

**The American Physiological Society  
Medical Curriculum Objectives Project**

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**Respiration**  
**(revised 2006)**  
**Pulmonary Mechanics**

PUL 1. Diagram how pleural pressure, alveolar pressure, airflow, and lung volume change during a normal quiet breathing cycle. Identify on the figure the onset of inspiration, cessation of inspiration, and cessation of expiration. Describe how differences in pressure between the atmosphere and alveoli cause air to move in and out of the lungs.

PUL 2. Draw a normal pulmonary pressure-volume (compliance) curve (starting from residual volume to total lung capacity and back to residual volume), labeling the inflation and deflation limbs. Explain the cause and significance of the hysteresis in the curves.

PUL 3. Define compliance and identify two common clinical conditions in which lung compliance is higher or lower than normal.

PUL 4. Draw the pressure-volume (compliance) curves for the lungs, chest wall, and respiratory system on the same set of axes. Show and explain the significance of the resting positions for each of these three structures.

PUL 5. Identify the forces that generate the negative intrapleural pressure when the lung is at functional residual capacity, and predict the direction that the lung and chest wall will move if air is introduced into the pleural cavity (pneumothorax).

PUL 6. Draw a normal spirogram, labeling the four lung volumes and four capacities. List the volumes that comprise each of the four capacities. Identify which volume and capacities cannot be measured by spirometry.

PUL 7. Define the factors that determine total lung capacity, functional residual capacity, and residual volume. Describe the mechanisms responsible for the changes in those volumes that occur in patients with emphysema and pulmonary fibrosis.

PUL 8. Define surface tension and describe how it applies to lung mechanics, including the effects of alveolar size and the role of surfactants. Define atelectasis and the role of surfactants in preventing it.

PUL 9. Describe the principal components of pulmonary surfactant and explain the roles of each.

PUL 10. Describe the effects of airway diameter and turbulent flow on airway resistance.

PUL 11. Describe how airway resistance alters dynamic lung compliance.

PUL 12. Draw a spirogram resulting from a maximal expiratory effort. Label the forced vital

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capacity (FVC), timed forced expiratory volumes (FEVs), and the maximal expiratory flow rate between 25-75% of FVC (FEF<sub>25-75%</sub>).

PUL 13. Draw a normal maximal effort flow-volume curve, labeling the effort-dependent and -independent regions. Use the concept of dynamic compression of airways to explain why each point in the effort-independent region of the curve represents a maximal flow rate that is uniquely dependent on lung volume. Describe how and why the shape of the flow-volume curve is shifted in chronic obstructive lung disease (COPD).

PUL 14. Differentiate between the two broad categories of restrictive and obstructive lung disease, including the spirometric abnormalities associated with each category.

PUL 15. Describe the regional differences in alveolar ventilation in healthy and diseased lungs and explain the basis for these differences.

### **Alveolar Ventilation**

PUL 16. Define partial pressure and fractional concentration as they apply to gases in air. List the normal fractional concentrations and sea level partial pressures for O<sub>2</sub>, CO<sub>2</sub>, and N<sub>2</sub>.

PUL 17. List the normal airway, alveolar, arterial, and mixed venous PO<sub>2</sub> and PCO<sub>2</sub> values. List the normal arterial and mixed venous values for O<sub>2</sub> saturation, [HCO<sub>3</sub><sup>-</sup>], and pH.

PUL 18. Define and contrast the following terms: anatomic dead space, physiologic dead space, wasted (dead space) ventilation, total minute ventilation and alveolar minute ventilation.

PUL 19. Describe the concept by which physiological dead space can be measured.

PUL 20. Define and contrast the relationships between alveolar ventilation and the arterial PCO<sub>2</sub> and PO<sub>2</sub>.

PUL 21. Describe in quantitative terms the effect of ventilation on PCO<sub>2</sub> according to the alveolar ventilation equation.

PUL 22. Be able to estimate the alveolar oxygen partial pressure (P<sub>A</sub>O<sub>2</sub>) using the simplified form of the alveolar gas equation. Be able to use the equation to calculate the amount of supplemental O<sub>2</sub> required to overcome a reduction in P<sub>A</sub>O<sub>2</sub> caused by hypoventilation or high altitude.

PUL 23. Define the following terms: hypoventilation, hyperventilation, hypercapnea, eupnea, hypopnea, and hyperpnea.

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**Pulmonary Circulation**

PUL 24. Contrast the systemic and pulmonary circulations with respect to pressures, resistance to blood flow, and response to hypoxia.

PUL 25. Describe the regional differences in pulmonary blood flow in an upright person. Define zones I, II, and III in the lung, with respect to pulmonary vascular pressure and alveolar pressure.

PUL 26. Describe how pulmonary vascular resistance changes with alterations in cardiac output or pulmonary arterial pressure. Explain in terms of distention and recruitment of pulmonary vessels. Identify the zones in which these two mechanisms apply.

PUL 27. Describe how pulmonary vascular resistance changes with lung volume. Explain in terms of alterations in alveolar and extra-alveolar blood vessels.

PUL 28. Describe the consequence of hypoxic pulmonary vasoconstriction on the distribution of pulmonary blood flow.

PUL 29. Describe the effects of inspired nitric oxide on pulmonary vascular resistance and hypoxic vasoconstriction.

PUL 30. Explain the development of pulmonary edema by a) increased hydrostatic pressure, b) increased permeability, c) impaired lymphatic outflow or increased central venous pressure, and d) hemodilution (e.g., with saline volume resuscitation).

PUL 31. Describe the major functions of the bronchial circulation.

**Pulmonary Gas Exchange**

PUL 32. Name the factors that affect diffusive transport of a gas between alveolar gas and pulmonary capillary blood.

