

About the Authors

We dedicate this work to our students both present and past, who always inspire us to “push the envelope.”

Elaine N. Marieb

After receiving her Ph.D. in zoology from the University of Massachusetts at Amherst, Elaine N. Marieb joined the faculty of the Biological Science Division of Holyoke Community College. While teaching at Holyoke Community College, where many of her students were pursuing nursing degrees, she developed a desire to better understand the relationship between the scientific study of the human body and the clinical aspects of the nursing practice. To that end, while continuing to teach full time, Dr. Marieb pursued her nursing education, which culminated in a Master of Science degree with a clinical specialization in gerontology from the University of Massachusetts. It is this experience that has informed the development of the unique perspective and accessibility for which her publications are known.

Dr. Marieb has given generously to provide opportunities for students to further their education. She funds the E.N.

Marieb Science Research Awards at Mount Holyoke College, which promotes research by undergraduate science majors, and has underwritten renovation of the biology labs in Clapp Laboratory at that college. Dr. Marieb also contributes to the University of Massachusetts at Amherst, where she provided funding for reconstruction and instrumentation of a cutting-edge cytology research laboratory. Recognizing the severe national shortage of nursing faculty, she underwrites the Nursing Scholars of the Future Grant Program at the university.

In 2012 and 2017, Dr. Marieb gave generous philanthropic support to Florida Gulf Coast University as a long-term investment in education, research, and training for healthcare and human services professionals in the local community. In honor of her contributions, the university is now home to the Elaine Nicpon Marieb College of Health and Human Services.



Katja Hoehn

Dr. Katja Hoehn is a professor in the Department of Biology at Mount Royal University in Calgary, Canada. Dr. Hoehn’s first love is teaching. Her teaching excellence has been recognized by several awards during her 24 years at Mount Royal University. These include a PanCanadian Educational Technology Faculty Award (1999), a Teaching Excellence Award from the Students’ Association of Mount Royal (2001), and the Mount Royal Distinguished Faculty Teaching Award (2004).

Dr. Hoehn received her M.D. (with Distinction) from the University of Saskatchewan, and her Ph.D. in Pharmacology from Dalhousie University. In 1991, the Dalhousie Medical Research Foundation presented her with the Max Forman (Jr.) Prize for excellence in medical research. During her Ph.D. and postdoctoral studies, she also pursued her passion for teaching by presenting guest lectures to first- and second-year medical students at Dalhousie University and at the University of Calgary.

Dr. Hoehn has been a contributor to several books, written numerous research papers in Neuroscience and Pharmacology,

and has co-authored the previous four editions of this textbook. For many years, she has also reviewed and authored electronic media that accompanies Pearson anatomy and physiology books.

Following Dr. Marieb’s example, Dr. Hoehn provides financial support for students in the form of a scholarship that she established in 2006 for nursing students at Mount Royal University.

Dr. Hoehn is also actively involved in the Human Anatomy and Physiology Society (HAPS) and is a member of the American Association of Anatomists. When not teaching, she likes to spend time outdoors with her husband and two sons. She also enjoys competing in long-course triathlons, and playing Irish flute down at the local pub.



Preface

Today's students have access to an enormous amount of information about anatomy and physiology. As educators, our biggest challenge is to help students focus on mastering the basic concepts of this field. Providing this firm foundation will help students to become lifelong learners who can critically evaluate new information, connect that information to the

foundation they have already established, and apply it in a clinical setting. How can we help students build a strong foundation in anatomy and physiology? We believe that this new edition of our textbook will help learners by building on the strengths of previous editions while using new and innovative ways to help students visualize connections between various concepts.

Unifying Themes

Three unifying themes that have helped to organize and set the tone of this textbook continue to be valid and are retained in this edition. These themes are:

Interrelationships of body organ systems. This theme emphasizes the fact that nearly all regulatory mechanisms have interactions with several organ systems. The respiratory system, for example, cannot carry out its role of gas exchange in the body if there are problems with the cardiovascular system that prevent the normal delivery of blood throughout the body. The System Connections feature and Make Connections questions throughout the book help students connect new information to old information and think of the body as a community of dynamic parts instead of a number of independent units.

