ECON 0150 | Economic Data Analysis

The economist's data analysis skillset.

Part 3.1 | Data vs the Population

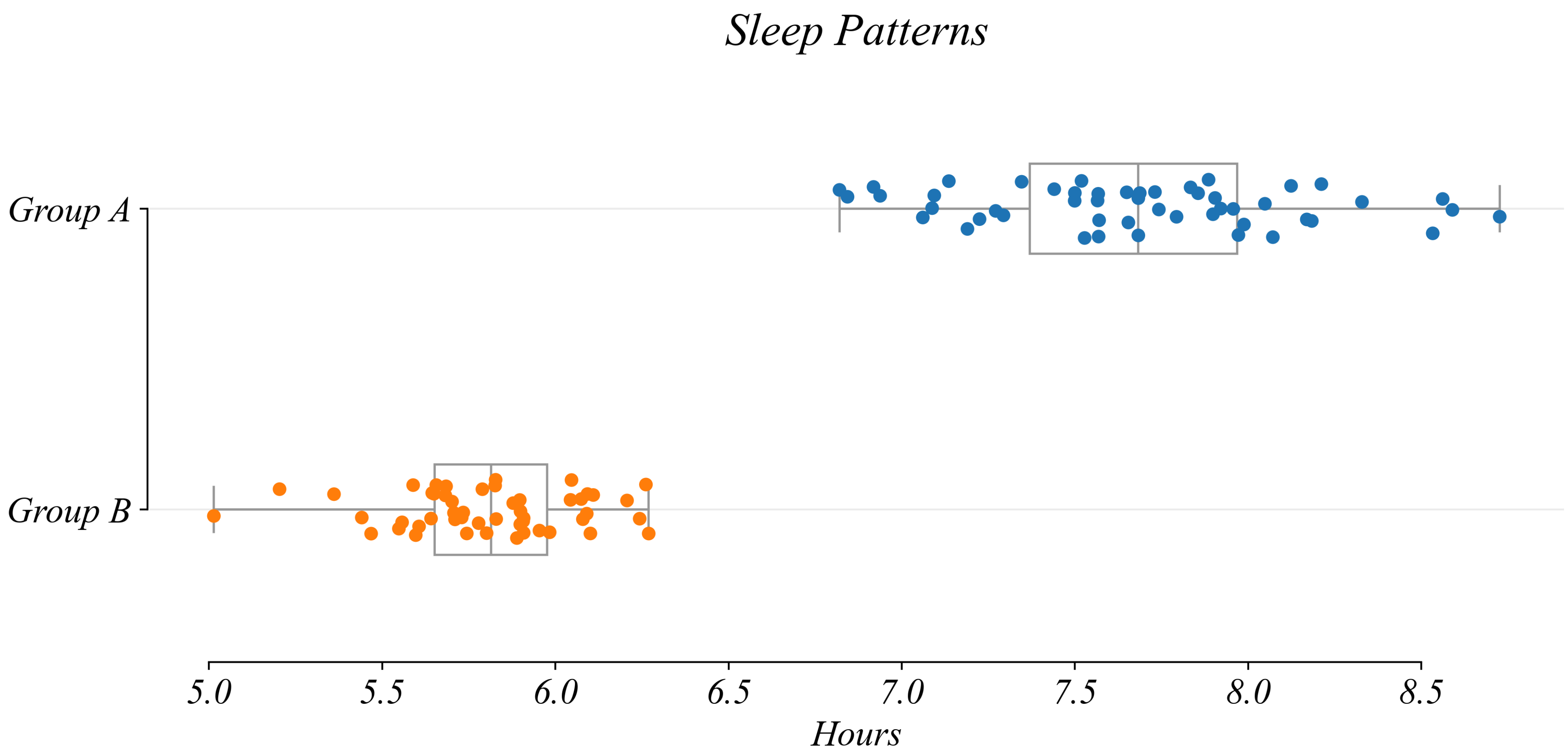
Inferences From Data

What can we infer about those not in our data?

- *We've **summarized** data*
- *But often we want to say something about the **population**, not just our **data***

