Overview

> **The Variation in the Stats River**
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> With multiple sources of water, there are multiple sources of variation. In general, with data coming from several groups, we should consider both *within* group variation and *between* group variation.

Throughout statistics, we encounter situations where we would like to understand the relationships between two or more random variables, or use observed random variables to predict another random variable that has not yet been observed. This leads to the notion of *joint distributions*, in which we look at the probabilities for several random variables at the same time, rather than considering each random variable separately.

As the name suggests, *conditional expectation* is expectation, made conditional. Using conditional expectation, we can predict the value of one random variable, given the information we have about other random variables. Furthermore, conditional expectation is often useful even for finding *unconditional* expectations and variances, just as conditional probability is often useful for finding unconditional probabilities (via LOTP). For example, the fundamental identities known as *Adam's law* and *Eve's law* helped Jimmy to study the Bayesium content of a water bottle, allowing him to focus on the content *within* water sourced from each particular city and then *combine* the within-city quantities to obtain overall results.

Learning Objectives

In this section, you will:

- Define and connect joint, marginal, and conditional distributions
- Use covariance and correlation to study how two random variables vary together
- Generalize the Binomial distribution to the case where there are more than two categories (rather than having success and failure as the only categories)
- Generalize the Normal distribution to the multivariate setting
- Use conditional expectation, including properties such as Adam's law and Eve's law