Homeostasis. Homeostasis is the normal and most desirable condition of the body. Its loss is always associated with past or present pathology. This theme is not included to emphasize pathological conditions, but rather to illustrate what happens in the body “when things go wrong” and homeostasis is lost. Whenever students see a red balance beam symbol accompanied by an associated clinical topic, their understanding of how the body works to stay in balance is reinforced.

Complementarity of structure and function. This theme encourages students to understand the structure of some body part (ranging from a molecule to an organ) in order to understand the function of that structure. For example, muscle cells can produce movement because they are contractile cells.

New to the Eleventh Edition

New and augmented elements aim to help learners in the following ways.

To help students make connections between new and previously learned material. In order for students to master new concepts, they must link these new concepts with concepts they already understand. In this edition, we help them do this by adding:

- **Text recall icons** (◀). These icons direct the student back to the specific pages where a concept was first introduced.
- **Make Connections questions.** We've added more of this type of question to the Check Your Understanding review questions that follow each module within a chapter. To answer these questions, the student must employ concepts learned previously (most often in previous chapters).
- **New kinds of higher-level questions.** Each chapter now has at least five higher-level questions that require students to think more deeply, pulling together strands from multiple concepts. These questions are clearly identified as **APPLY**, **DRAW**, **PREDICT**, **MAKE CONNECTIONS**, and **WHAT IF?** questions.
- **New summary tables.** Students have told us that they want more summary tables. In response, 13 new summary tables (two with illustrations) have been added in order to help students see the big picture.

To enhance students' visual literacy. Anatomy is and has always been taught principally through images. Increasingly, however, physiological data is also represented as images, whether it be molecular interactions or graphical descriptions of

processes. Throughout their future health care careers, students will need to be able to understand and interpret information presented visually. In this edition, we help them do this by:

- **Adding new Focus figures.** Focus figures are illustrations that use a “big picture” layout and dramatic art to guide the student through difficult physiological processes in a step-by-step way. Our previous Focus figures have been a hit with both students and instructors. In response to requests for additional Focus figures, we are pleased to present six new two-page features.
- **Adding **DRAW** questions in each chapter.** Students often think that they understand an illustration simply by looking at it, but to truly comprehend an illustration and cement its concepts requires a more active learning approach. For this reason we now include at least one higher-level review question within each chapter that requires a student either to draw an illustration or to add to an existing diagram.
- **Adding questions about illustrations.** To help students practice their visual literacy skills, we have added 47 new Check Your Understanding questions that include an illustration as part of the question. Some of these are as simple as labeling exercises, but many require more advanced interpretation.
- **Updating art to improve its teaching effectiveness.** As always, this is a major part of the revision. Today’s students are accustomed to seeing sophisticated photorealistically rendered images. However, many students are not adept at extracting, and thinking critically about, the relevant information contained in such illustrations. With this in mind we continue to refine and update our illustrations as students’ needs change, improving their ability to teach important concepts. In many cases we have added blue “instructor’s voice” text within the figure to guide a student through it, replacing much of the more remote figure legend. In addition, new photos were painstakingly chosen and labeled to enhance the learning process.
- **Adding new illustrations to existing tables and adding new illustrated tables.** Students find illustrated tables particularly effective because they provide a visual cue that helps them remember a topic. In this edition, we have added illustrations to two tables and added two new illustrated tables.
- **Adding in-line figures.** These are small (less than a half-column wide) illustrations or photos strategically located within the text that discuss the concept they illustrate. This edition now has 31 such in-line figures, most of them newly added.

To help students clinically apply what they have learned

- **Updated Homeostatic Imbalance features.** Many of the Homeostatic Imbalance features have been updated and relevant photos have been added to some. All have been reviewed for accuracy and relevancy. In addition, the updated book design makes these features stand out more clearly.
- **Updated Clinical Case Studies in Chapters 5-29 with added new **+** NCLEX-STYLE questions.** The end-of-chapter

review questions, which are now organized into three levels of difficulty based on Bloom’s Taxonomy categories, culminate in a clinical case study that allows students to apply some of the concepts they have learned to a clinical scenario. These case studies have been extensively revised and each case study has two questions that are similar in style to those in the NCLEX exam.

- **New clinically relevant photos.** We have added or updated a number of photos that have clinical relevance (procedures, conditions, etc.) that will help students apply what they are reading to real-life situations and to their future careers.

