

Understanding Canadian Demography with Mathematics

Math Camp 2025

Theoretical Population Biology

The use of mathematics and statistics to understand “populations”

- People → demographer
- Genes → population geneticist
- Cancer cells → oncologist
- Diseases → epidemiologist
- Organisms → ecologist
- Species → macroevolutionary biologist

Demography:

The study of the composition of a population.

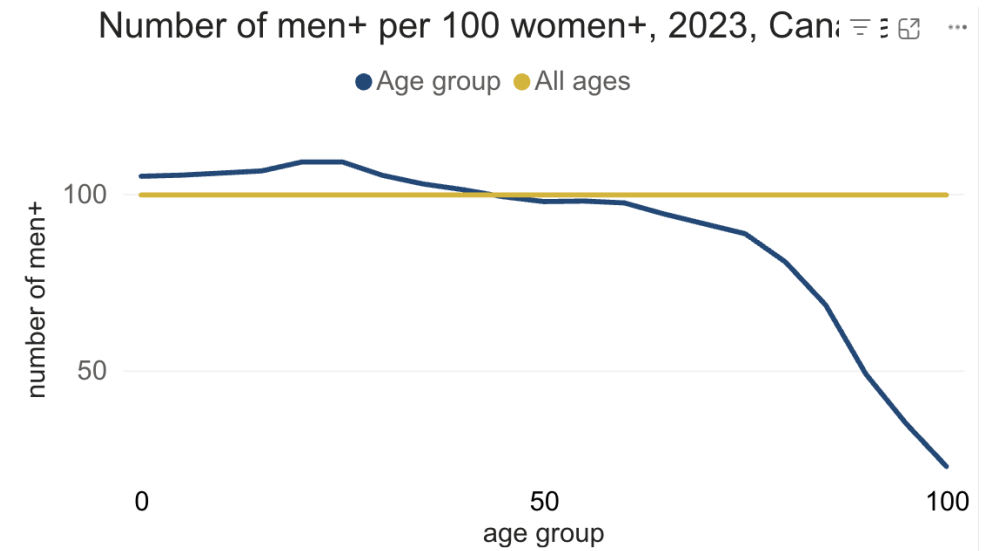
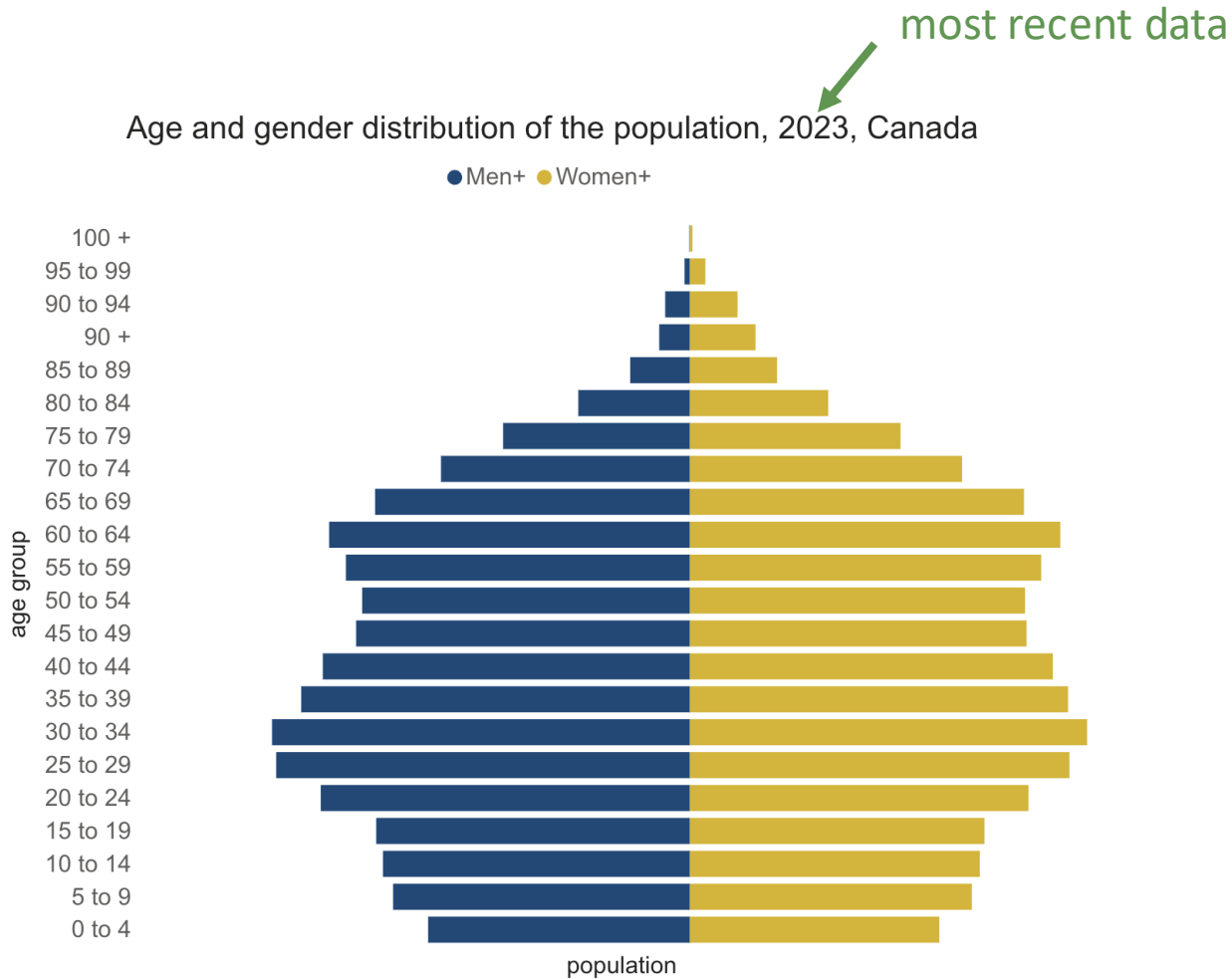
The study of births, deaths, aging, and migration.

