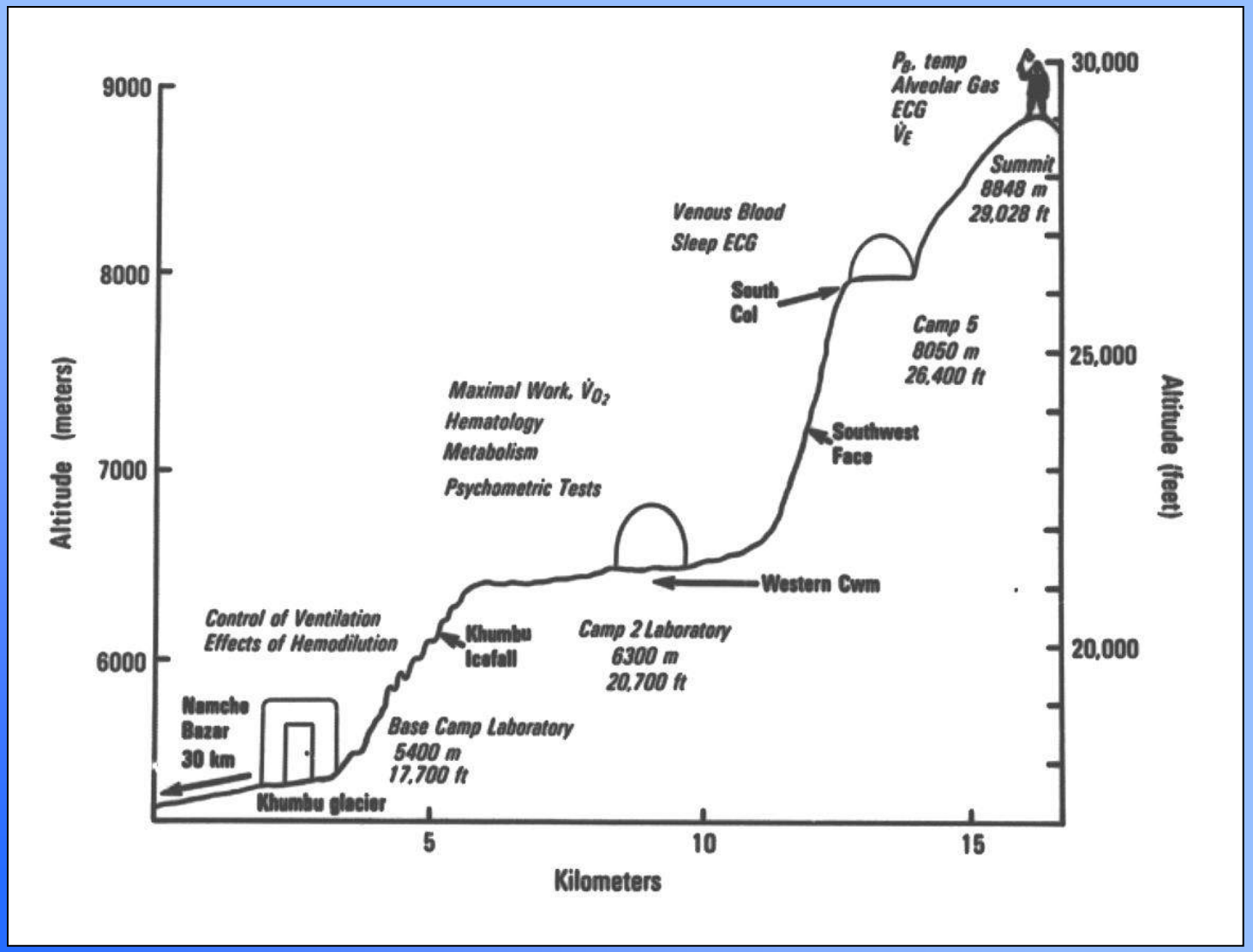
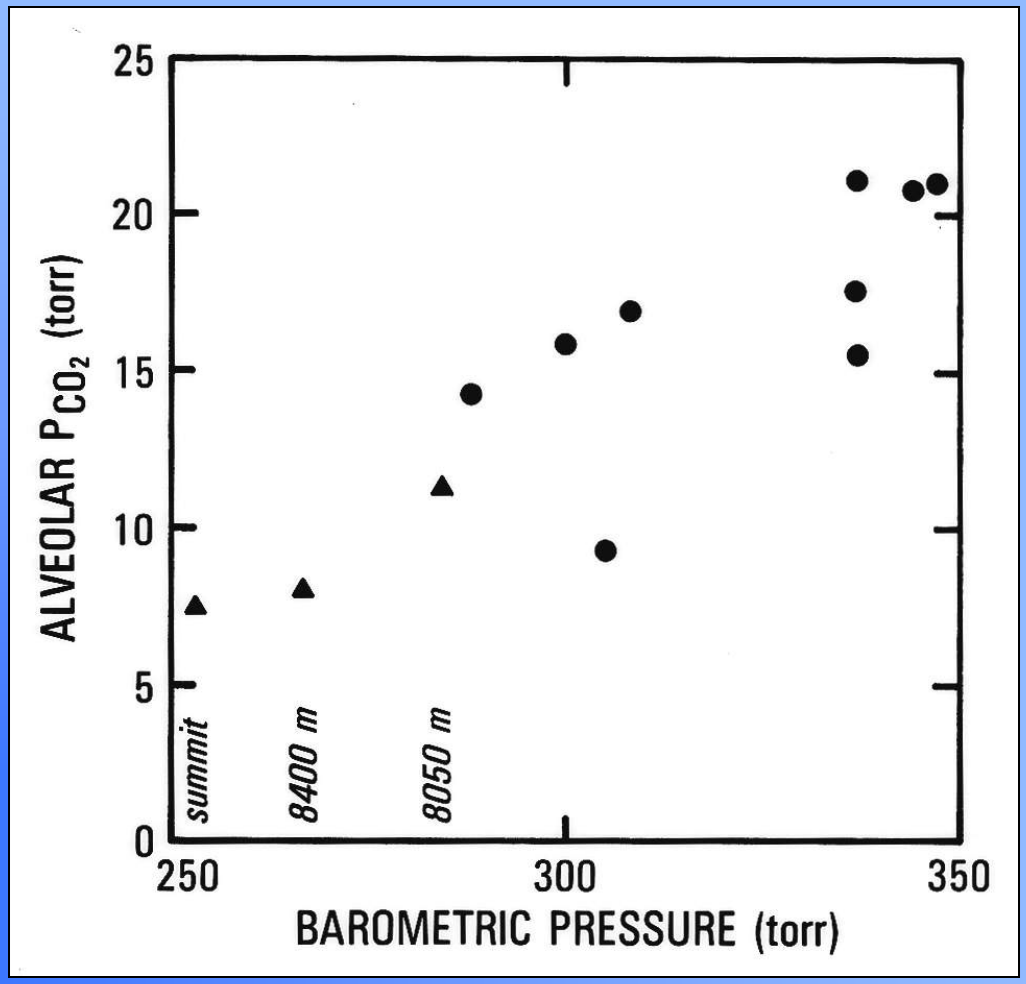
