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美国医师执照考试(USMLE)

Physiology

生理学（第13版）

- 500 USMLE-type questions and answers
- Detailed explanations for correct and incorrect answers
- Targets what you really need to know for exam success
- Student tested and reviewed

Patricia J. Metting
James F. Kleshinski

北京大学医学出版社

PreTest™

生 理 学
（第 13 版）
Physiology
PreTest™ Self-Assessment and Review
Thirteenth Edition

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北京大学医学出版社

图书在版编目（CIP）数据

生理学＝Physiology：英文／（美）迈廷（P. J. Metting），克莱斯克（J. F. Kleshinski）编写．—影印本
—北京：北京大学医学出版社，2010.5
（美国医师执照考试丛书）
ISBN 978-7-81116-929-4

Ⅰ.①生… Ⅱ.①迈…②克… Ⅲ.①人体生理学—医师—资格考核—美国—自学参考资料—英文 Ⅳ.①R33

中国版本图书馆 CIP 数据核字（2010）第 077725 号

北京市版权局著作权合同登记号：01-2010-2398

Patricia J. Metting，James F. Kleshinski
Physiology：PreTest™ Self-Assessment and Review，Thirteenth Edition
ISBN 978-0-07-162350-6

生理学（第 13 版）

编　　写：Patricia J. Metting，James F. Kleshinski
出版发行：北京大学医学出版社（电话：010-82802230）
地　　址：（100191）北京市海淀区学院路 38 号　北京大学医学部院内
网　　址：http://www.pumpress.com.cn
E - mail：booksale@bjmu.edu.cn
印　　刷：北京东方圣雅印刷有限公司
经　　销：新华书店
责任编辑：冯智勇　**责任校对**：齐　欣　**责任印制**：张京生
开　　本：889mm×1194mm　1/32　**印张**：14　**字数**：361 千字
版　　次：2010 年 6 月第 1 版　2010 年 6 月第 1 次印刷
书　　号：ISBN 978-7-81116-929-4
定　　价：52.00 元

出版说明

美国医师执照考试（United States Medical Licensing Examination，USMLE）是针对全世界各国医学院的学生或毕业生，欲到美国从医的执照考试，考试全部为选择题，采用计算机考试。考试分为：

Step 1（第一阶段）：考察医学基础学科知识，包括解剖学 Anatomy，生理学 Physiology，生物化学 Biochemistry，微生物学 Microbiology，病理学 Pathology，药理学 Pharmacology，遗传学 Genetics，营养学 Nutrition，神经科学 Neuroscience 等。

Step 2（第二阶段）：

（1）临床医学知识（Clinical Knowledge，CK）：包括内科学 Medicine，外科学 Surgery，妇产科学 Obstetrics and Gynecology，儿科学 Pediatrics，神经病学 Neurology，家庭医学 Family Medicine，急诊医学 Emergency Medicine，预防医学 Preventive Medicine 等。

（2）临床技能（Clinical Skill，CS）：要通过 Step 1、Step 2 及 TOEFL 之后才能报考，主要是考察考生的临床实践操作知识。

Step 3（第三阶段）：测试考生的实际工作能力。内容包括采集病史、体格检查、诊断、治疗措施，以及医疗法规等。

USMLE 在北京、上海和广州设有考点，在中国大陆可参加 USMLE Step 1 和 USMLE Step 2 CK 的考试。考试介绍及报名情况可参见 http：//www. ecfmg. com

为了帮助有志于参加 USMLE 的考生更好地复习，北京大学医学出版社全面引进了 McGraw Hill 公司的两个著名 USMLE 复习品牌丛书：PreTest 系列、FIRST AID 系列。这两套丛书经过多次再版，受到世界各地考生的欢迎。本次引进的均为其最新版本。

当前，我国很多医学院校在进行英文授课、考试的改革，本书对国内从事英语授课、考试的教师和学生也有重要的参考价值。为广大的医学生和医务工作者比较中美医学教育和自己掌握的知识提供参考。同时，该书也是学习专业英语的好教材。

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To my husband, Mike Metting, and our children,
Megan and Patrick Metting,
and
To my wife, Olga Kleshinski, and our children,
Jimmy and Olivia Kleshinski,
For your unconditional love and encouragement and the sacrifices you have made over the years in deference to our professional activities and responsibilities. We hope that somehow you know that there has never been anything more important in our lives than all of you.

