

A vertical splash of water on the left side of the page, with droplets and bubbles, set against a light green background.

# Precalculus

Concepts Through Functions

A Unit Circle Approach to Trigonometry

3

Sullivan  
Sullivan

## Getting Ready

Are you frustrated when you know you learned a math concept in the past, but you can't quite remember the skill when it's time to use it? Don't worry!

The authors have included Getting Ready material so you can brush up on forgotten material efficiently by taking a quick skill review quiz to pinpoint the areas where you need help.

Then, a personalized homework assignment provides additional practice on those forgotten concepts, right when you need it.

Item ID	Assignment
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## Retain Your Knowledge

As you work through your math course, these MyMathLab<sup>®</sup> exercises support ongoing review to help you maintain essential skills.

The ability to recall important math concepts as you continually acquire new mathematical skills will help you be successful in this math course and in your future math courses.



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# Achieve Your Potential

The authors, Michael Sullivan and Michael Sullivan, III, have developed specific content in MyMathLab® to ensure you have many resources to help you achieve success in mathematics - and beyond!

The MyMathLab features described here will help you:

- **Brush up** on math skills and concepts you may have forgotten
- **Retain** new concepts as you move through your math course
- **Develop** skills that will help with your transition to college to your profession

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The Study Plan will help you study more efficiently and effectively.

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The screenshot shows the 'Study Plan' interface. At the top, it says 'Study Plan' and 'Study Plan'. Below that, it indicates 'You have completed 0 of 817 study goals (0%)' and 'Practice items assigned and completed about 10%'. The main section is titled 'What to work on next' and lists several goals. The first goal is 'Identify types of numbers' with 'Practice' and 'Quiz Me' buttons and '0 of 1' progress. Below it, a section titled 'More objectives to practice and master' lists four more goals: 'Introduction System', 'Introduction to a number line', 'The number system', and 'Calculate with real numbers'. Each of these goals has 'Practice' and 'Quiz Me' buttons and '0 of 1' progress. The MyMathLab logo is in the bottom right corner.



## Skills for Success

The Skills for Success Module supports your continued success in college.

This module provides tutorials and guidance on a variety of topics, including transitioning to college, online learning, time management and more.

Additional content is provided to help with the development of professional skills such as resume writing or creation and interview preparation.

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# Precalculus

Concepts Through Functions

A Unit Circle Approach To Trigonometry

## Third Edition

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Chicago State University

**Michael Sullivan, III**

Joliet Junior College

**PEARSON**

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*Maeve, Sean, and Nolan (Sullivan)*

*Kaleigh, Billy, and Timmy (O'Hara)*

*The Next Generation*



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# To the Student

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As you begin, you may feel anxious about the number of theorems, definitions, procedures, and equations. You may wonder if you can learn it all in time. Don't worry, your concerns are normal. This textbook was written with you in mind. If you attend class, work hard, and read and study this book, you will build the knowledge and skills you need to be successful. Here's how you can use the book to your benefit.

## Read Carefully

When you get busy, it's easy to skip reading and go right to the problems. Don't . . . the book has a large number of examples and clear explanations to help you break down the mathematics into easy-to-understand steps. Reading will provide you with a clearer understanding, beyond simple memorization. Read before class (not after) so you can ask questions about anything you didn't understand. You'll be amazed at how much more you'll get out of class if you do this.

## Use the Features

We use many different methods in the classroom to communicate. Those methods, when incorporated into the book, are called "features." The features serve many purposes, from providing timely review of material you learned before (just when you need it), to providing organized review sessions to help you prepare for quizzes and tests. Take advantage of the features and you will master the material.

To make this easier, we've provided a brief guide to getting the most from this book. Refer to the "Prepare for Class," "Practice," and "Review" on pages xxi–xxiii. Spend fifteen minutes reviewing the guide and familiarizing yourself with the features by flipping to the page numbers provided. Then, as you read, use them. This is the best way to make the most of your textbook.

Please do not hesitate to contact us, through Pearson Education, with any questions, suggestions, or comments that would improve this text. We look forward to hearing from you, and good luck with all of your studies.

*Best Wishes!*

*Michael Sullivan*

*Michael Sullivan, III*

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# Three Distinct Series

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Students have different goals, learning styles, and levels of preparation. Instructors have different teaching philosophies, styles, and techniques. Rather than write one series to fit all, the Sullivans have written three distinct series. All share the same goal—to develop a high level of mathematical understanding and an appreciation for the way mathematics can describe the world around us. The manner of reaching that goal, however, differs from series to series.