Vocabulary
words are in
purple.



Data from Statistics Canada

Age and Gender Distribution of Canada in 2023

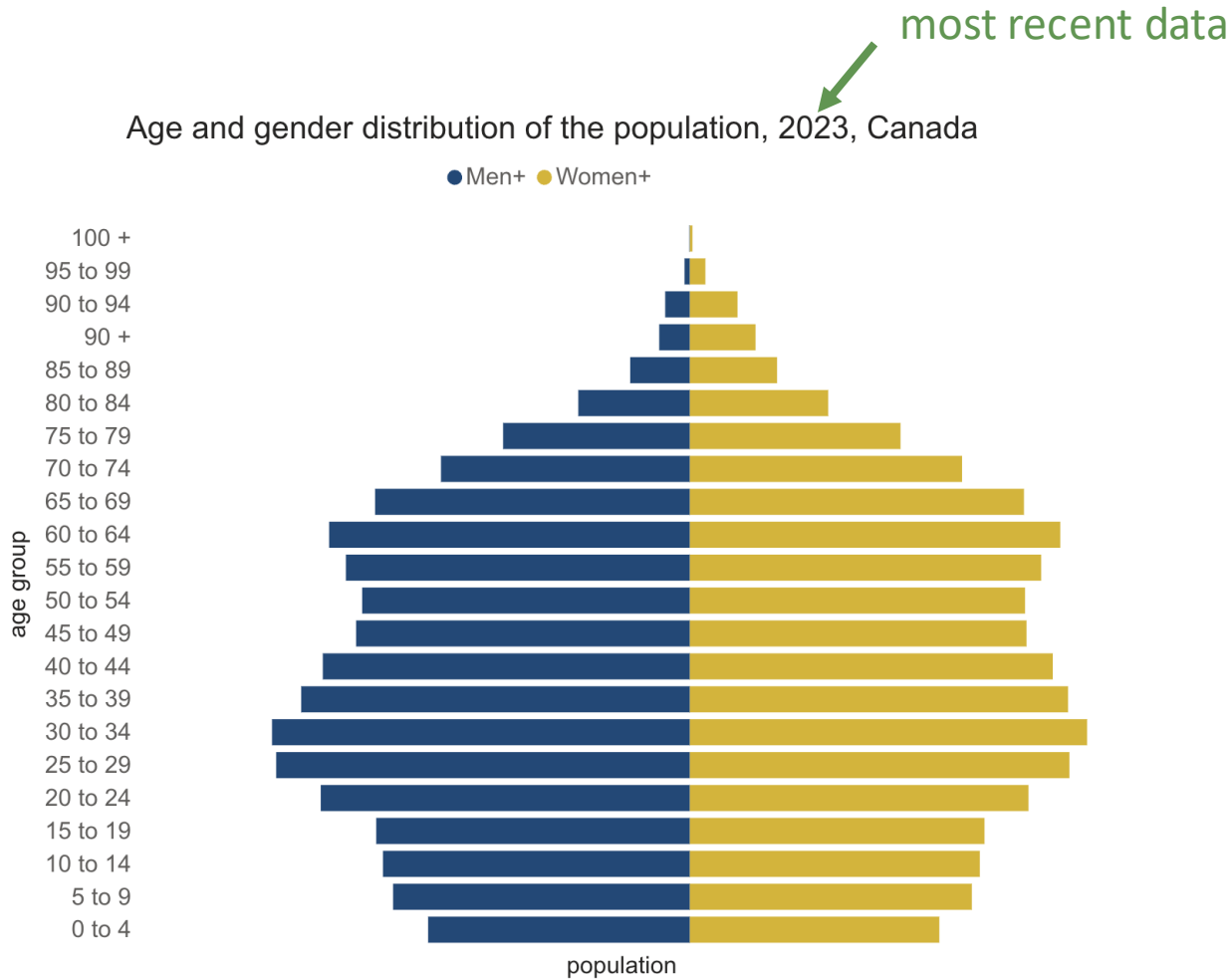


Q: What is the most common age to be in Canada? What is the least common age to be?

Q: In Canada, who lives longer, women or men?

Note: In demography we focus on people who self-report their gender as either men and women this does not mean that other genders do not exist.