In this edition, certain chapters have received the bulk of our attention and have been more heavily revised. As you can see in the Highlights of New Content (below), these are Chapters 2–4, 9, and 27–29.

As in the previous edition, we have taken painstaking care to ensure that almost all the text and the associated art are covered on the same two-page spread. Although this sounds like a simple goal, it actually takes a great deal of work and has not usually been achieved by other textbooks. We make this effort because it is invaluable to student learning to not have to flip pages back and forth between art and text. Finally, you will notice the appearance of new icons referencing MasteringA&P[®] interspersed within the text. This guides students to go to the relevant on-line activities to supplement their learning.

Other Highlights of New Content

Chapter 1 The Human Body: An Orientation

- New Figure 1.1 illustrates complementarity of structure and function.
- Updated *A Closer Look* feature on types of medical imaging and added five new photos.
- New Homeostatic Imbalance features about hiatal hernias and about “wrong site surgery.”

Chapter 2 Chemistry Comes Alive

- New Homeostatic Imbalance feature about patient’s pH predicting outcome of CPR.
- New figures illustrate triglyceride structure (2.16); the difference between saturated and unsaturated fatty acids (2.17); phospholipids (2.18); and protein functions (2.20).
- Revised Figures 2.6 (formation of ionic bonds) and 2.12 (dissociation of salt in water) teach more effectively.
- New summary tables reinforce information about chemical bonds (Table 2.2) and about macromolecules and their monomers and polymers (Table 2.5).

Chapter 3 Cells: The Living Units

- Added Focus Figure 3.1 about the plasma membrane, and reorganized accompanying text.
- Reorganized text about passive membrane transport for improved clarity; updated and reorganized discussion of autophagy and apoptosis.
- Updated information about Tay-Sachs disease.

- New micrographs show micro- and intermediate filaments (Figure 3.20).
- Improved teaching effectiveness of Figures 3.5 (diffusion), 3.17 (processing and distribution of newly synthesized proteins), and 3.30 (stages of transcription).
- New information about telomeres in cancer cells.
- New Homeostatic Imbalance feature about progeria.

Chapter 4 Tissue: The Living Fabric

- New images of cilia show the difference between transmission and scanning electron microscopy (Figure 4.2).
- New in-line figure illustrates apical and basal surfaces of epithelial cells.
- Revised art for epithelial and connective tissue for clarity (Figures 4.4 and 4.11).
- New Figure 4.5 shows how exocrine and endocrine glands differ, and new Figure 4.10 gives an overview of the classification of connective tissue.
- Updated *A Closer Look* feature about cancer.

Chapter 5 The Integumentary System

- New illustrated summary table comparing cutaneous glands (Table 5.1).
- Revised Figures 5.3 and 5.4 for better teaching effectiveness.
- Updated information about skin color and disease states.
- Updated Homeostatic Imbalance features about hirsutism and about hair loss.
- New Homeostatic Imbalance feature about nail changes with disease.
- Updated statistics for and treatment of melanoma, with new photo (Figure 5.11c).

Chapter 6 Bones and Skeletal Tissues

- New summary Table 6.1 compares cartilage and bone tissue.
- New photos of an osteoclast (Figure 6.7); of a femur in longitudinal section to show compact and spongy bone (Figure 6.3); and of a section of a flat bone (skull bone) (Figure 6.4 top).
- Extensive revision of Figure 6.12, which teaches bone growth at epiphyseal plates, including new X ray to show epiphyseal plates, and new photomicrograph of epiphyseal cartilage.
- Updated information about bone remodeling, hormonal regulation of bone growth, and osteoporosis.

Chapter 7 The Skeleton

- New drawings to illustrate the location of the true and false pelvis, and the pelvic inlet and outlet (Figure 7.33).
- Updated Homeostatic Imbalance features about pes planus (flat feet) and about developmental dysplasia of the hip.
- New photos of bimalleolar fracture (Figure 7.35) and of cleft lip and palate (Figure 7.39).

Chapter 8 Joints

- New Homeostatic Imbalance feature about shoulder dislocations.
- New Table 8.3 summarizes movements at synovial joints.

- Revised Figure 8.4 (bursae and tendon sheaths).
- Updated *A Closer Look* about prostheses.