PM and JK

Introduction

Each *PreTest™ Self-Assessment and Review* is designed to allow allopathic and osteopathic medical students, as well as international medical graduates, a comprehensive and convenient way to assess and review their knowledge of a particular medical science, in this instance, physiology. The 500 questions have been organized to parallel the Content Outline for the United States Medical Licensing Examination (USMLE™) Step 1 (http://www.usmle.org/Examinations/step1/step1_content.html). By familiarizing yourself with the Step 1 Content Outline, you will get a more accurate idea of the subject areas covered in each section. For example, acid-base balance and high-altitude physiology are topics covered under General Principles: Multisystem Processes and oxygen and carbon dioxide transport are covered in the chapter on the Physiology of the Hematopoietic and Lymphoreticular Systems, rather than under Respiratory or Renal Physiology, where you likely learned them during your medical school education. The value of organizing the questions this way is that the Step 1 Content Outline is used by the National Board of Medical Examiners (NBME) in the score reports that go to each examinee to provide them with their relative performance in each of the various areas tested by the USMLE Step 1. Thus, when you eventually find out how you performed in each category, you will have a more accurate understanding of your areas of strength and weakness.

Physiology: PreTest™ has been updated to incorporate a clinical vignette and/or graphic interpretation in every question. In this way, the questions in *Physiology: PreTest™* more closely parallel the length and the degree of difficulty of the questions that you should expect to find on the USMLE Step 1.

Physiology: PreTest™ will also be a valuable resource for osteopathic medical students studying for the Comprehensive Osteopathic Medical Licensing Examination (COMLEX)-USA. Similar to Step 1 of the USMLE, Level 1 of the COMLEX-USA, administered by the National Board of Osteopathic Medical Examiners, Inc., emphasizes an understanding of the basic science mechanisms underlying health and disease, and is constructed with clinical presentations in the context of medical problem solving (http://www.nbome.org).

Each question in *Physiology: PreTest™* is followed by multiple answer options. For each question, select the *one best* answer from the choices given. Each question is also accompanied by the correct answer and its explanation. The explanation provides the reason why the correct answer is correct and, in most cases, the reasons why the wrong answers are wrong.

The explanations also provide additional information relevant to the clinical vignette and the basic science topic the question is intended to test. The references accompanying each question are from popular and excellent physiology, pathophysiology, and internal medicine textbooks. Step 1 is the first of three exams required for medical licensure in the United States. Although it is a test that examines knowledge of the basic sciences, the expectation is that you can apply the basic knowledge in clinical problem solving. By using clinical vignettes and clinical reference texts, our hope is that your preparation for the USMLE Step 1 (and/or COMLEX-USA Level 1) will also serve to enhance your ability to function competently in the clinical environment. The material in the referenced pages will provide a more expansive description of the subject matter covered by the question.

One effective way to use the *PreTest*™ is to use it as a review for each topic area. Start by reading the High-Yield Facts on a selected topic found at the beginning of the book. The High-Yield Facts are not meant to be a complete list of all of the important facts, concepts, and equations necessary for understanding physiology. Those that are included, however, offer a solid foundation and should be included in your review of physiology in preparation for a class test or for the USMLE Step 1. Once you've completed. your reading on a topic, answer the questions for that chapter. As you check your answers, be sure to read the explanations, as they are designed to reinforce and expand on the material covered by the questions. If you are still unsure of why the correct answer is correct, you should also read the referenced text pages.

PreTest™ can also be used as a practice testing session. Set aside two-and-a-half hours, and answer 150 of the questions, writing the answers on a separate sheet of paper. Once you have completed all 150, then you can go back and compare your answers to the ones provided in the book. This exercise will help you assess your level of competence and confidence prior to taking the USMLE Step 1. Whichever way you use *PreTest*™, an important part of your review can be found in the explanations.

Good luck on your exam and best wishes for your clinical training. Keep in mind that there is a *PreTest*™ available for the other basic sciences, as well as in each of the required clinical disciplines, so we encourage you to make the *PreTest*™ series your review books of choice throughout the preclinical and clinical portions of the medical school curriculum, as well as during your preparation for Step 1 and Step 2 Clinical Knowledge (CK) of the USMLE or for the COMLEX-USA Level 1 and Level 2-Cognitive Evaluation (CE).