Data Question 1: Sleep Time in Two Samples

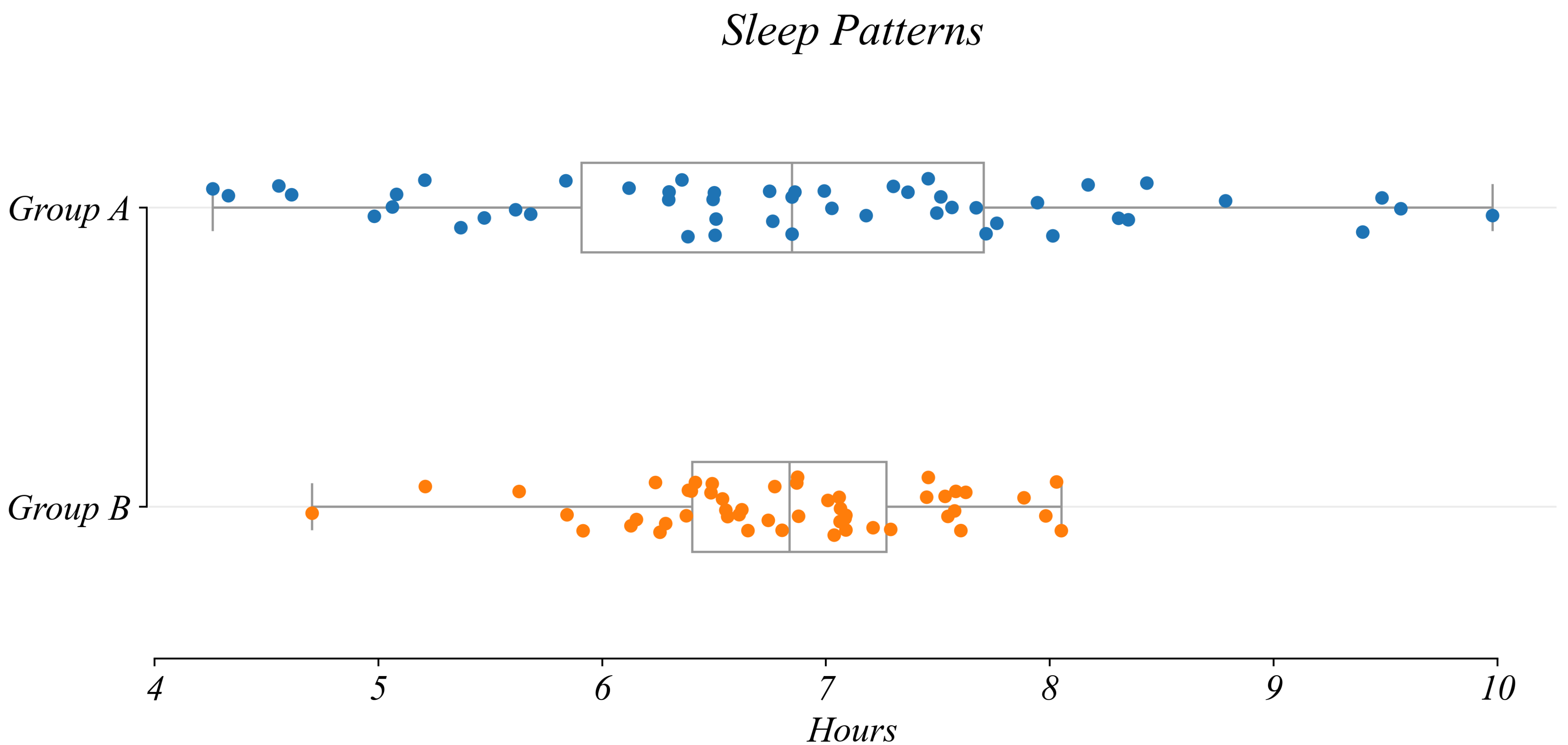
Which sample sleeps longer?



> *everyone in Group A sleeps longer than anyone in Group B*

Data Question 2: Sleep Time in Two Samples

Which sample sleeps longer?



> *these distributions overlap… lets compare them more precisely*

Measures of Location

Where is the "center" of each sample group?

Sample (Data) Mean: The average value

$$\bar{x} = \frac{x_1 + x_2 + \ldots x_N}{N}$$

Measures of Location

Where is the "center" of each sample group?

Sample (Data) Mean: The average value

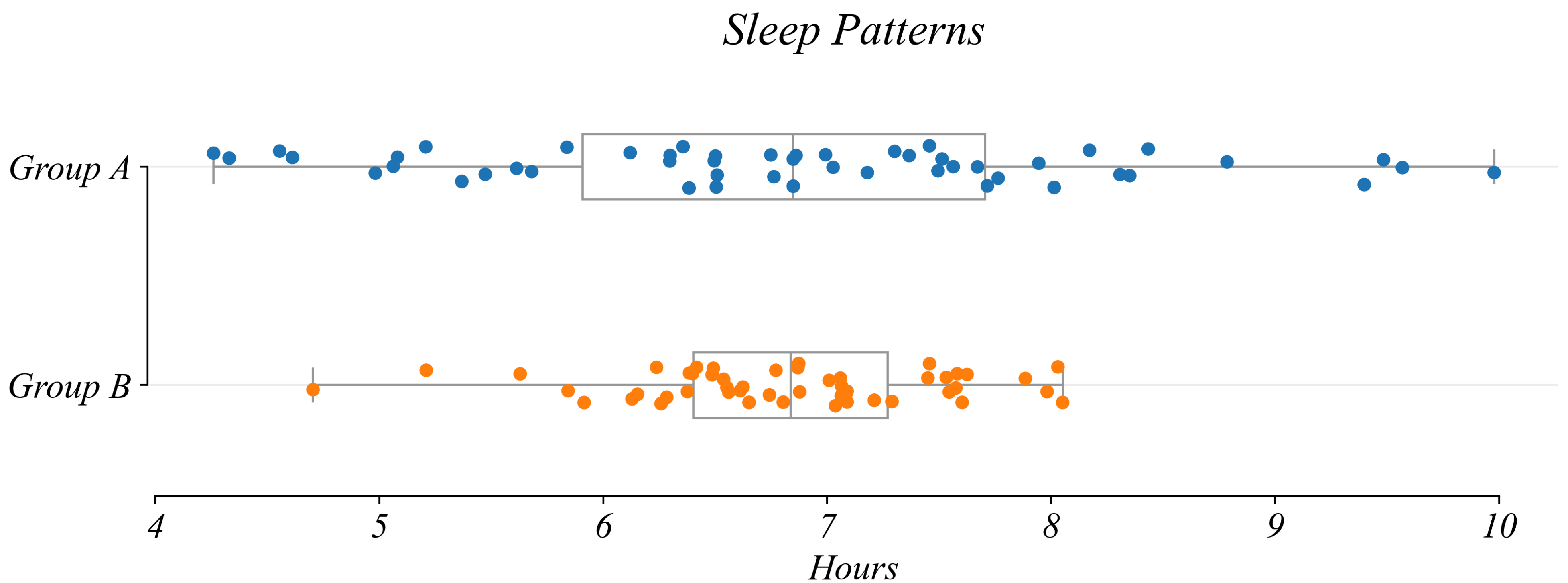
$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

```
# Calculate means
mean_A = group_A.mean()
mean_B = group_B.mean()
```

```
Group A mean: 7.20 hours
Group B mean: 6.72 hours
```