Chapter 9 Muscles and Muscle Tissue

- New “Background and Overview” section begins the discussion of the mechanisms of excitation and contraction of skeletal muscle, including a new “big picture” overview in Figure 9.7.
- New introduction to ion channels with art helps students understand skeletal muscle excitation and contraction.
- Reorganized discussions of graded muscle contractions and of smooth muscle, including new Figure 9.24 showing calcium sources for smooth muscle contraction.
- Updated discussion of muscle fatigue.
- Updated Homeostatic Imbalance feature on Duchenne muscular dystrophy.
- Updated *A Closer Look* feature about anabolic steroids.

Chapter 10 The Muscular System

- Revised art about levers for clarity (Figure 10.2 and 10.3).
- New cadaver dissection photos show dissection of muscles of the anterior neck and throat, superficial muscles of the thorax and shoulder in posterior view, and posterior muscles of the thigh and hip (Figures 10.9, 10.14, and 10.21).
- New photos illustrate thumb movements and show torticollis.

Chapter 11 Fundamentals of the Nervous System and Nervous Tissue

- New Focus Figure 11.4 illustrates postsynaptic potentials and their summation.
- Improved teaching effectiveness of Figure 11.12 (coding of action potentials for stimulus intensity) and Figure 11.19 (illustrating a reflex).
- New information about synthetic opiates in *A Closer Look*, with new PET scans showing effects of drug addiction.
- Added new research findings associating synaptic pruning and development of schizophrenia.

Chapter 12 The Central Nervous System

- New Figure 12.26 and revised text teach more effectively about the blood brain barrier.
- New Figure 12.30 shows spinal cord segment location in relation to vertebral column.
- New Table 12.2 summarizes spinal cord cross-sectional anatomy.
- Updated Homeostatic Imbalance features about hypothalamic disorders, cerebral palsy, anencephaly, and spina bifida, and about narcolepsy and insomnia, including new use of orexin receptor antagonists to treat insomnia.
- New type of MRI photo shows fiber tracts in brain and spinal cord.

Chapter 13 The Peripheral Nervous System and Reflex Activity

- New drawings of nerves of cervical, brachial, lumbar, and sacral plexuses show their position in relationship to the vertebrae (and hip bone in some cases) (Figures 13.9–13.12).

- New images illustrating the results of damage to the ulnar and radial nerves.
- New summary table of nerve plexuses (Table 13.7).
- New Homeostatic Imbalance feature and photo about an abnormal plantar reflex (Babinski's sign).
- Redrawn figure illustrating crossed-extensor reflex for improved student understanding.

Chapter 14 The Autonomic Nervous System

- New Figure 14.8 shows sympathetic innervation of the adrenal medulla.
- Clarified section about visceral sensory neurons.
- New photo illustrates Raynaud's disease.
- Revised Figure 14.5 on the sympathetic trunk for better teaching effectiveness.

Chapter 15 The Special Senses

- Revised Figure 15.2 (the lacrimal apparatus) for better teaching effectiveness.
- New photo of fundus of retina (Figure 15.7).

Chapter 16 The Endocrine System

- New Table 16.1 compares the endocrine and nervous systems.
- New Focus Figure 16.2 describes short- and long-term stress responses.
- Figures 16.5 (effects of growth hormone) and 16.9 (synthesis of thyroid hormone) revised for clarity.
- Updated information about diabetes mellitus, Addison's disease, and thyroid deficiency in childhood.

Chapter 17 Blood

- Updated information about anticoagulant medications.
- New photo shows petechiae resulting from thrombocytopenia (Figure 17.16).

Chapter 18 The Cardiovascular System: The Heart

- New Focus Figure 18.2 teaches students how to understand the cardiac cycle, with accompanying text reorganized.
- New photo shows an individual having an ECG (Figure 18.16).

Chapter 19 The Cardiovascular System: Blood Vessels

- New "drinking straw" analogy and art to explain resistance.
- New Figure 19.4 shows the structure of most capillary beds according to current understanding, and new text describes those capillary beds.
- Revised Figure 19.6 on proportions of blood volume throughout the vascular tree for greater teaching effectiveness.
- New illustration of cerebral arterial circle (circle of Willis) (Figure 19.24).

Chapter 20 The Lymphatic System and Lymphoid Organs and Tissues

- New illustrated Table 20.1 summarizes key characteristics of the major lymphoid organs.
- Revised Figure 20.9 with orientation diagrams helps students locate Peyer's patches (aggregated lymphoid nodules).
- Updated information about lymphatic drainage of the CNS.

