



"Into Thin Air"

A Case Study in Physiology

by

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Part I - Mt. Denali, Alaska, 17,660 Feet

The winded climbers slowly ascended the icy cliff in the near darkness of 4 a.m., carefully avoiding the steep crevasses that fell off sharply to either side. Several times each hour, Tom Benman, lead climber and expedition frontman, would call out "Everyone okay?" They had stopped replying long ago, too exhausted by the supreme effort of simply placing each foot in the proper direction. Three hours into a 12+ hour climbing day, the silence was permeated only by labored breathing and the crunch of ice under crampons.

Emily Norman, a Registered Nurse and the only woman on the six-person expedition team, was third in line, following her friend Mark McKinley, the least experienced climber of the group. For the last couple of days, Mark had been coughing heavily, and all morning had been slowing up, causing a backlog behind them and prompting several "everyone okay"s from Tom. Knowing Mark's competitive spirit, Emily was hesitant to urge him to pick up the pace, and when he pulled up to rest on a protected ledge, Emily motioned to the other climbers to pass on by. Her head was pounding anyway, and she rationalized she could use the break.

"You okay?" Emily asked.

"Yeah....I just....can't seem to....catch my breath," gasped Mark.

"Just rest a minute. There's no rush, Mark. Take your time....slow, deep breaths."

Tom appeared from the upper trail. "What's up?"

"Mark's having a little trouble catching his breath." Emily was getting worried.

Tom looked sharply at her. "How much trouble?"

"Quite a bit, I think." Emily looked over at Mark, whose breathing didn't appear eased by the rest stop, and then back at Tom. "I think we should get him down to a lower altitude. Quickly."

Tom nodded. "I'll get the others."

Questions:

1. What types of physiological problems do humans encounter at high altitudes?
2. What symptoms did the climbers exhibit that might be related to altitude? Explain.
3. Compare the air at 18,000 feet (atmospheric pressure 280 mm Hg) to the air at sea level (760 mm Hg). What specific changes in the primary atmospheric gases (nitrogen, oxygen, carbon dioxide) might occur? Are they significant?
4. What is the specific pulmonary response to high altitude? [Assume you are considering a subject at rest.]
5. How will this response affect overall blood gases? What about oxygen loading and unloading from hemoglobin? Explain how you arrived at your conclusions.
6. After breathing at altitude for a few days, the body normally begins producing more 2,3-DPG. What is the significance of this change? How will it affect the pulmonary changes observed?

Image Credit: Climber descending the summit ridge, Mt. Denali, Alaska, 1999. Photograph by Scott Darsney, used with permission.

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Part II - Gasping for Air

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John, the assistant expedition leader and a seasoned alpinist, helped Tom guide Mark down the steep trail. Mark's breathing, increasingly labored with every passing moment, was loud enough to worry Emily and Pete, the expedition's final climber.

"Geez, do we sound like that?" gasped Pete. "I mean, I'm out of breath, too, but he sounds horrible!"

"No, we're not that bad. Remember, that's why we spent the prep month at 15,000 feet. Mark was with us, so he experienced the same physiological changes we did. This," Emily nodded at Mark, "is some sort of problem."

Questions:

1. What physiological changes is Emily referring to (above) that will occur when someone lives at altitude for an extended period?
2. How are these changes advantageous?
3. What is the specific physiological pathway that results in the changes described?

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Part III - Airlift

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Mark deteriorated rapidly and lost consciousness by the time the group reached the lower camp. The urgency of the situation strengthened the tired legs of the climbers, as Tom, John, and Pete carried Mark the final yards towards camp. Emily had run ahead to call for support help, and the group was told an airlift was on its way and would be there within the hour. The camp's medical tent had some basic supplies and a resident paramedic, and he and Emily went to work stabilizing Mark with oxygen and a Gammow bag (a pressurization bag).

90 Minutes Later, Denali Valley Hospital

"We have a 28-year-old white male, unresponsive, no prior history of pulmonary disease, who became unconscious around 15,000 feet after hiking to 17,000 feet earlier today. His friends say he was having severe breathing difficulty prior to losing consciousness...."

As the paramedic droned on, Emily looked around for the nearest phone so she could locate Mark's family in case this was as serious as it looked.

Questions:

1. How would the oxygen and Gammow bag help Mark?
2. If you were a member of the medical team examining Mark, what types of tests would you run? Why? [Try to focus on what types of things you would like to measure, whether or not you know of a possible test for them.]
3. What types of results do you expect to find? Explain your reasoning.

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Part IV - Mark's Medical Data

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The following tables summarize the findings of the Denali Valley Hospital Medical Team:

BLOOD LEVELS

	MARK'S	NORMAL
Arterial Oxygen	52 Torr	80-100 Torr
Arterial Carbon Dioxide	30 Torr	35-45 Torr
Arterial pH	7.23	7.38-7.44
Hematocrit	58%	42-52%
Arterial glucose	102 mg/100ml	60-110 mg/100ml
Urea Nitrogen (BUN)	12 M	7-14 M
Creatinine	1.1 mg/100ml	1-1.5 mg/100ml
Potassium	4.0 meq/L	3.5-5.0 meq/L
Sodium	145 meq/L	136-145 meq/L
Bicarbonate	18 meq/L	20-24 meq/L
Chloride	100 meq/L	98-106 meq/L

No prescription medications or other pharmacological agents were found.

PULMONARY FUNCTION TESTS

Inspired Oxygen Tension	147 Torr	150 Torr
Vapor Pressure	45 Torr	47 Torr
Alveolar Oxygen	110 Torr	98-104 Torr
RQ	0.66	0.78-0.82 Torr
Tidal Volume	0.4 L	0.5 L

HEART RATE: 88 bpm (normal: 60-90 bpm)

BLOOD PRESSURE: 105/60 (normal: 110-120/60-80 mm Hg)

Questions:

1. Are the results as you expected? What values agree/disagree with your predictions?
2. Which lab values appear to represent the most serious problem Mark is having? Is his situation life-threatening?
3. Compare the results of Alveolar Oxygen Tension to Arterial Oxygen levels. What might cause this type of discrepancy?
4. Overall, what do these findings tell you about possible diagnoses for Mark's condition?

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Part V - "Mark This..."

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Denali Valley Hospital, 8 pm

"Well, Mark, you gave us quite a scare!" Emily smiled down at him.

"I gave *myself* quite a scare... from what I remember at least. Most of it's pretty fuzzy. I just remember thinking that the acclimating didn't do much good! But I guess no amount of training can help with pulmonary edema."

"Nope," said Emily. "This sort of thing comes out of the blue. And it's virtually impossible to predict who will develop it. HAPE (High Altitude Pulmonary Edema) is a rare occurrence, but it can be quite serious."

"The doctors told me I'm susceptible to recurrence. Is that true?"

"Yes, unfortunately. You need to be careful about your climbing from now on."