Data Question 2: Sleep Time in Two Samples

Which sample group sleeps longer?




```
Sample Group A mean: 7.20 hours
Sample Group B mean: 6.72 hours
```

> *Group A sleeps longer **on average*** in our sample

> *but some in Sample Group B sleep longer than most in Sample Group A!*

Measures of Dispersion

How spread out is the data?

Range: difference between the largest and smallest value in the data

- *Simple but doesn't respond to changes near the middle of the distribution*

Measures of Dispersion

How spread out is the data?

Mean Deviation: difference between each value and the average

$$\sum \frac{x_i - \bar{x}}{n}$$

- *Simple but the average of the difference is zero…*

Measures of Dispersion

How spread out is the data?

Mean Absolute Deviation: absolute value of the difference from the average

$$\sum \frac{|x_i - \bar{x}|}{n}$$

- *The mean isn't zero*
- *A little more complex and isn't so nice mathematically*

Measures of Dispersion

How spread out is the data?

Variance: average squared difference from the mean

$$Var_X = \sum \frac{(x_i - \bar{x})^2}{n}$$

- *Treats negatives appropriately*
- *The mean isn't zero*
- *Mathematically nice*
- *Units are uninformative*

Measures of Dispersion

How spread out is the data?

Standard Deviation: A measure of spread

$$S_X = \sqrt{\sum \frac{(x_i - \bar{x})^2}{n}}$$

- *Treats negatives appropriately*
- *The mean isn't zero*
- *Mathematically nice*
- *Units are roughly average deviation from the mean*

Measures of Dispersion

How spread out is the data?

Standard Deviation: A measure of spread

$$S_X = \sqrt{\sum \frac{(x_i - \bar{x})^2}{n}}$$

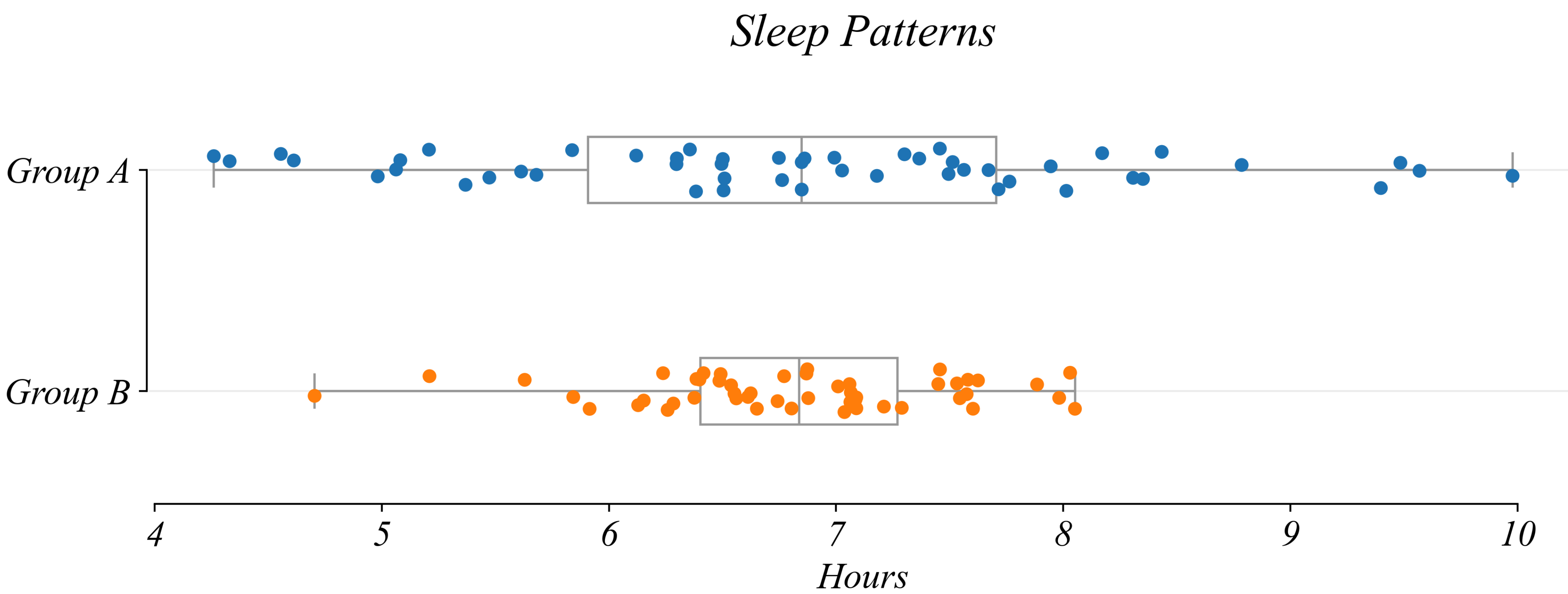
```
# Calculate standard deviations
std_A = group_A.std()
std_B = group_B.std()
```

```
Group A std dev: 1.60 hours
Group B std dev: 0.70 hours
```