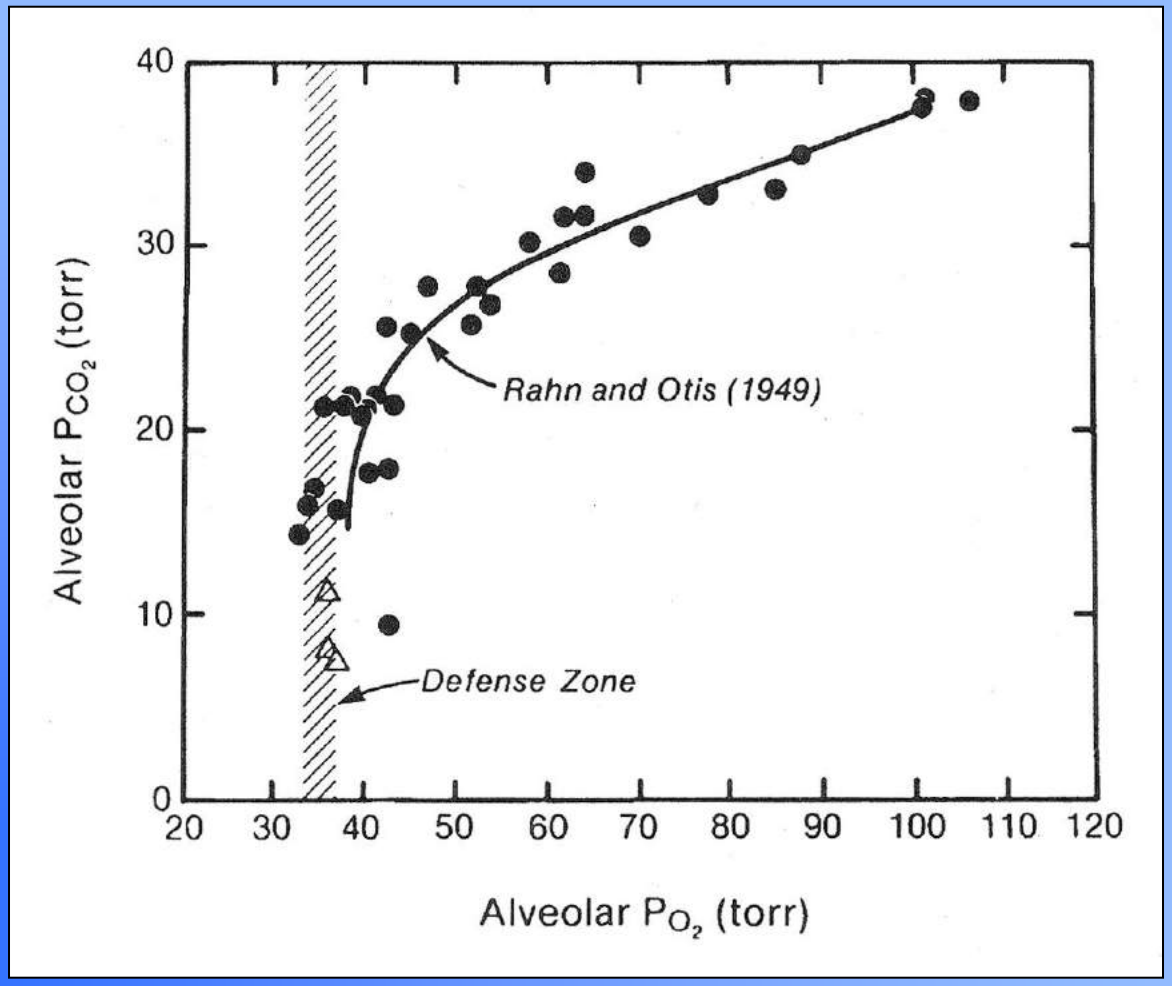