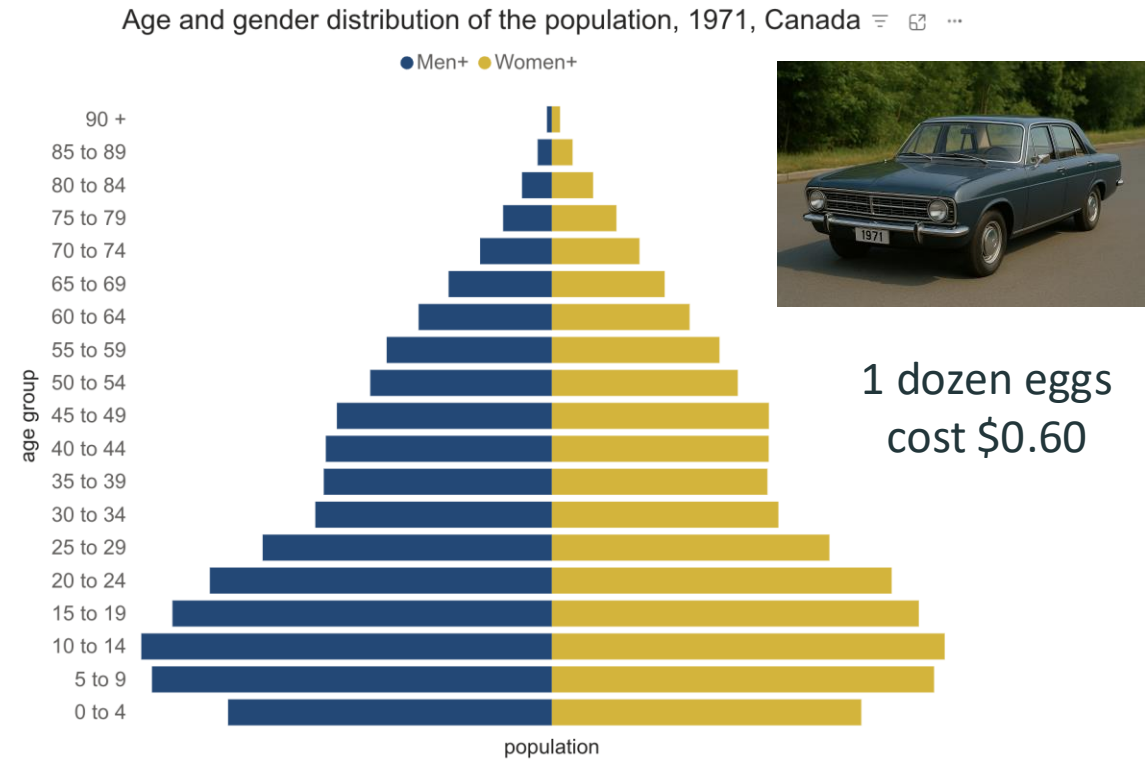
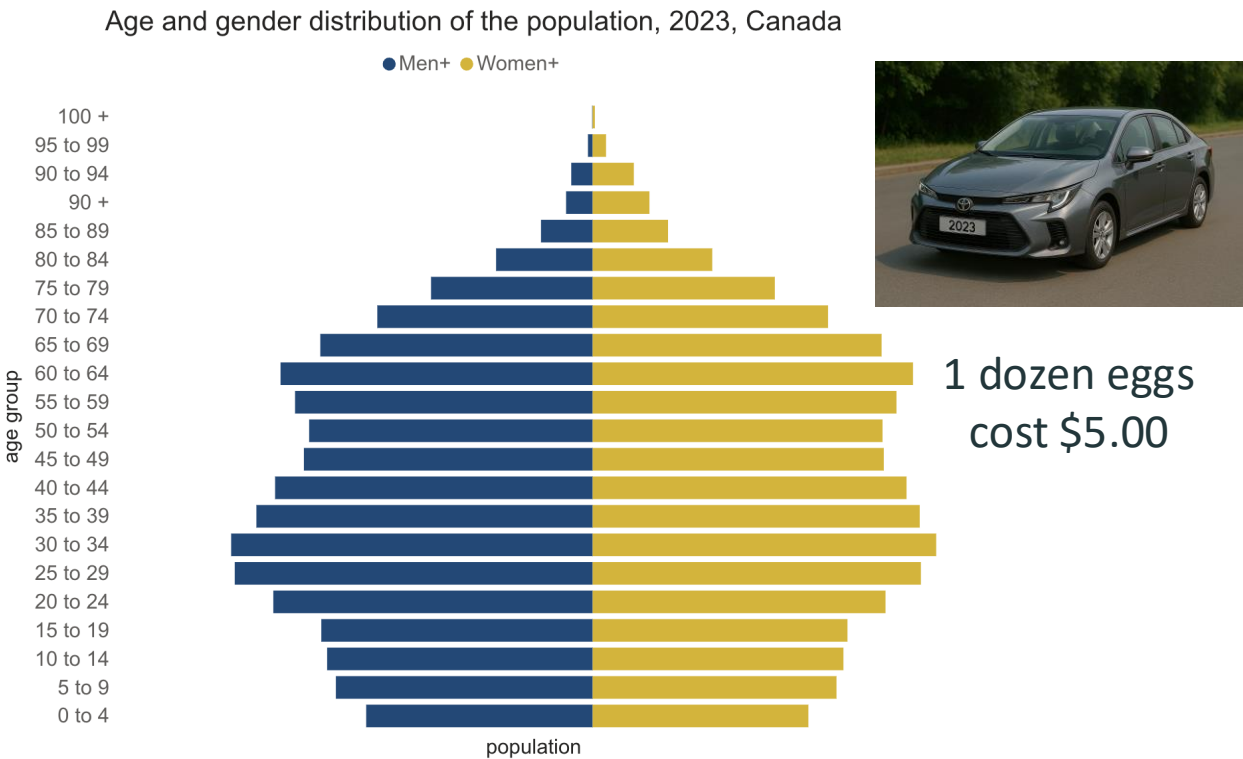
Age and Gender Distribution of Canada in 2023



Q: How long do you spend in each age group? What **proportion** of people age-up each year?

