2. Motivation

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Reflect

This unit is devoted to using calculus to solve **optimization** problems. Optimization problems occur all over science and engineering. In broad terms, optimization problems are problems that ask you to determine where a function's value is largest or smallest.

Definition 2.1 To **maximize** a function, we find a point (x, y) where the value $f(x, y)$ is greater than (or equal to) the value at any other (nearby) point.

To **minimize** a function, we find a point (x, y) where the value $f(x, y)$ is less than (or equal to) the value at any other (nearby) point.

Here are some examples.

- Where is the largest primary source of oxygen production in the Mediterranean sea? (Where is the highest concentration of chlorophyll?)
- What is the smallest change to global carbon emissions necessary to mitigate effects of global warming?
- How can you design better machines to maximize the product output while minimizing the energy usage?
- How can you fit data to a mathematical model that gives the best predictions of future data?

In this first lecture, we will identify the mathematical characteristics of the gradient at local maxima and minima and use graphical methods to determine whether a point is a maximum or minimum.

In the next lecture, we will use higher order partial derivatives to determine if a point is really a maximum or minimum without graphical methods.

The third and fourth lectures introduce **constrained optimization** problems, which ask for the maximum or minimum of a function restricted to a region. This is the most common type of optimization problem one encounters in the real world.

The last lecture is an application of optimization to data science where we fit data to a linear model in a way that minimizes the error of the model. The type of error minimization scheme we will learn is called **least squares approximation.** (The process of fitting data to a linear model more generally is known as linear regression.)

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