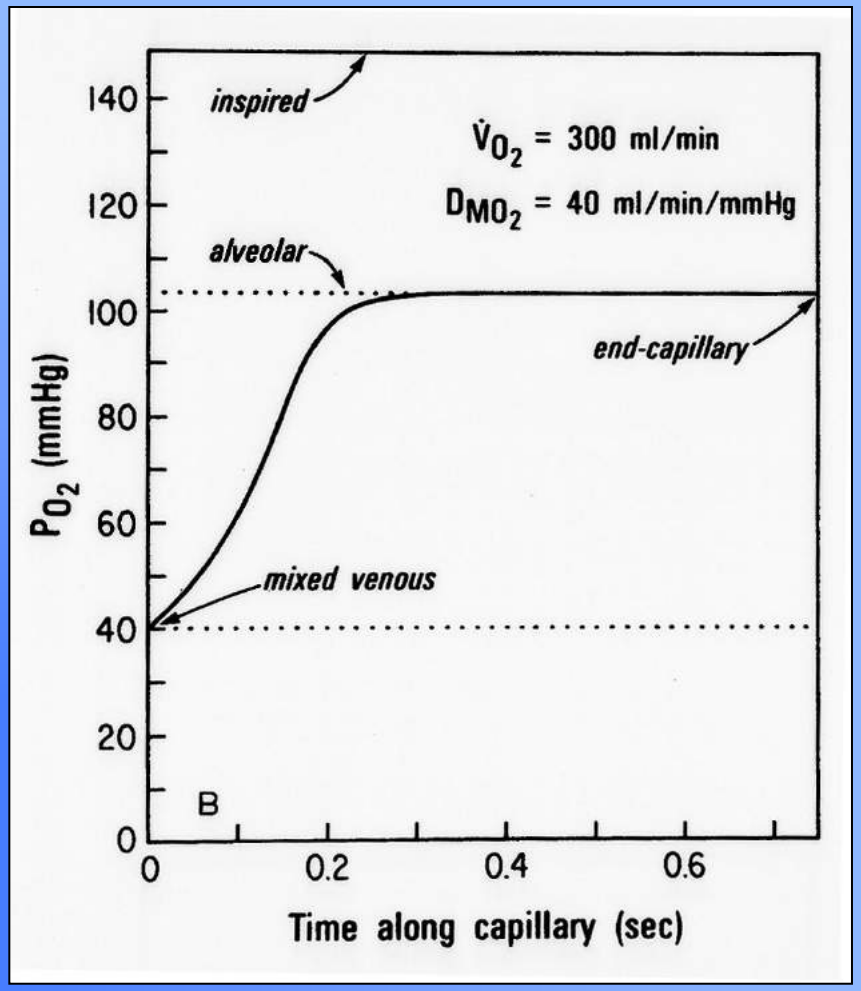
Alveolar Pco_2 at Extreme Altitudes



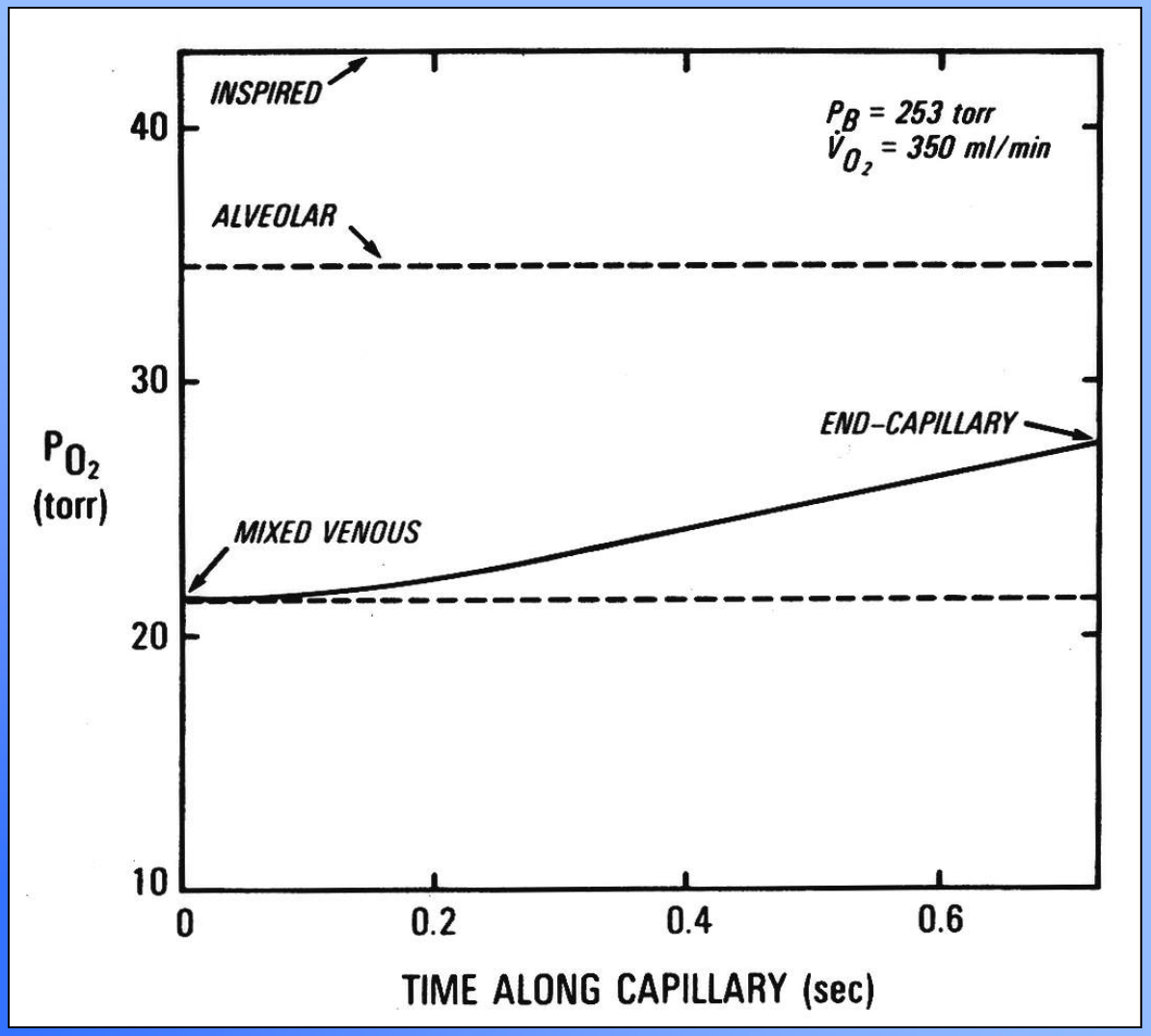
Alveolar Po_2 and Pco_2 at Extreme Altitudes