## Concepts through Functions Series, Third Edition

This series differs from the others, utilizing a functions approach that serves as the organizing principle tying concepts together. Functions are introduced early in various formats. This approach supports the Rule of Four, which states that functions are represented symbolically, numerically, graphically, and verbally. Each chapter introduces a new type of function and then develops all concepts pertaining to that particular function. The solutions of equations and inequalities, instead of being developed as stand-alone topics, are developed in the context of the underlying functions. Graphing utility coverage is optional and can be included or excluded at the discretion of the instructor: *College Algebra*; *Precalculus, with a Unit Circle Approach to Trigonometry*; *Precalculus, with a Right Triangle Approach to Trigonometry*.

## Contemporary Series, Ninth Edition

The Contemporary Series is the most traditional in approach yet modern in its treatment of precalculus mathematics. Graphing utility coverage is optional and can be included or excluded at the discretion of the instructor: *College Algebra*, *Algebra & Trigonometry*, *Trigonometry*, *Precalculus*.

## Enhanced with Graphing Utilities Series, Sixth Edition

This series provides a thorough integration of graphing utilities into topics, allowing students to explore mathematical concepts and foreshadow ideas usually studied in later courses. Using technology, the approach to solving certain problems differs from the Concepts or Contemporary Series, while the emphasis on understanding concepts and building strong skills does not: *College Algebra*, *Algebra & Trigonometry*, *Precalculus*.

# Preface to the Instructor

As professors at both an urban university and a community college, Michael Sullivan and Michael Sullivan, III, are aware of the varied needs of Precalculus students, ranging from those who have little mathematical background and a fear of mathematics courses, to those having a strong mathematical education and a high level of motivation. For some of your students, this will be their last course in mathematics, whereas others will further their mathematical education. This text is written for both groups.

As a teacher, and as an author of precalculus, engineering calculus, finite mathematics, and business calculus texts, Michael Sullivan understands what students must know if they are to be focused and successful in upper-level math courses. However, as a father of four, he also understands the realities of college life. As an author of a developmental mathematics series, Michael's co-author and son, Michael Sullivan, III, understands the trepidations and skills students bring to the Precalculus course. Michael, III also believes in the value of technology as a tool for learning that enhances understanding without sacrificing math skills. Together, both authors have taken great pains to ensure that the text contains solid, student-friendly examples and problems, as well as a clear and seamless writing style.

A tremendous benefit of authoring a successful series is the broad-based feedback we receive from teachers and students. We are sincerely grateful for their support. Virtually every change in this edition is the result of their thoughtful comments and suggestions. We are sincerely grateful for this support and hope that we have been able to take these ideas and, building upon a successful first edition, make this series an even better tool for learning and teaching. We continue to encourage you to share with us your experiences teaching from this text.

## About This Book

This book utilizes a functions approach to Precalculus. Functions are introduced early (Chapter 1) in various formats: maps, tables, sets of ordered pairs, equations, and graphs. Our approach to functions illustrates the symbolic, numeric, graphic, and verbal representations of functions. This allows students to make connections between the visual representation of a function and its algebraic representation.

It is our belief that students need to “hit the ground running” so that they do not become complacent in their studies. After all, it is highly likely that students have been exposed to solving equations and inequalities prior to entering this class. By spending precious time reviewing these concepts, students are likely to think of the course as a rehash of material learned in other courses and say to themselves, “I know this material, so I don't have to study.” This may result in the students developing poor study habits for

this course. By introducing functions early in the course, students are less likely to develop bad habits.

Another advantage of the early introduction of functions is that the discussion of equations and inequalities can focus around the concept of a function. For example, rather than asking students to solve an equation such as  $2x^2 + 5x + 2 = 0$ , we ask students to find the zeros of  $f(x) = 2x^2 + 5x + 2$  or solve  $f(x) = 0$  when  $f(x) = 2x^2 + 5x + 2$ . While the technique used to solve this type of problem is the same, the fact that the problem looks different to the student means the student is less apt to say, “Oh, I already have seen this problem before, and I know how to solve it.” In addition, in Calculus students are going to be asked to solve equations such as  $f'(x) = 0$ , so solving  $f(x) = 0$  is a logical prerequisite skill to practice in Precalculus. Another advantage to solving equations through the eyes of a function is that the properties of functions can be included in the solution. For example, the linear function  $f(x) = 2x - 3$  has one real zero because the function  $f$  is increasing on its domain.