Acknowledgments

We are indebted to all of The University of Toledo College of Medicine medical students past and present, who have challenged us to be vigilant in correlating the basic and clinical sciences.

We wish to thank Jeffrey P. Gold, MD, Provost and Executive Vice President for Health Affairs and Dean of the College of Medicine at The University of Toledo, Joseph I. Shapiro, MD, Mercy Heath Partners Education Professor and Chairman, Department of Medicine, The University of Toledo, and all of our faculty colleagues for their support and encouragement.

The contributions of the authors of all previous editions of this book are gratefully acknowledged. In addition, the input of the medical student reviewers was valuable for enhancing the quality of this latest edition. We would also like to thank Kirsten Funk, Editor, Medical Publishing Division, McGraw-Hill Professional, for her editorial assistance and guidance throughout the preparation of this text, Cindy Yoo, Project Development Editor, and Sherri Souffrance, Production Supervisor, McGraw-Hill Professional, for their assistance in the production phase, and Madhu Bhardwaj, Glyph International limited, for her involvement in the typesetting and revisions.

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(References: Ganong, pp 1-49. Widmaier et al, pp 43-54, 96-136.)

Membrane Transport Mechanisms

The transport of ions, gases, nutrients, and waste products through biological membranes is essential for many cellular processes. Membrane transport mechanisms can be classified as *passive* (do not require energy input, as with simple diffusion or facilitated diffusion) and *active transport* (requires energy input). Membrane transport mechanisms can also be classified as either *simple diffusion* (does not require a membrane transporter, eg, diffusion through the lipid bilayer or diffusion through ion channels) or *mediated transport* (requiring an integral membrane protein transporter, as with facilitated diffusion or active transport).

Diffusion is defined as the net flux of a substance from an area of higher concentration to an area of lower concentration from movement solely by random thermal motion, which does not require energy input.

Facilitated diffusion is a type of mediated transport, but is a passive process in which carrier proteins move substances in the direction of their electrochemical gradients (eg, glucose transport in adipose tissue and muscle).

Active transport is a carrier-mediated transport process that requires energy to transport substances against their electrochemical gradients. The most important primary active transporter in mammalian cells is the Na^+-K^+ pump, which generates energy from the hydrolysis of ATP. Secondary active transport processes derive their energy from ion gradients. One example is the glucose transporter, which uses energy derived from the Na^+ electrochemical gradient.

Table 1 summarizes the major characteristics of the various membrane transport processes. Note that nonpolar substances, such as oxygen, carbon dioxide, and fatty acids, are transported by simple diffusion through the lipid bilayer of biological membranes. Ions and hydrophilic solutes, which do not readily cross the lipid bilayer, utilize an integral membrane protein to cross the membrane either via diffusion through a protein channel or via a carrier-mediated transport process.

TABLE 1. MAJOR CHARACTERISTICS OF MEMBRANE TRANSPORT MECHANISMS

	Diffusion Through Lipid Bilayer	Diffusion Through Ion Channel	Facilitated Diffusion	Primary Active Transport	Secondary Active Transport
Direction of net flux	High to low concentration	High to low concentration	High to low concentration	Low to high concentration	Low to high concentration
Use of energy and source	No, passive	No, passive	No, passive	Yes, ATP	Yes, ion gradient
Equilibrium or steady state	$C_0 = C_i$	$C_0 = C_i$[a]	$C_0 = C_i$	$C_0 \neq C_i$	$C_0 \neq C_i$
Uses integral membrane protein	No	Yes	Yes	Yes	Yes
Exhibits saturation kinetics	No	No	Yes, mediated transport	Yes, mediated transport	Yes, mediated transport
Chemical specificity	No	Yes	Yes	Yes	Yes
Typical molecules using pathway	Nonpolar: O_2, CO_2, fatty acids	Ions: Na^+, K^+, Ca^{2+}	Polar: glucose	Ions: Na^+, K^+, Ca^{2+}, H^+	Polar: amino acids, glucose, some ions

[a] In the presence of a membrane potential, the intracellular and extracellular ion concentrations will not be equal at equilibrium.

(Modified, with permission, from Widmaier EP, Raff H, Strang KT. *Vander's Human Physiology: The Mechanisms of Body Function.* 11th ed. New York, NY: McGraw-Hill; 2008: 108.)