> *Group A has **more variability** - some sleep much less, some much more*

Sample vs Population

Both sample groups are 50 people selected from two different counties.



Old question: "Which **sample group** sleeps longer?" *(about the **data**)*

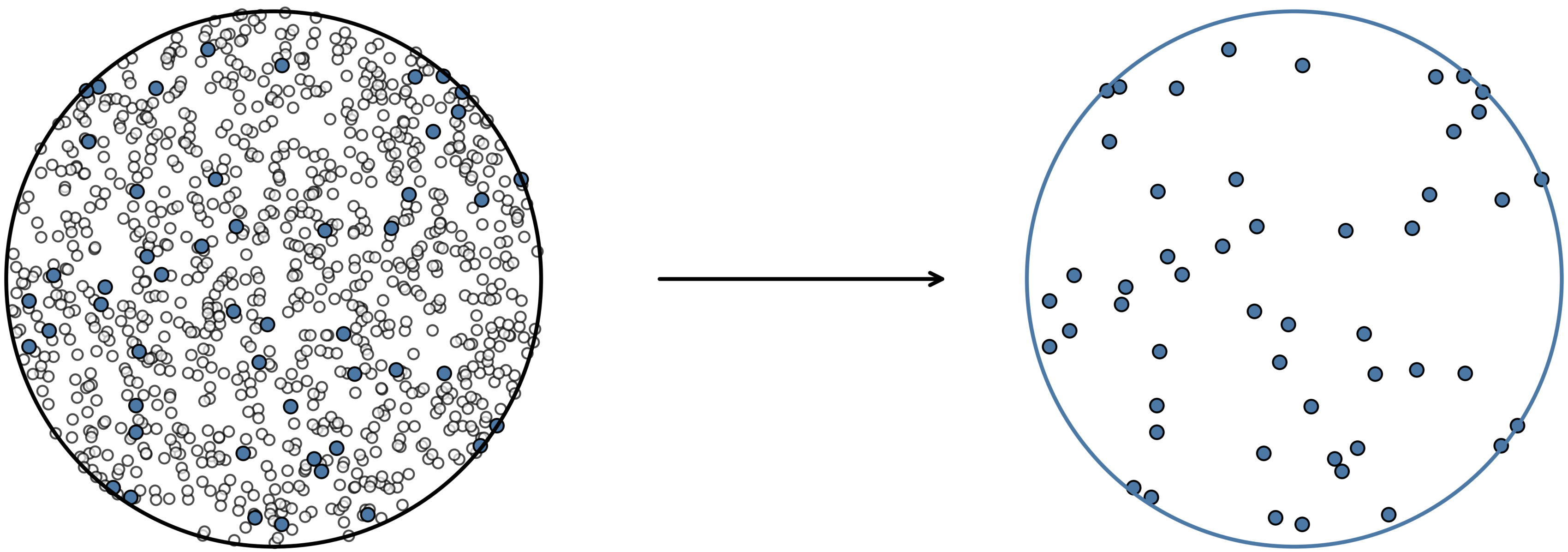
New question: "Which **county** sleeps longer?" *(about the **population**)*

Sample vs Population

The data is a sample drawn from a population.

Population (μ=?; σ=?)

Sample ($n = 50$; $\bar{x}$; S)



μ - population mean

σ - population standard deviation

Sample vs Population

*We observe **samples**. We study **populations**.*

- ***Data**: 50 individuals we happened to sample from both counties*
- ***Population**: All people who could live in these counties*
  - *Even if we surveyed everyone today, tomorrow would bring new residents*
  - *The population is a theoretical concept - an infinite pool of possibilities*

***Fundamental Tension**: we observe data, which is drawn from a population, but is not the population itself, which is the object of our study.*

Sample vs Population

What is data? A sample.

Random Variable: a random process about a population

- *the random variable is like a deck of cards*

Probability (Mass/Density) Function: a function that assigns probabilities to each possible outcome

- *the probability function is like which cards are in the deck*

Observation: a realization of a random variable . . .