## Features in the Third Edition

Rather than provide a list of new features here, that information can be found on pages xxi–xxiii.

This places the new features in their proper context, as building blocks of an overall learning system that has been carefully crafted over the years to help students get the most out of the time they put into studying. Please take the time to review the features listed on pages xxi–xxiii and to discuss them with your students at the beginning of your course. Our experience has been that when students utilize these features, they are more successful in the course.

## New to the Third Edition

- **Retain Your Knowledge** This new category of problems in the exercise set are based on the article “To Retain New Learning, Do the Math” published in the *Educati Review* in which author Kevin Washburn suggests that “the more students are required to recall new content or skills, the better their memory will be.” It is frustrating when students cannot recall skills learned earlier in the course. To alleviate this recall problem, we have created “Retain Your Knowledge” problems. These are problems considered to be “final exam material” that students must complete to maintain their skills. All the answers to these problems appear in the back of the book and all are programmed in MyMathLab.
- **Guided Lecture Notes** Ideal for online, emporium/re-design courses, inverted classrooms or traditional lecture classrooms. These lecture notes assist students in taking thorough, organized, and understandable notes as they watch the Author in Action videos by asking students to complete definitions, procedures, and examples based

on the content of the videos and book. In addition, experience suggests that students learn by doing and understanding the why/how of the concept or property. Therefore, many sections will have an exploration activity to motivate student learning. These explorations will introduce the topic and/or connect it somehow to either a real world application or previous section. For example, when teaching about the vertical line test in Section 1.2, after the theorem statement, the notes ask the students to explain why the vertical line test works by using the definition of a function. This helps students process the information at a higher level of understanding.

- **Chapter Projects**, which apply the concepts of each chapter to a real-world situation, have been enhanced to give students an up-to-the-minute experience. Many projects are new and Internet-based, requiring the student to research information online in order to solve problems.
- **Author Solves It MathXL Video Clips**—author Michael Sullivan, III solves MathXL exercises typically requested by his students for more explanation or tutoring. These videos are a result of Sullivan’s experiences in the classroom and experiences in teaching online.
- **Exercise Sets** at the end of each section remain classified according to purpose. The “*Are You Prepared?*” exercises have been expanded to better serve the student who needs a just-in-time review of concepts utilized in the section. The *Concepts and Vocabulary* exercises have been updated. These fill-in-the-blank and True/False problems have been written to serve as reading quizzes. *Skill Building* exercises develop the student’s computational skills and are often grouped by objective. *Mixed Practice* exercises have been added where appropriate. These problems offer a comprehensive assessment of the skills learned in the section by asking problems that relate to more than one objective. Sometimes these require information from previous sections so students must utilize skills learned throughout the course. *Applications and Extension* problems have been updated and many new problems involving sourced information and data have been added to bring relevance and timeliness to the exercises. The *Explaining Concepts: Discussion and Writing* exercises have been updated and reworded to stimulate discussion of concepts in online discussion forums. These can also be used to spark classroom discussion. Finally, in the **Annotated Instructor’s Edition**, we have preselected problems that can serve as sample homework assignments. These are indicated by a blue underline, and they are assignable in MyMathLab<sup>®</sup> as part of a “Ready-to-Go” course, if desired.
- The **Chapter Review** now includes answers to all the problems. We have created a separate review worksheet for each chapter to help students review and practice key skills to prepare for exams. The worksheets can be found within MyMathLab<sup>®</sup> or downloaded from the Instructor’s Resource Center.