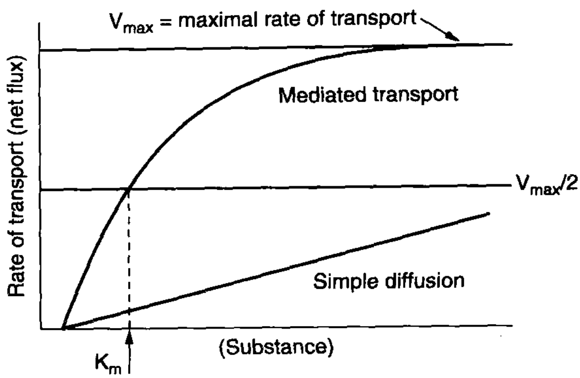

Figure 1

The kinetics of diffusion versus carrier-mediated transport processes vary, as depicted in Figure 1.

Simple diffusion of a substance is described by the Fick equation, as follows:

$$\text{Net flux} = A \times ([S1] - [S2]) \times D/d$$

where

A is area available for diffusion,

$[S1] - [S2]$ is concentration gradient of the substance across the membrane,

d is distance for diffusion,

D is diffusion coefficient of the substance,

= solubility coefficient/$\sqrt{\text{gram molecular weight}}$ of the substance.

According to the Fick equation, substances will diffuse more rapidly if the substance has a smaller mass, if the surface area for diffusion is increased, and if the concentration of the substance in one region greatly exceeds the concentration in the other region. For diffusion across membranes, the magnitude of the net flux is also directly proportional to the membrane permeability coefficient for the molecule.

Mediated transport exhibits saturation kinetics described by the Michaelis-Menten equation, as follows:

$$\text{Net flux} = V_{max} \times [S]/K_m + [S],$$

where

V_{max} is the maximal rate of transport.
[S] is the concentration of the transported substance.
K_m is the concentration required for half-maximal transport of the substance.

Osmosis is a term given to the passive diffusion of water across a semipermeable membrane from a compartment in which the solute concentration is lower (chemical potential of water is higher) to a compartment in which the solute concentration is higher (chemical potential of water is lower), as depicted in Figure 2. A semipermeable membrane is permeable to water but impermeable to solutes.

The flow of water through membranes by osmosis is described by the osmotic flow equation:

$$\text{Flow} = \sigma \times L \times (\pi_1 - \pi_2),$$

where

σ is reflection coefficient.
L is hydraulic conductivity.
$\pi_1 - \pi_2$ is osmotic pressure difference across membrane.

The reflection coefficient (σ) is an index of the membrane's permeability to a solute and varies between 0 and 1. Particles that are impermeable

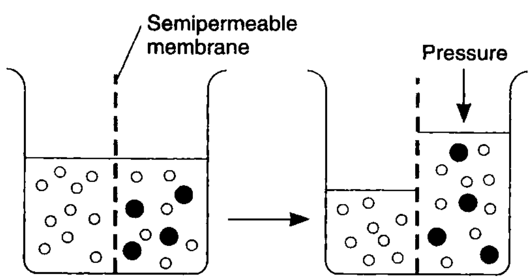

Figure 2
Diagrammatic representation of osmosis. Water molecules are the open circles and solute molecules are the closed circles. Osmosis is the passive flow of water molecules across a semipermeable membrane from a compartment in which the chemical potential of water is higher (solute concentration is lower) to a compartment in which the chemical potential of water is lower (solute concentration is higher). ***(Reproduced, with permission, from Ganong WF.* Review of Medical Physiology. *22nd ed. New York, NY: McGraw-Hill;2005: 5.)***

to the membrane have a reflection coefficient of 1. Particles that are freely permeable to the membrane have a reflection coefficient of 0.

The *osmotic pressure* (π) of a solution is the pressure necessary to prevent solute migration. The osmotic pressure (in units of mm Hg) is calculated with the van't Hoff equation:

$$\pi = R\,T\,(\varphi i c),$$

where

R is the ideal gas constant.
T is absolute temperature.
φ is the osmotic coefficient.
i is the number of ions formed by the dissociation of a molecule.
c is the molar concentration of solute.
(φic) is the osmolarity of the solution.