Chapter 21 The Immune System: Innate and Adaptive Body Defenses

- New Focus Figure 21.1 gives an example of a primary immune response and summarizes innate and adaptive defenses.
- New illustrated Table 21.8 summarizes the components of adaptive immunity and complements the new Focus figure.
- New photo of a macrophage engulfing bacteria.
- Revised Figure 21.4 and text on inflammation, Figure 21.6 on complement activation, and Figure 21.11 on clonal selection of a B cell for greater teaching effectiveness.

Chapter 22 The Respiratory System

- New Figure 22.1 illustrates the four respiratory processes.
- Added section about sleep apnea.
- New scanning electron micrographs of emphysematous and normal lung tissue (Figure 22.22).
- Updated statistics about lung cancer and trends in asthma prevalence.

Chapter 23 The Digestive System

- New Figure 23.25 teaches the enterohepatic circulation of bile salts, and new Figure 23.30 shows the macroscopic anatomy of the small intestine.
- Improved teaching effectiveness of Figure 23.7 (neural reflex pathways in the gastrointestinal tract) and 23.16 (microscopic anatomy of the stomach).
- Added Homeostatic Imbalance features about dry mouth (xerostomia) and about tooth decay in primary teeth.
- Updated Homeostatic Imbalance feature about acute appendicitis to state that surgery is no longer always the first choice of treatment.

Chapter 24 Nutrition, Metabolism, and Energy Balance

- New Figure 24.24 shows the size and composition of various lipoproteins.
- Improved teaching effectiveness of Figure 24.21 (insulin effects during the postabsorptive stage).
- Updated Homeostatic Imbalance features with mechanism of cell death in frostbite, and diet recommendations for individuals with phenylketonuria.
- New information about environmental factors that may contribute to the obesity epidemic in *A Closer Look*.
- Updated nutritional information about lipids, and updated statistics about the prevalence of obesity in adults and children and about the prevalence of diabetes mellitus.

Chapter 25 The Urinary System

- New Figure 25.18 shows the medullary osmotic gradient and interstitial fluid osmolalities in the renal cortex and medulla.
- New Table 25.1 summarizes the regulation of glomerular filtration rate.
- Improved teaching effectiveness of Figures 25.9 (blood vessels of the renal cortex), 25.12 (the filtration membrane), 25.15 (routes for tubular reabsorption), and 25.16 (tubular reabsorption of water and nutrients).

- New pyelogram shows anatomy of kidneys, ureters, and urinary bladder (Figure 25.23).
- Added Homeostatic Imbalance feature about renal trauma.
- Updated Homeostatic Imbalance feature about kidney stones.

Chapter 26 Fluid, Electrolyte, and Acid-Base Balance

- New Figure 26.12 summarizes the body's chemical buffers.
- Improved teaching effectiveness of Figure 26.1 (major fluid compartments of the body), 26.2 (electrolyte composition of blood plasma, interstitial fluid, and intracellular fluid), and 26.7 (disturbances in water balance).
- Clarified definitions of sensible and insensible water loss.

Chapter 27 The Reproductive System

- This chapter has been extensively updated, revised, and reorganized. Almost every figure has been reconceptualized and several new figures have been added. These changes have been made for better teaching effectiveness.
- New opening module now compares male and female reproductive system anatomy and physiology and highlights common features, allowing students to make connections more easily. Homologous structures, patterns of hormone release, and meiosis are included in this section.
- New Figure 27.1 illustrates the basic pattern of interactions along the hypothalamic-pituitary-gonadal (HPG) axis in both males and females.
- The section about meiosis has been extensively rewritten to help increase student understanding. New in-line figures help introduce the basic terminology and some of the concepts before meiosis is discussed in detail.
- A new big-picture overview of meiosis introduces the major events before the details of each step are presented.
- Figures 27.22 (events of oogenesis) and 27.24 (regulation of the ovarian cycle) are extensively revised and updated for increased teaching effectiveness and accuracy.
- New Figure 27.26 depicts the genetic determination of sex.