## Changes in the Third Edition

### • CONTENT

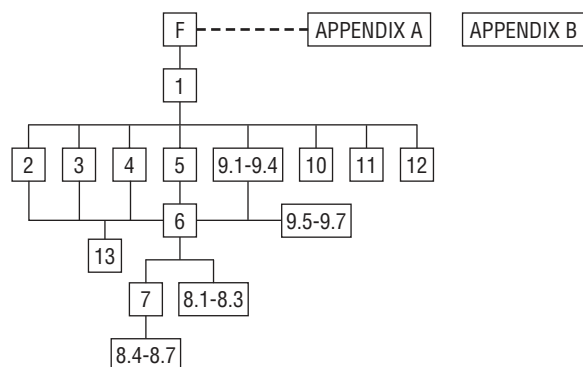
- **Chapter 2, Section 4** A new objective “Find a quadratic function given its vertex and one point” has been added.
- **Chapter 2, Section 5** A new example was added to illustrate that quadratic inequalities may have the empty set or all real numbers as a solution.
- **Chapter 3, Sections 1 and 4** The content related to describing the behavior of the graph of a polynomial or rational function near a zero has been removed.
- **Chapter 3, Section 4** Content has been added that discusses the role of multiplicity and behavior of the graph of rational function as the graph approaches a vertical asymptote.

### • ORGANIZATION

- **Chapter 3, Sections 5 and 6** Section 5, *The Real Zeros of a Polynomial Function* and Section 6, *Complex Zeros, Fundamental Theorem of Algebra* have been moved to Sections 2 and 3, respectively. This was done in response to reviewer requests that “everything involving polynomials” be located sequentially. Skipping the new Sections 2 and 3 and proceeding to Section 4 *Properties of Rational Functions* can be done without loss of continuity.

## Using this Book Effectively and Efficiently with Your Syllabus

To meet the varied needs of diverse syllabi, this book contains more content than is likely to be covered in a typical Precalculus course. As the chart illustrates, this book has been organized with flexibility of use in mind. Even within a given chapter, certain sections are optional and can be omitted without loss of continuity. See the detail following the flow chart.



### Foundations A Prelude to Functions

Quick coverage of this chapter, which is mainly review material, will enable you to get to Chapter 1, *Functions and Their Graphs*, earlier.

**Chapter 1 Functions and Their Graphs**

Perhaps the most important chapter. Sections 1.6 and 1.7 are optional.

**Chapter 2 Linear and Quadratic Functions**

Topic selection depends on your syllabus. Sections 2.2, 2.6, and 2.7 may be omitted without a loss of continuity.

**Chapter 3 Polynomial and Rational Functions**

Topic selection depends on your syllabus. Section 3.6 is optional.

**Chapter 4 Exponential and Logarithmic Functions**

Sections 4.1–4.6 follow in sequence. Sections 4.7–4.9 are optional.

**Chapter 5 Trigonometric Functions**

The sections follow in sequence. Section 5.6 is optional.

**Chapter 6 Analytic Trigonometry**

Sections 6.2 and 6.7 may be omitted in a brief course.

**Chapter 7 Applications of Trigonometric Functions**

Sections 7.4 and 7.5 may be omitted in a brief course.

**Chapter 8 Polar Coordinates; Vectors**

Sections 8.1–8.3 and Sections 8.4–8.7 are independent and may be covered separately.

**Chapter 9 Analytic Geometry**

Sections 9.1–9.4 follow in sequence. Sections 9.5, 9.6, and 9.7, are independent of each other, but each requires Sections 9.1–9.4.

**Chapter 10 Systems of Equations and Inequalities**

Sections 10.2–10.7 may be covered in any order. Section 10.8 requires Section 10.7.

**Chapter 11 Sequences; Induction; the Binomial Theorem**

There are three independent parts: Sections 11.1–11.3, Section 11.4, and Section 11.5.

**Chapter 12 Counting and Probability**

The sections follow in sequence.

**Chapter 13 A Preview of Calculus: The Limit, Derivative, and Integral of a Function**

If time permits, coverage of this chapter will provide your students with a beneficial head-start in calculus. The sections follow in sequence.

Gary Amara—South Maine Community College  
 Richard Andrews—Florida A&M University  
 Jay Araas—Sheridan College  
 Jessica Bernards—Portland Community college  
 Rebecca Berthiaume—Edison State College  
 Susan Bradley—Angelina College  
 Michael Brook—University of Delaware  
 Tim Chappell—Penn Valley Community College  
 Christine Cole—Moorpark College  
 Alicia Collins—Mesa Community College  
 Rebecca Cosner—Spokane Community College  
 Jerry DeGroot—Purdue North Central  
 Joanna DelMonaco—Middlesex Community College