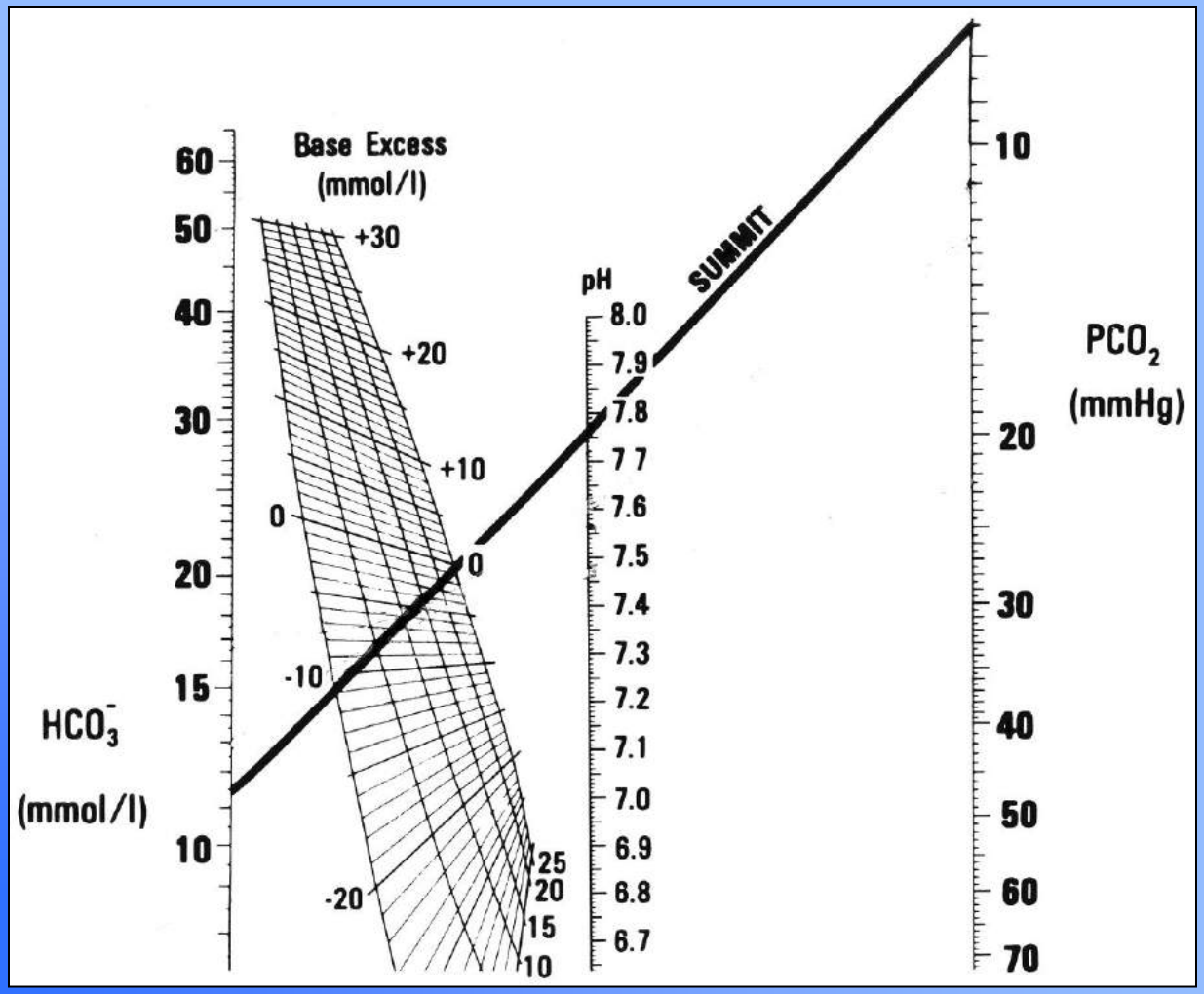
Changes in Po_2 along the pulmonary capillary at sea level