- *the observation is the card you drew*

Sample: a collection of observations

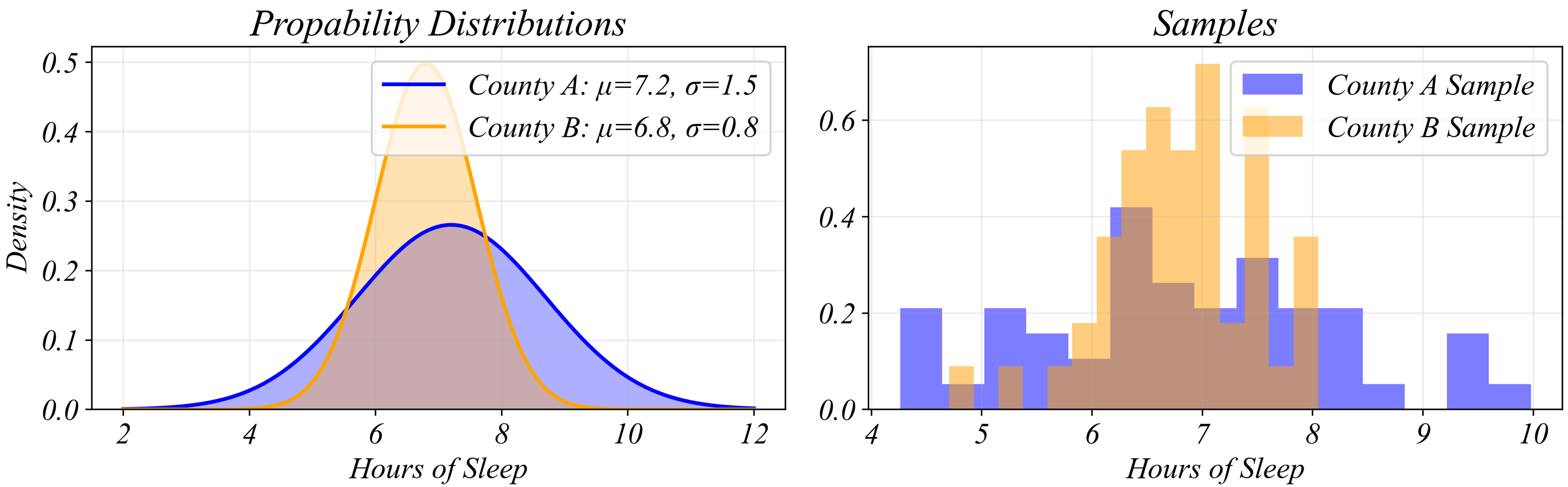
- *the sample is the record of cards you've drawn*

Data is a Sample

A random variable generates our data.

Random Variable: a random process about a population

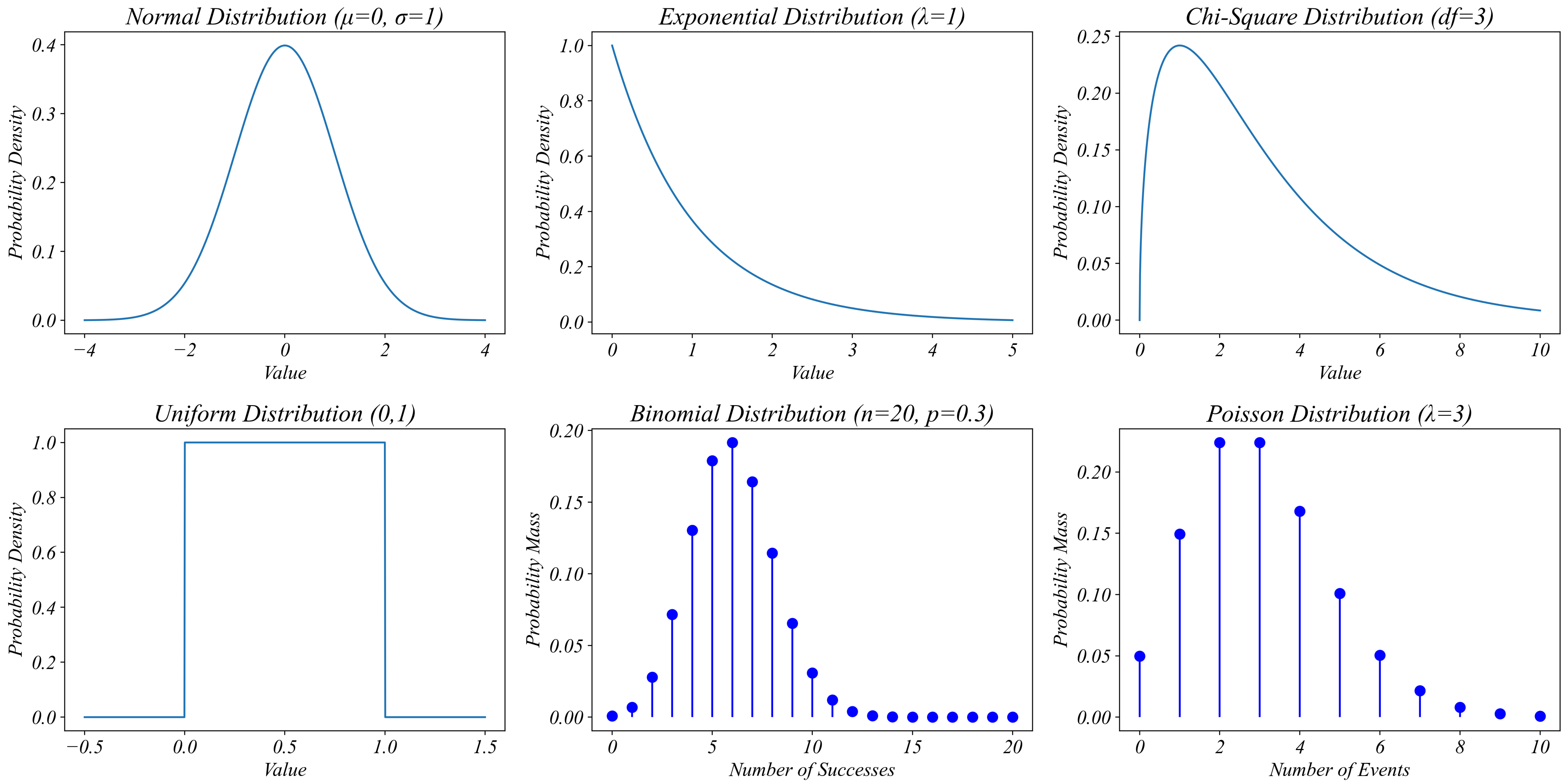
Probability Function: a function that assigns probabilities to each possibility