Stephanie Deacon—Liberty University  
 Jerrett Dumouchel—Florida Community College at Jacksonville  
 Vaden Fitton—North Virginia Community College  
 Carrie Rose Gibson—North Idaho College  
 Nina Girard—University of Pittsburgh at Johnstown  
 Mary Beth Grayson—Liberty University  
 Scott Greenleaf—South Maine Community College  
 Donna Harbin—University of Hawaii-Maui  
 Celeste Hernandez—Richland College  
 Gloria P. Hernandez—Louisiana State University at Eunice

Maritza Jimenez-Zeljak—Los Angeles Harbor College  
 Glenn Johnson—Middlesex Community College  
 Susitha Karunaratne—Purdue University North Central  
 Debra Kopcsó—Louisiana State University  
 Yelena Kravchuk—University of Alabama at Birmingham  
 Mary Krohn—Butler University  
 Lynn Marecek—Santa Ana College  
 James McLaughlin—West Chester University  
 Kathleen Miranda—SUNY at Old Westbury  
 Chris Mirbaha—The Community College of Baltimore County

**Appendix A Review**

This review material may be covered at the start of a course or used as a just-in-time review. Specific references to this material occur throughout the text to assist in the review process.

**Appendix B Graphing Utilities**

Reference is made to these sections at the appropriate place in the text.

**Acknowledgments**

Textbooks are written by authors, but evolve from an idea to final form through the efforts of many people. It was Don Dellen who first suggested this book and series. Don is remembered for his extensive contributions to publishing and mathematics.

Thanks are due to the following people for their assistance and encouragement to the preparation of this edition:

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- Bob Walters, Production Manager, who passed away after a long and valiant battle fighting lung disease. He was an old and dear friend—a true professional in every sense of the word.
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# Prepare for Class “Read the Book”

Feature	Description	Benefit	Page
<b>Every Chapter Opener begins with...</b>			
<b>Chapter Opening Article &amp; Project</b>	Each chapter begins with a current article and ends with a related project. The article describes a real situation.	The Article describes a real situation. The Project lets you apply what you learned to solve a related problem.	273, 374
<b>NEW! Internet Based Projects</b>	The projects allow for the integration of spreadsheet technology that students will need to be a productive member of the workforce.	The projects allow the opportunity for students to collaborate and use mathematics to deal with issues that come up in their lives.	273, 374
<b>Every Section begins with...</b>			
<b>Learning Objectives</b>	Each section begins with a list of objectives. Objectives also appear in the text where the objective is covered.	These focus your studying by emphasizing what's most important and where to find it.	294
<b>Sections contain...</b>			
<b>Preparing for this Section</b>	Most sections begin with a list of key concepts to review with page numbers.	Ever forget what you've learned? This feature highlights previously earned material to be used in this section. Review it, and you'll be ready to move forward.	294
<b>Now Work the 'Are You Prepared?' Problems</b>	Problems that assess whether you have the prerequisite knowledge for the upcoming section.	Not sure you need the Preparing for This Section review? Work the 'Are You Prepared?' problems. If you get one wrong, you'll know exactly what you need to review and where to review it!	294, 305
<b>Now Work PROBLEMS</b>	These follow most examples and direct you to a related exercise.	We learn best by doing. You'll solidify your understanding of examples if you try a similar problem right away, to be sure you understand what you've just read.	307, 306
<b>WARNING</b>	Warnings are provided in the text.	These point out common mistakes and help you to avoid them.	328
<b>Exploration and Seeing the Concept</b>	These represent gripping utility activities to refresh a concept or solidify a concept just presented.	You will obtain a deeper and more intuitive understanding of theorems and definition.	200, 315
<b>In Words</b>	These provide alternative descriptions of select definitions and theorems.	Does math ever look foreign to you? This feature translates math into plain English.	311
<b>CALCULUS</b>	These appear next to information essential for the study of calculus.	Pay attention—if you spend extra time now, you'll do better later!	70, 307
<b>SHOWCASE EXAMPLES</b>	These examples provide “how to” instruction by offering a guided, step-by-step approach to solving a problem.	With each step presented on the left and the mathematics displayed on the right, students can immediately see how each step is employed.	204
<b>Model It! Examples and Problems</b>	These are examples and problems that require you to build a mathematical model from either a verbal description or data. The benchmark Model It! problems are marked by purple headings.	It is rare for a problem to come in the form, “Solve the following equation”. Rather, the equation must be developed based on an explanation of the problem. These problems require you to develop models that will allow you to describe the problem mathematically and suggest a solution to the problem.	319, 347



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