Changes of Po_2 along the pulmonary capillary on the Everest summit



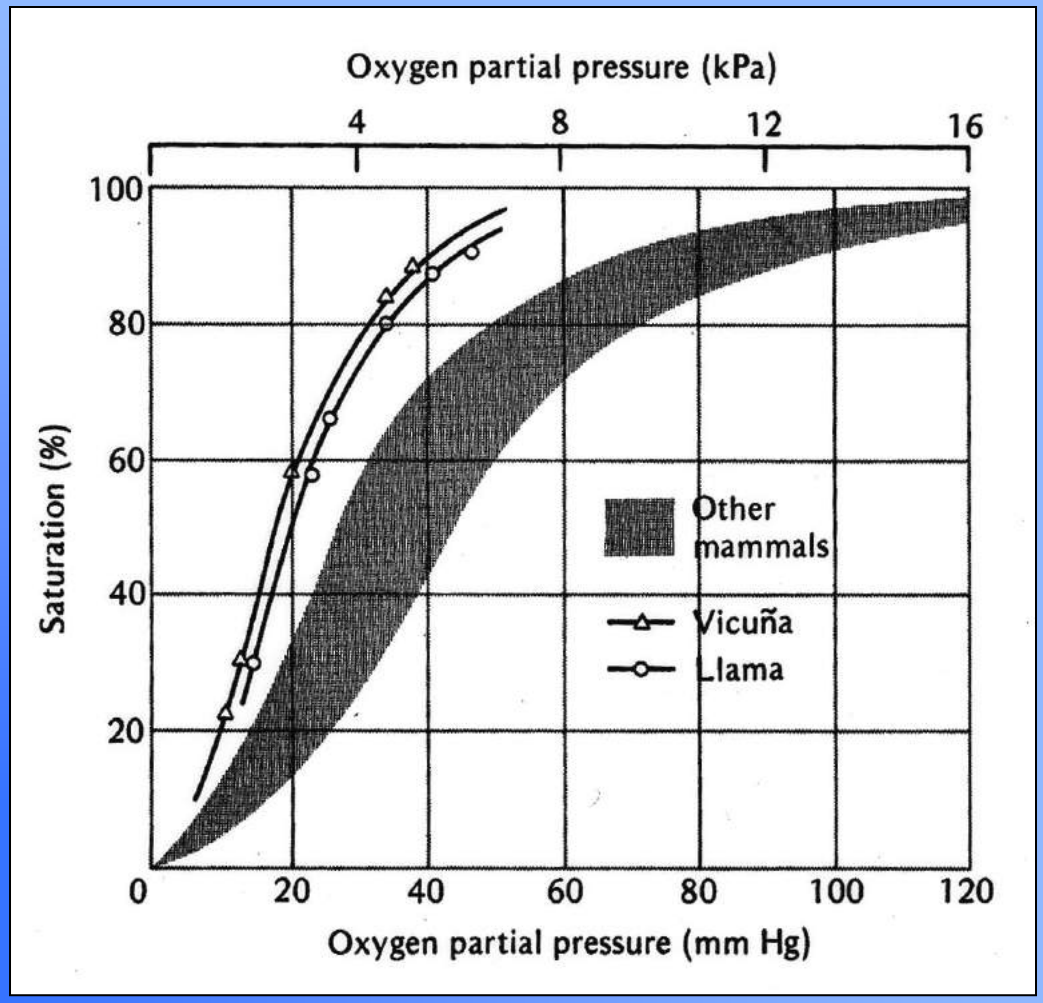
Determination of arterial pH on the Everest summit



Pulmonary Gas Exchange on the Everest Summit

ALTITUDE	BAROMETRIC PRESSURE	INSPIRED P_{O_2}	ALVEOLAR P_{O_2}	ARTERIAL P_{O_2}	ARTERIAL P_{CO_2}	ARTERIAL pH
meters	torr	torr	torr	torr	torr	
8848 (summit)	253	43	35	28	7.5	>7.7
sea level	760	149	100	95	40	7.40