> ***data** is a **sample** drawn from a **random variable***

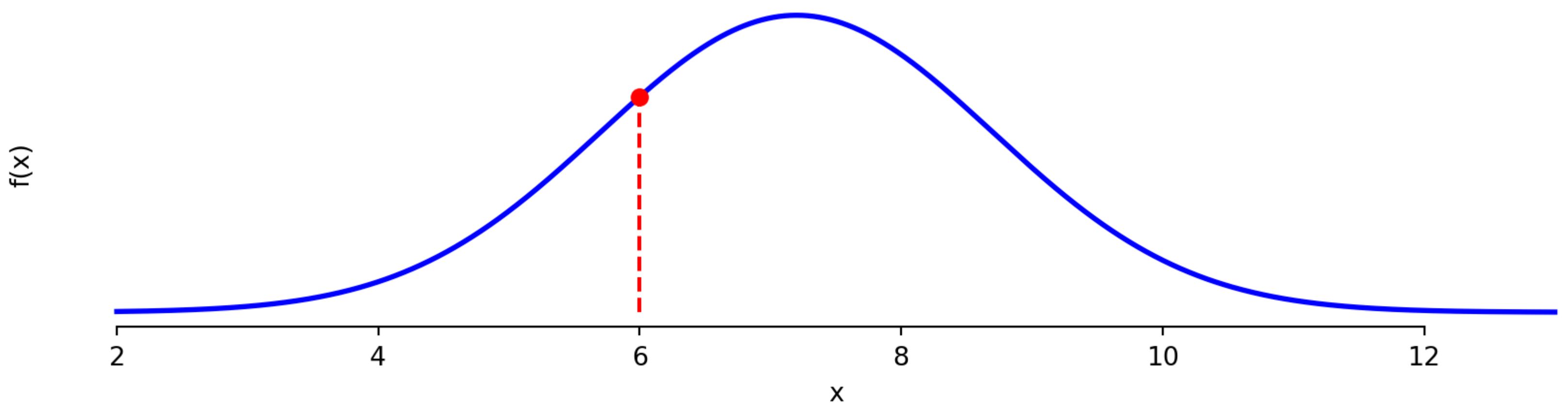
Probability Functions

Random variables can have many kinds of probability functions.



Probability Density Function (PDF)

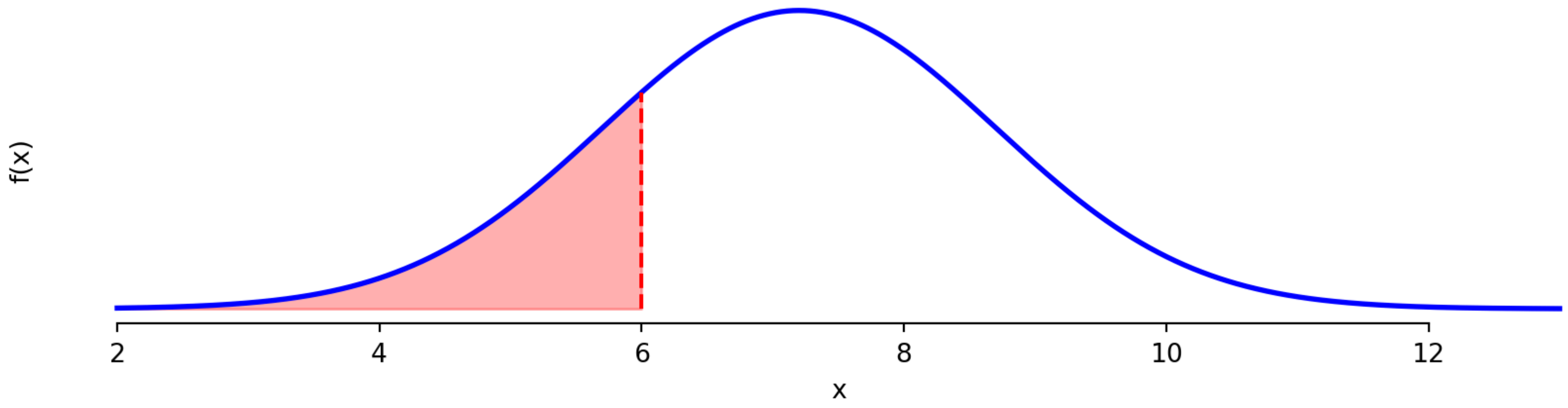
The height of $f(x)$ at each value.