The value of i is 1 for nonionic substances such as glucose and urea, 2 for substances such as HCl, NaCl, KCl, NH_4Cl, $NaHCO_3$, and $MgSO_4$, and 3 for compounds such as $CaCl_2$ and $MgCl_2$.

A value of 1 is often used as an approximate value of φ. Thus, the osmolarity and osmotic pressure of 1 M $CaCl_2$ > 1 M NaCl > 1 M glucose.

Similarly, a 1 M solution of glucose has approximately the same osmolarity and osmotic pressure as 0.5 M $NaHCO_3$ or 0.33 M $MgCl_2$.

One osmol is equal to 1 mol of solute particles. The osmolarity is the number of osmoles per liter of solution, whereas the osmolality is the number of osmoles per kilogram of solvent. In the body, osmolal concentrations are expressed as osmoles per kilogram of water.

The term tonicity is used to describe the osmolality of a solution relative to plasma. Solutions that have the same osmolality as plasma (~300 mOsm/L) are isotonic; those with greater osmolality are hypertonic; and those with lesser osmolality are hypotonic.

The plasma membranes of most cells are relatively impermeable to many of the solutes of the extracellular fluid but are highly permeable to water. Thus the movement of water by osmosis leads to swelling or shrinking of cells. As shown in Figure 3, cells shrink when placed in hypertonic solutions and swell when placed in hypotonic solutions.

The steady-state volume of a cell can be calculated as:

$$\pi_{\text{initial}} \times V_{\text{initial}} = \pi_{\text{final}} \times V_{\text{final}}$$

Isotonic solutions are commonly used for intravenous fluid administration and as drug diluents because administration of an isotonic solution

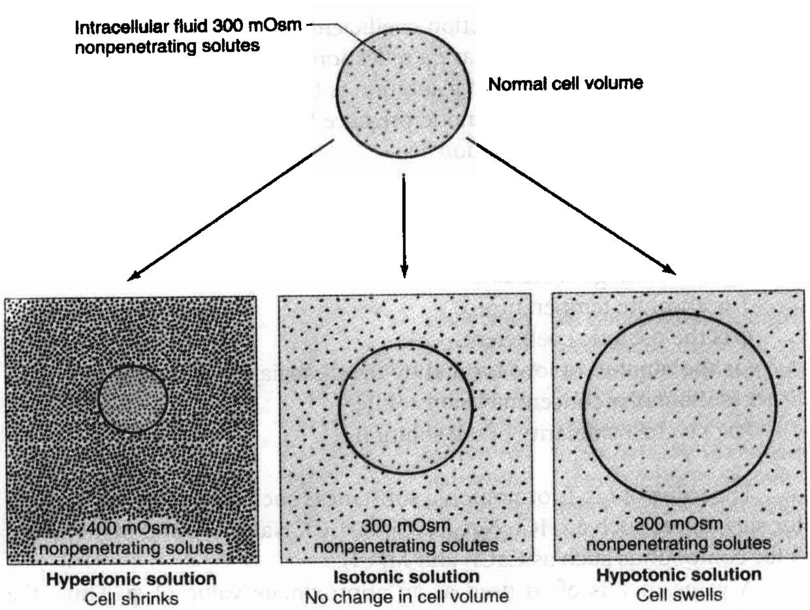

Figure 3

Cell volume changes with hypertonic, isotonic, and hypotonic solutions. ***(Reproduced, with permission, from Widmaier EP, Raff H, Strang KT.*** **Vander's Human Physiology: The Mechanisms of Body Function.** ***11th ed. New York, NY: McGraw-Hill;2008: 111.)***

does not produce changes in cell volume, that is, no net water movement. Isotonic saline has a concentration of 154 mM NaCl, containing 154 × 2 or 308 mM of osmotically active particles. An isotonic solution of glucose is a 5% dextrose solution.

Intercellular Connections and Communication

Two types of connections form between the cells comprising a tissue. One type of junction serves to fasten the cells to one another and to surrounding tissues. Examples of fastening junctions that lend strength and stability to tissues include tight junctions or zona occludens, desmosomes, zona adherins, hemidesmosomes, and focal adhesions. The other type of connection between cells serves the purpose of transferring ions and other molecules from cell to cell. This type of junction is called a gap junction, though transport of ions across epithelial cells can occur via tight junctions.