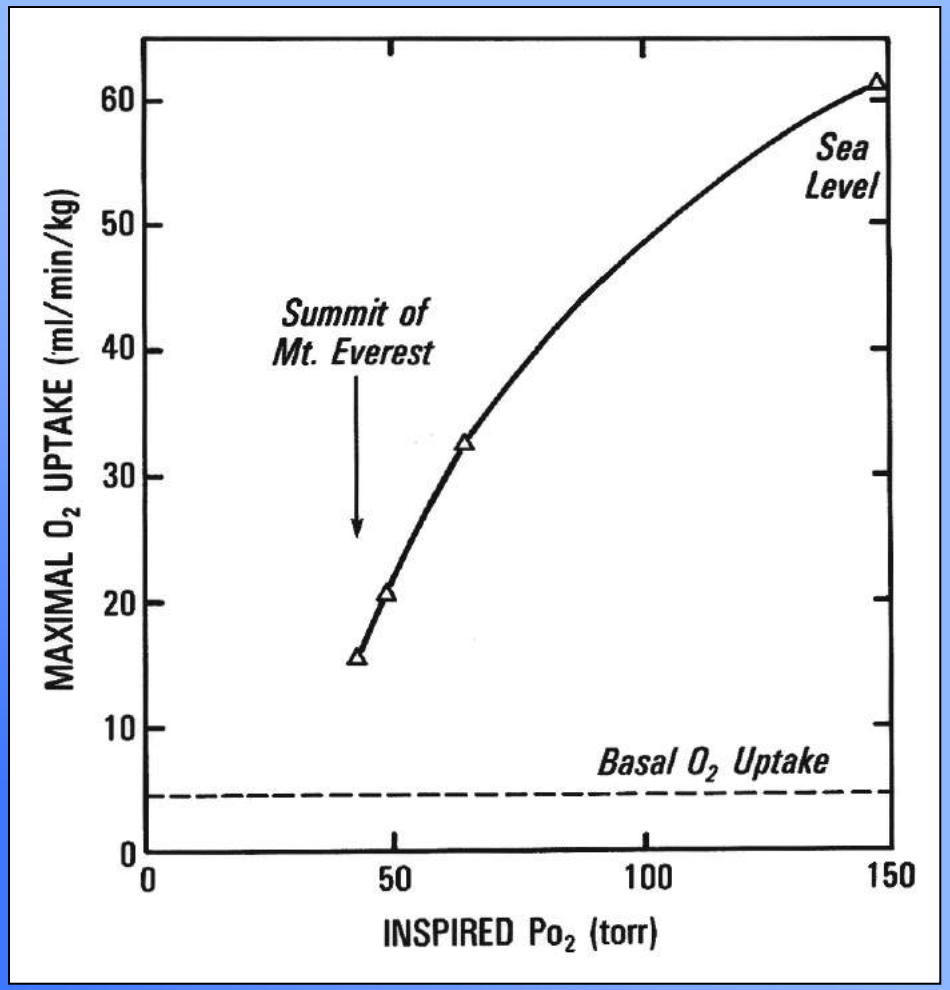
O_2 Dissociation Curves in High-Altitude Mammals