Chapter 28 Pregnancy and Human Development

- New photo of sperm surrounding an oocyte (Figure 28.2).
- New Figure 28.5 illustrates implantation of a blastocyst.
- New photo of a 22-day embryo illustrates lateral folding (Figure 28.10d).
- Figure 28.12 (neurulation and early mesodermal differentiation) revised for clarity.
- New Focus Figure 28.2 (*Focus on Fetal and Newborn Circulation*) teaches the special features of fetal circulation and changes that occur in this circulation after birth.
- New Table 28.1 summarizes the special structures of the fetal circulation, their functions, and their postnatal structure.
- Updated information about placental hormone secretion and about the hormonal control of the initiation of labor.
- New information about fetal cells that enter the maternal circulation.
- New Homeostatic Imbalance feature about preeclampsia.

Chapter 29 Heredity

- Added Punnett square showing X-linked inheritance.
- Figure 29.1 (preparing a karyotype) and 29.4 (genotype and phenotype probabilities) revised for clarity.
- New photo of a couple with achondroplasia.
- Updated information about small noncoding RNAs.
- It has become increasingly clear that very few benign traits in humans follow a simple dominant-recessive inheritance pattern. Tongue rolling, astigmatism, freckles, dimples, phenylthiocarbamide tasting, widow's peak, and double-jointed thumb were all at one time thought to follow this pattern of inheritance. Closer examination has revealed compelling evidence against each of these. Consequently, the examples throughout the chapter have changed.

Acknowledgments

Producing a new edition of this book is an enormous undertaking. Let us take you through the steps and introduce you to the people behind the scenes that have helped make this book what it is. Every new edition begins with a revision plan. We'd like to thank all of the students and instructors who have provided the feedback (gathered by our editorial team) that forms the basis of this plan. Once this plan was in place, Barbara Price (our text Development Editor) scoured each chapter. This was Barbara's first exposure to the book and her fresh eyes on the text found opportunities to further clarify the presentation. In addition, she noted places where additional chunking of the text (such as bulleted lists) would help the students. Her excellent work has made this text better. We incorporated her ideas, and reviewer feedback, together with our own updates and ideas for reorganization of the text and art. Thanks to Patricia Bowne for contributing to the Clinical Case Studies and Wendy Mercier for reviewing all of the Case Studies. We also very much appreciate the help of Karen Dougherty, who used her expertise as a physician and educator to review all of the Homeostatic Imbalance features and help us revise and update them.

We then laid out each chapter to maintain text-art correlation before passing the manuscript off to Michele Mangelli. Michele wore many different hats during this revision. She was both the Program Manager for the editorial side of things as well as the Goddess of Production. She reviewed the revised manuscript before she sent it to ace copyeditor Anita Hueftle. Anita saved us on many occasions from public embarrassment by finding our spelling and grammar errors, our logical lapses, and various other inconsistencies. We can't thank Anita enough for her meticulous and outstanding work! (Any remaining errors are our fault.)

At the same time the text was in revision, the art program was going through a similar process. This book would not be what it is without the help of Laura Southworth, our superb Art Development Editor. Laura's creativity, attention to detail, and her sense of what will teach well and what won't have helped us immensely. She has worked tirelessly to make our Focus figures and other art even better. Finding good, usable photos is never easy, and we are grateful for the hard work of Kristin Piljay (Photo Researcher). It was also a pleasure to work with Jean Lake again, who expertly juggled the administrative aspects of the art program and kept us all on track. This team ensured that the artists at Imagineering had all the information they needed to produce beautiful final art products.

As the manuscript made the transition from Editorial to Production, Michelle Mangelli (wearing a different hat—this

one as the Production and Design Manager) took over again. As head honcho and skilled handler of all aspects of production, everyone answered to her from this point on. Kudos to our excellent production coordinator, Karen Gulliver, who did much of the hands-on handling, routing, and scheduling of the manuscript. We'd also like to thank Martha Ghent (Proofreader), Betsy Dietrich (Art Proofreader), Sallie Steele (Indexer), Alicia Elliot (Project Manager at Imagineering), and Cenveo (Compositor). Izak Paul meticulously read every chapter for scientific accuracy, and we are very grateful for his careful work. Thanks also to Gary Hespeneide for his stunning design work on the cover, chapter opening pages, and the text.

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Kudos to our entire team. We feel we have once again prepared a superb textbook. We hope you agree.

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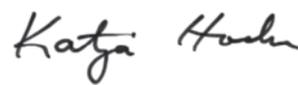
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