Note: In demography we focus on people who self-report their gender as either men and women this does not mean that other genders do not exist.

Demography in 2023 versus 1971



Q: What is the biggest age group in 1971? Is the Canadian population getting older or younger?

What will the age distribution of Canada look like in 2050?

What do we need to know to answer this question?

1) **Census:** How many people are in each age group now?

2) **Fecundity:** How many people give birth each year? And how old are mom's when they give birth?

Important:

In predicting future demography we focus only on women and mothers as they are the ones who give birth.

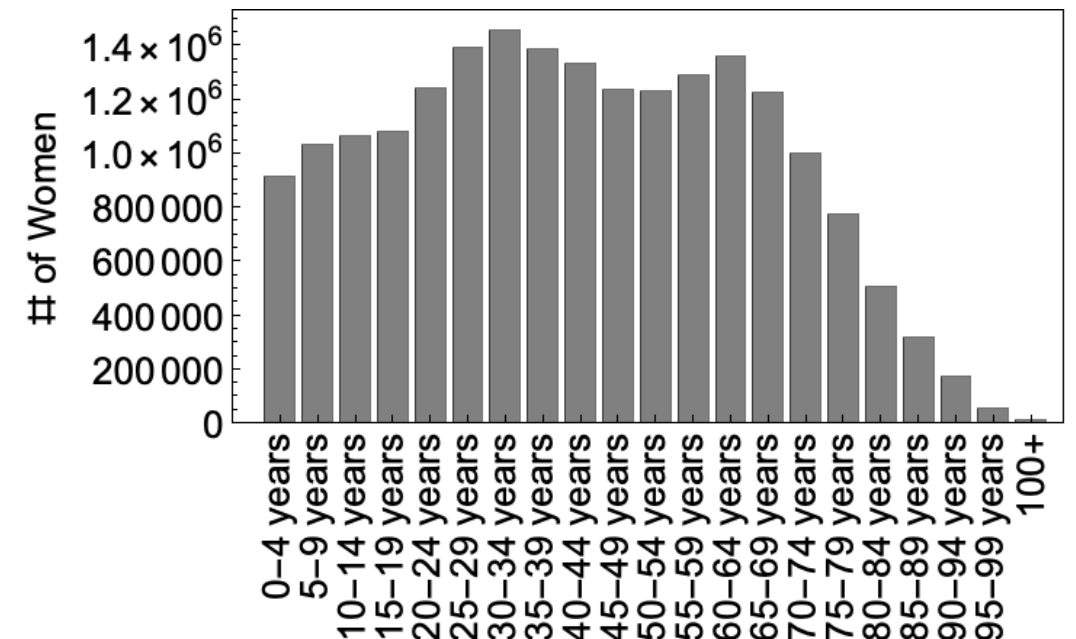
3) **Mortality:** How many people die each year and how old are they when they die?

4) **Aging:** What proportion of each age group ages up to the next group each year?

The Canadian Census:

Q: Use this table to estimate the population size of Canada.