PUL 33. Describe the kinetics of oxygen transfer from alveolus to capillary and the concept of capillary reserve time (i.e., the portion of the erythrocyte transit time in which no further diffusion of oxygen occurs).

PUL 34. Define oxygen diffusing capacity, and describe the rationale and technique for the use of carbon monoxide to determine diffusing capacity.

PUL 35. Describe how the ventilation/perfusion (V/Q) ratio of an alveolar-capillary lung unit determines the PO<sub>2</sub> and PCO<sub>2</sub> of the blood emerging from that lung unit.

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PUL 36. Identify the average V/Q ratio in a normal lung. Explain how V/Q is affected by the vertical distribution of ventilation and perfusion in the healthy lung.

PUL 37. Describe the normal relative differences from the apex to the base of the lung in alveolar and arterial PO<sub>2</sub>, PCO<sub>2</sub>, pH, and oxygen and carbon dioxide exchange.

PUL 38. Predict how the presence of abnormally low and high V/Q ratios in a person's lungs will affect arterial PO<sub>2</sub> and PCO<sub>2</sub>.

PUL 39. Describe two causes of abnormal V/Q distribution.

PUL 40. Define right-to-left shunts, anatomic and physiological shunts, and physiologic dead space (wasted ventilation). Describe the consequences of each for pulmonary gas exchange.

PUL 41. Describe the airway and vascular control mechanisms that help maintain a normal ventilation/perfusion ratio. Name two compensatory reflexes for V/Q inequality.

PUL 42. Be able to calculate the alveolar to arterial PO<sub>2</sub> difference, (A-a)DO<sub>2</sub>. Describe the normal value for (A-a) DO<sub>2</sub> and the significance of an elevated (A-a) DO<sub>2</sub>.

PUL 43. Name five causes of hypoxemia.

## **Oxygen and Carbon Dioxide Transport**

PUL 44. Define oxygen partial pressure (tension), oxygen content, and percent hemoglobin saturation as they pertain to blood.

PUL 45. Draw an oxyhemoglobin dissociation curve (hemoglobin oxygen equilibrium curve) showing the relationships between oxygen partial pressure, hemoglobin saturation, and blood oxygen content. On the same axes, draw the relationship between PO<sub>2</sub> and dissolved plasma O<sub>2</sub> content (Henry's Law). Compare the relative amounts of O<sub>2</sub> carried bound to hemoglobin with that carried in the dissolved form.

PUL 46. Describe how the shape of the oxyhemoglobin dissociation curve influences the uptake and delivery of oxygen.

PUL 47. Define P50.

PUL 48. Show how the oxyhemoglobin dissociation curve is affected by changes in blood temperature, pH, PCO<sub>2</sub>, and 2,3-DPG, and describe a situation where such changes have important physiological consequences.

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- PUL 49. Describe how anemia and carbon monoxide poisoning affect the shape of the oxyhemoglobin dissociation curve, PaO<sub>2</sub>, and SaO<sub>2</sub>.
- PUL 50. List the forms in which carbon dioxide is carried in the blood. Identify the percentage of total CO<sub>2</sub> transported as each form.
- PUL 51. Describe the importance of the chloride shift in the transport of CO<sub>2</sub> by the blood.
- PUL 52. Identify the enzyme that is essential to normal carbon dioxide transport by the blood and its location.
- PUL 53. Draw the carbon dioxide dissociation curves for oxy- and deoxyhemoglobin. Describe the interplay between CO<sub>2</sub> and O<sub>2</sub> binding on hemoglobin that causes the Haldane effect.
- PUL 54. Explain why the total gas pressure of the venous blood is subatmospheric and why this situation is accentuated when breathing 100% O<sub>2</sub>. Explain how breathing 100% O<sub>2</sub> can result in further arterial O<sub>2</sub> desaturation in hypoxemic patients who develop mucous plugging of their airways (absorption atelectasis).
- PUL 55. Define respiratory acidosis and alkalosis and give clinical examples of each.
- PUL 56. Describe the mechanism and function of respiratory acid base compensations.

### **Respiratory Control**

- PUL 57. Identify the regions in the central nervous system that play important roles in the generation and control of cyclic breathing.
- PUL 58. Give three examples of reflexes involving pulmonary receptors that influence breathing frequency and tidal volume. Describe the receptors and neural pathways involved.
- PUL 59. List the anatomical locations of chemoreceptors sensitive to changes in arterial PO<sub>2</sub>, PCO<sub>2</sub>, and pH that participate in the control of ventilation. Identify the relative importance of each in sensing alterations in blood gases.
- PUL 60. Describe how changes in arterial PO<sub>2</sub> and PCO<sub>2</sub> alter alveolar ventilation, including the synergistic effects when PO<sub>2</sub> and PCO<sub>2</sub> both change.
- PUL 61. Describe the respiratory drive in a COPD patient, and predict the change in respiratory drive when oxygen is given to a COPD patient.
- PUL 62. Describe the mechanisms for the shift in alveolar ventilation that occur immediately upon ascent to high altitude, after remaining at altitude for two weeks, and immediately upon return to sea level.

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PUL 63. Describe the physiological basis of shallow water blackout during a breath-hold dive.

PUL 64. Describe the significance of the feedforward control of ventilation (central command) during exercise, and the effects of exercise on arterial and mixed venous  $\text{PCO}_2$ ,  $\text{PO}_2$ , and pH.

**Age Effects and Nonrespiratory Lung Functions**

PUL 65. Describe the effect of aging on lung volumes, lung and chest wall compliance, blood gases, and respiratory control.

PUL 66. Identify the mechanism by which particles are cleared from the airways.

PUL 67. Describe mechanisms for clearance of vasoactive substances from the blood during passage through the lung. Identify a substance that is almost completely cleared and one that is not cleared to any significant extent.

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