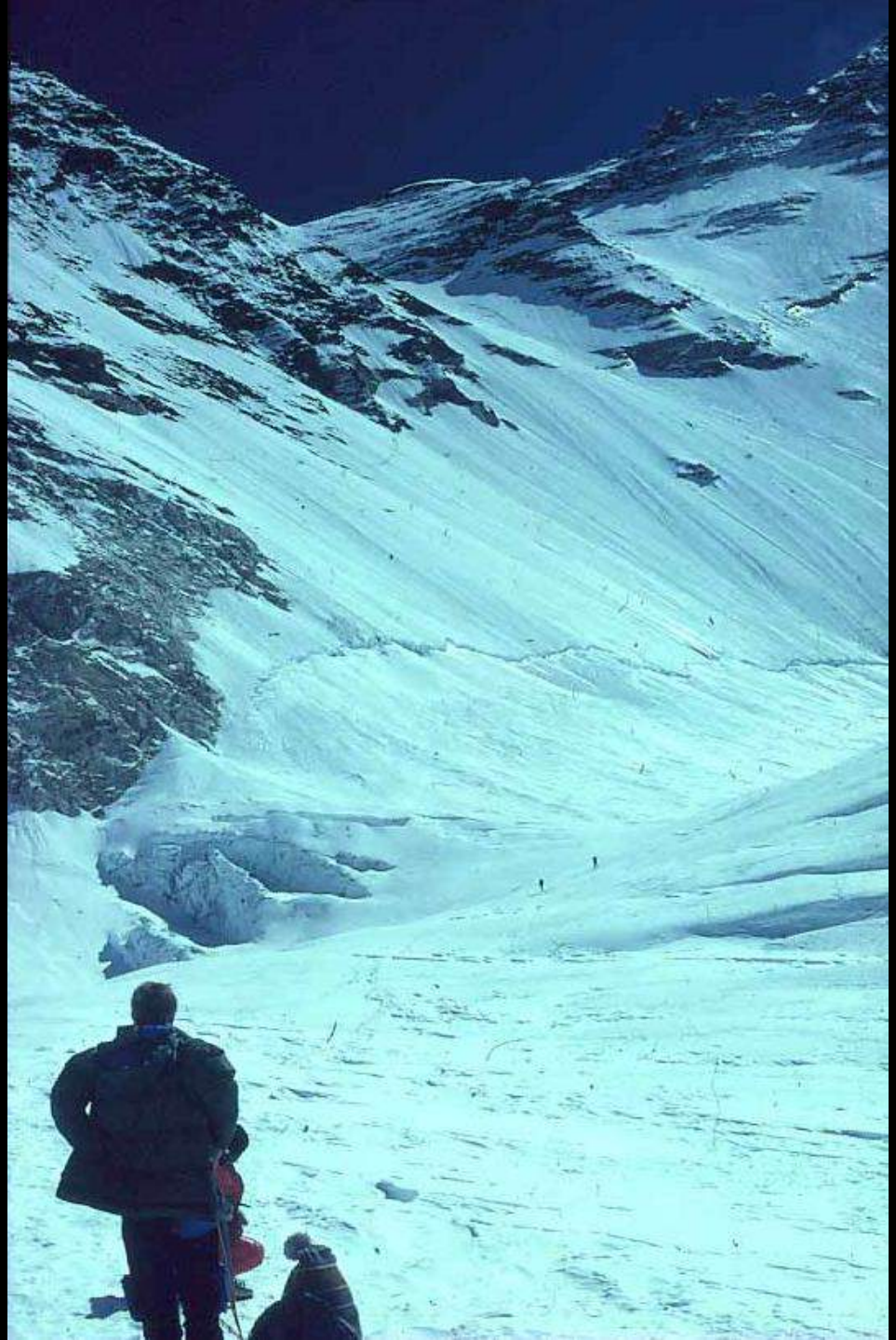


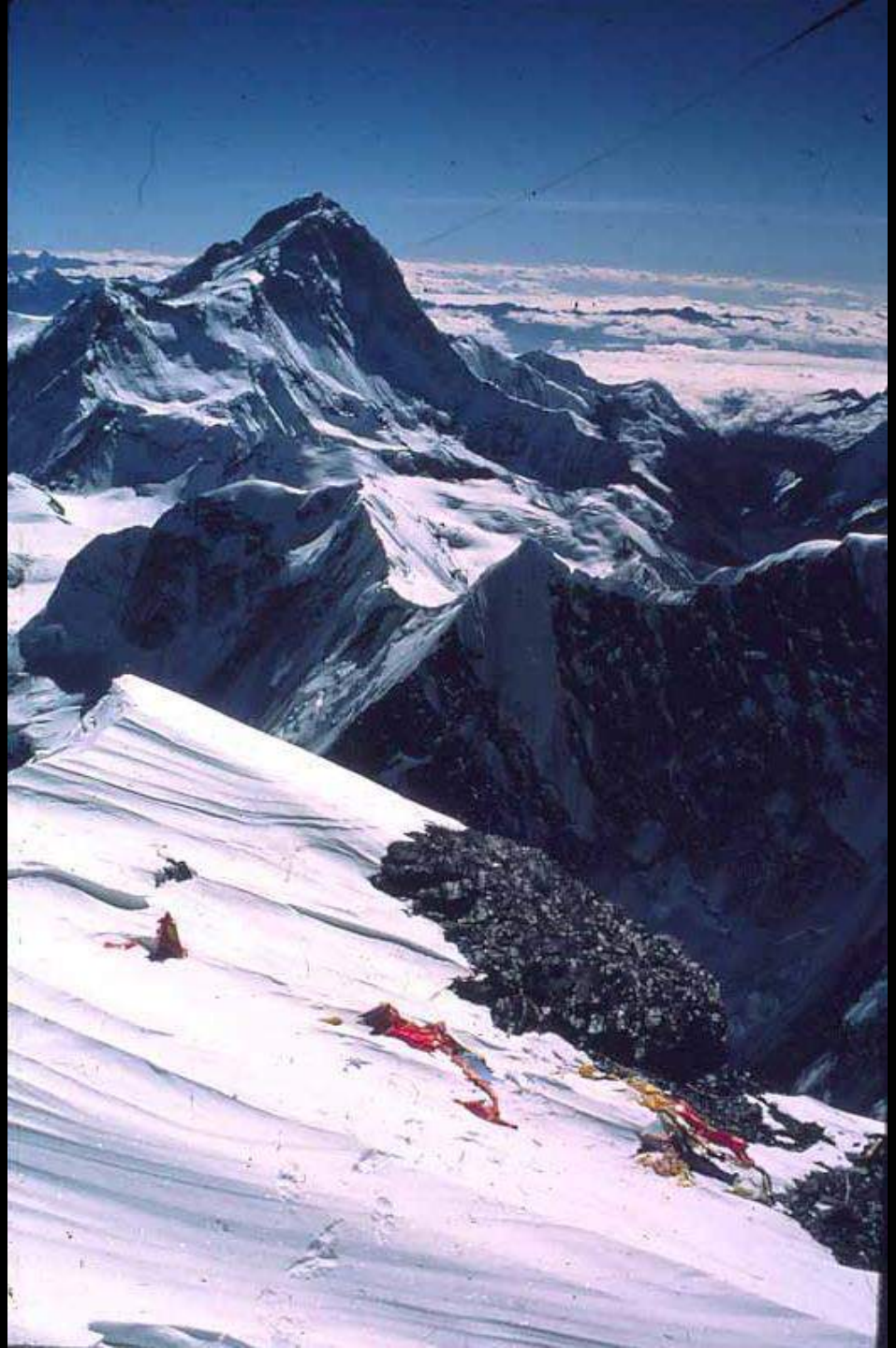
Strategies for increasing the oxygen affinity of hemoglobin in hypoxia