1. $f(x) \geq 0$: *probabilities are never negative.*
2. $\int f(x)\, dx = 1$: *total probability sums to one.*

Cumulative Distribution Function (CDF)

The area under $f(x)$ up to each value — $F(x) = P(X \leq x)$.



*1. $F(x)$ **is non-decreasing**: more area accumulates as x increases.*

2. $F(-\infty) = 0$, $F(\infty) = 1$: ranges from 0 to 1.

*3. $F(x)$ **gives probability directly**: $P(X \leq 5) = F(5)$.*

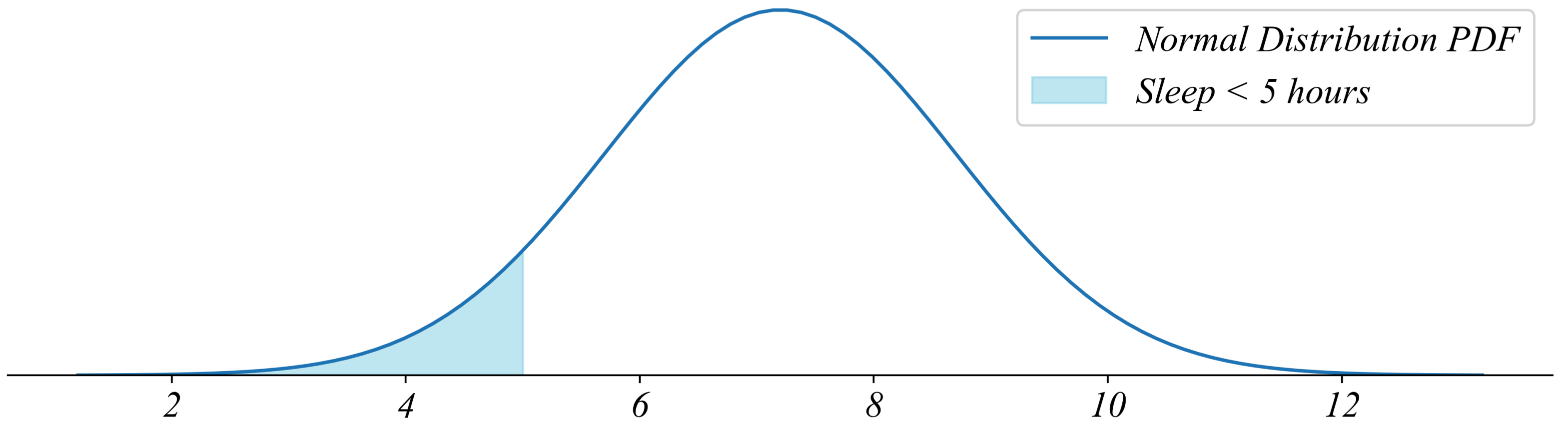
Exercise 3.1 | Known Distribution

*We can answer **many** kinds of probability questions when we know the distribution.*

County A's probability function:

$$x_i \sim N(\mu = 7.2, \sigma = 1.5)$$

1. What proportion of the population sleeps less than 5 hours?




```
stats.norm.cdf(5, loc=mu, scale=sigma).item()
```

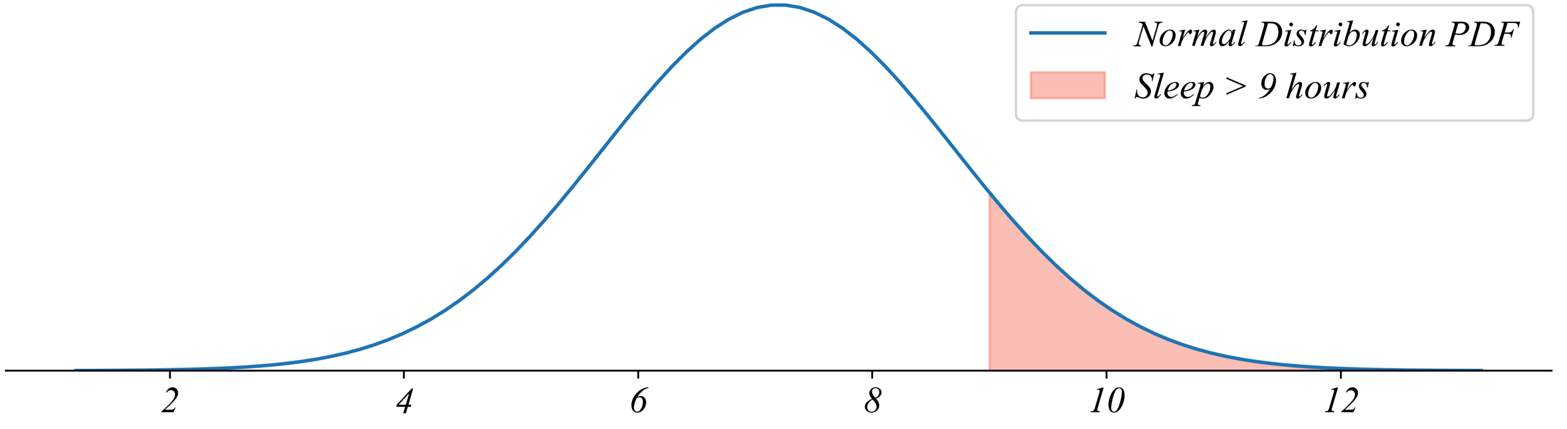
Exercise 3.1 | Known Distribution

*We can answer **many** kinds of probability questions when we know the distribution.*

County A's probability function:

$$x_i \sim N(\mu = 7.2, \sigma = 1.5)$$

2. What proportion of the population sleeps more than 9 hours?




```
1 - stats.norm.cdf(9, loc=mu, scale=sigma).item()
```

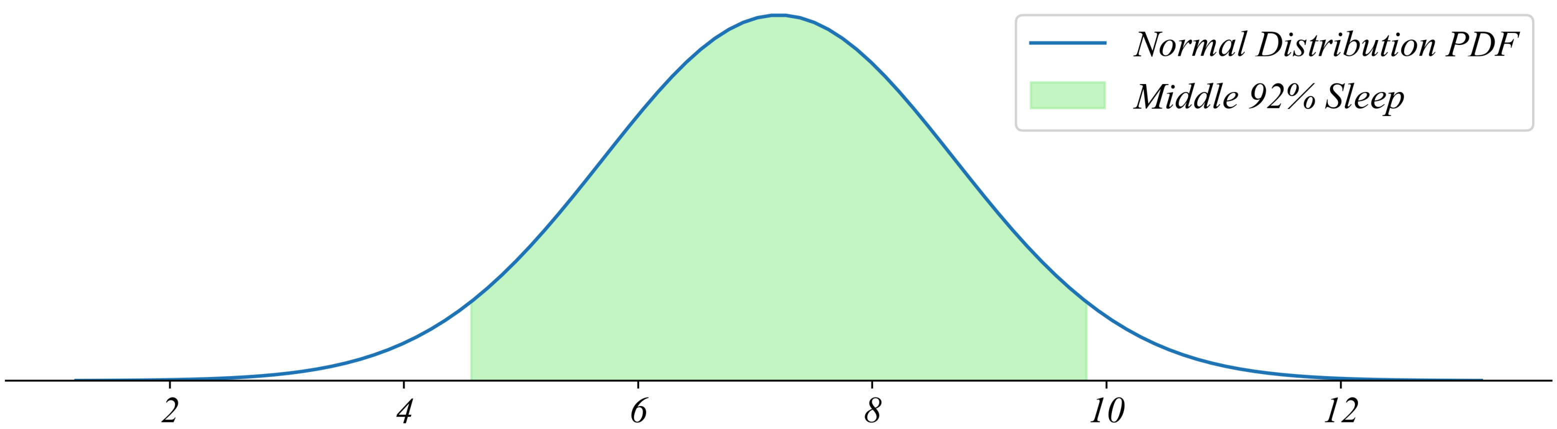
Exercise 3.1 | Known Distribution

*We can answer **many** kinds of probability questions when we know the distribution.*

County A's probability function:

$$x_i \sim N(\mu = 7.2, \sigma = 1.5)$$

3. How much sleep does the middle 92% of the population get?




```
lower_bound = stats.norm.ppf(0.04, loc=mu, scale=sigma)
upper_bound = stats.norm.ppf(0.96, loc=mu, scale=sigma)
```

Unknown Distributions

What can we say about an unknown population if all see see is the sample?

What we observe:

- *Sample size:* $n = 50$
- *Sample mean:* $\bar{x} = 7.24$ *hours*
- *Sample standard deviation:* $s = 1.48$ *hours*

What we want to know:

- *Population mean:* $\mu = ?$
- *Population standard deviation:* $\sigma = ?$
- *Population distribution:* $f(x) = ?$

Unknown Distributions

What can we say about an unknown population if all see see is the sample?

The sample statistics $(\bar{x}, S)$ are **not** the population parameters (μ, σ).

$$\bar{x} \neq \mu$$

$$s \neq \sigma$$

The Central Question

What can we say about an unknown population if all see see is the sample?

- *Part 3.2 | **Central Limit Theorem** - the distribution of the sample mean*
- *Part 3.3 | **Confidence Intervals** - the closeness of the sample mean to the truth*
- *Part 3.4 | **Statiscial Modeling** - testing wrongness of hypothetical relationships*

> we can answer questions about an unknown population using just a sample