Strategy	Subject/Animal
Different sequence in headed globin chain	Human fetus, bar-goose, toad-fish
Decrease in 2,3 DPG	Fetus of dog, horse, pig
Decrease in ATP	Trout, eel
Different Hb, small Bohr effect	Tadpole
Mutant Hb (Andrew - Minneapolis)	Family in Minnesota
Respiratory alkalosis	Climber at extreme altitude

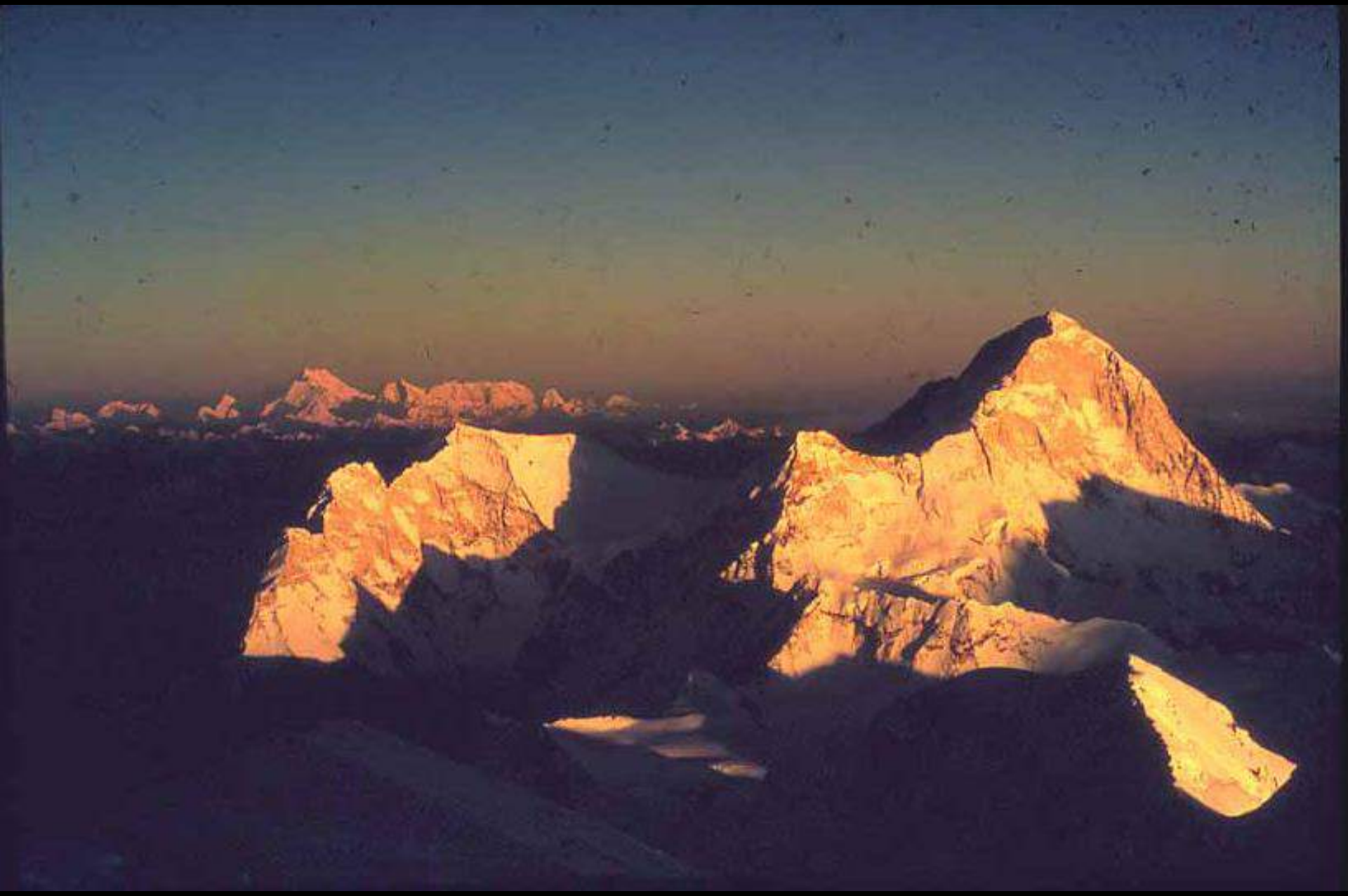
Maximal O_2 Uptake on the Everest Summit







Chris Pizzo, M.D. sitting on the summit of Mt. Everest collecting alveolar gas samples



Conclusions

1) Climbers on the summit of Mt. Everest are very close to the limit of survival because of the severe hypoxia
2) Barometric pressure on the summit is about 253 mmHg, that is 1/3 of the sea level value
3) The most important feature of acclimatization is extreme hyperventilation
4) The hyperventilation maintains the alveolar Po_2 at about 35 mmHg
5) The arterial Po_2 is about 30 mmHg and is lower than the alveolar value because of diffusion limitation across the blood-gas barrier

Conclusions

6) The alveolar Pco_2 is reduced to 7-8 mmHg (normal value 40 mmHg
7) The very low Pco_2 causes an extreme respiratory alkalosis with an arterial pH >7.7
8) This alkalosis increases the oxygen affinity of hemoglobin which assists oxygen uptake in the pulmonary capillary
9) Maximal oxygen uptake on the summit is only about 1 $l.min^{-1}$, equivalent to walking slowly on the level but just sufficient to explain how a climber can reach the summit