REF_DATE	Gender	Age group	VALUE
2023	Women+	0 to 4 years	914 872
2023	Women+	5 to 9 years	1 034 125
2023	Women+	10 to 14 years	1 063 378
2023	Women+	15 to 19 years	1 080 547
2023	Women+	20 to 24 years	1 241 956
2023	Women+	25 to 29 years	1 391 946
2023	Women+	30 to 34 years	1 456 831
2023	Women+	35 to 39 years	1 387 063
2023	Women+	40 to 44 years	1 331 021
2023	Women+	45 to 49 years	1 234 659
2023	Women+	50 to 54 years	1 229 275
2023	Women+	55 to 59 years	1 288 417
2023	Women+	60 to 64 years	1 358 461
2023	Women+	65 to 69 years	1 225 282
2023	Women+	70 to 74 years	998 233
2023	Women+	75 to 79 years	772 554
2023	Women+	80 to 84 years	507 257
2023	Women+	85 to 89 years	319 764
2023	Women+	90 to 94 years	174 701
2023	Women+	95 to 99 years	56 801
2023	Women+	100 years and older	9364



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We can express the current population age distribution as a **vector**.

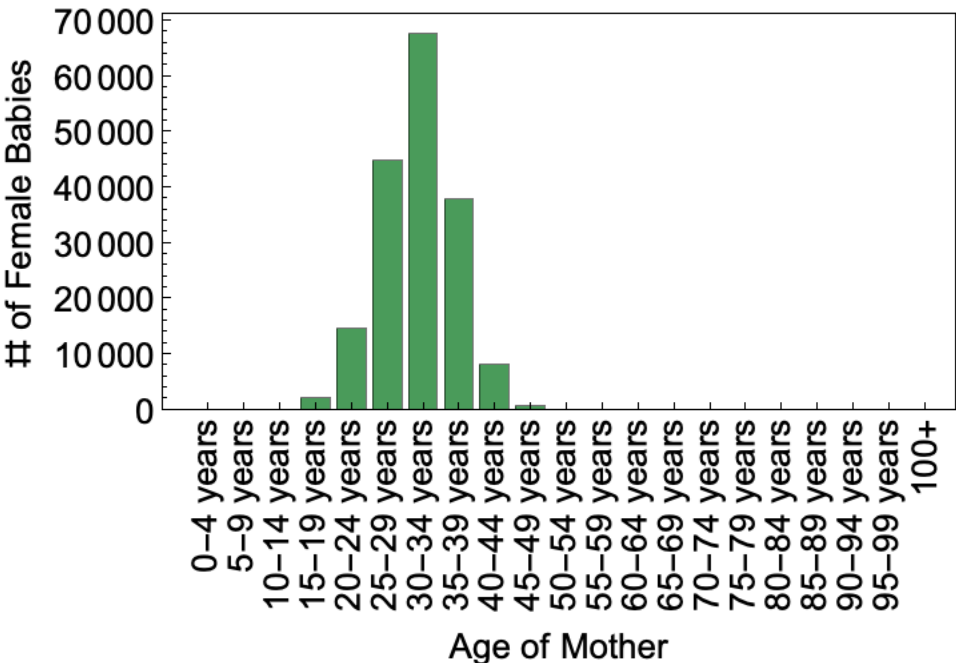
Here $\vec{v}_3 =$

How big is this vector

Fecundity:

Fecundity: the ability to produce a offspring.

REF_DATE	Age of mother	VALUE
2023	Age of mother, under 15 years	44
2023	Age of mother, 15 to 19 years	4461
2023	Age of mother, 20 to 24 years	29 106
2023	Age of mother, 25 to 29 years	89 568
2023	Age of mother, 30 to 34 years	135 381
2023	Age of mother, 35 to 39 years	75 681
2023	Age of mother, 40 to 44 years	16 351
2023	Age of mother, 45 to 49 years	1170



Q: How many female babies are born each year?

Q: What is the most common age for a mom to give birth?

Fecundity:

We can express the fecundity as a **vector**.

REF_DATE	Age of mother	VALUE
2023	Age of mother, under 15 years	44
2023	Age of mother, 15 to 19 years	4461
2023	Age of mother, 20 to 24 years	29 106
2023	Age of mother, 25 to 29 years	89 568
2023	Age of mother, 30 to 34 years	135 381
2023	Age of mother, 35 to 39 years	75 681
2023	Age of mother, 40 to 44 years	16 351
2023	Age of mother, 45 to 49 years	1170

Here $\vec{f}_3 =$

Here $\vec{f}_5 =$

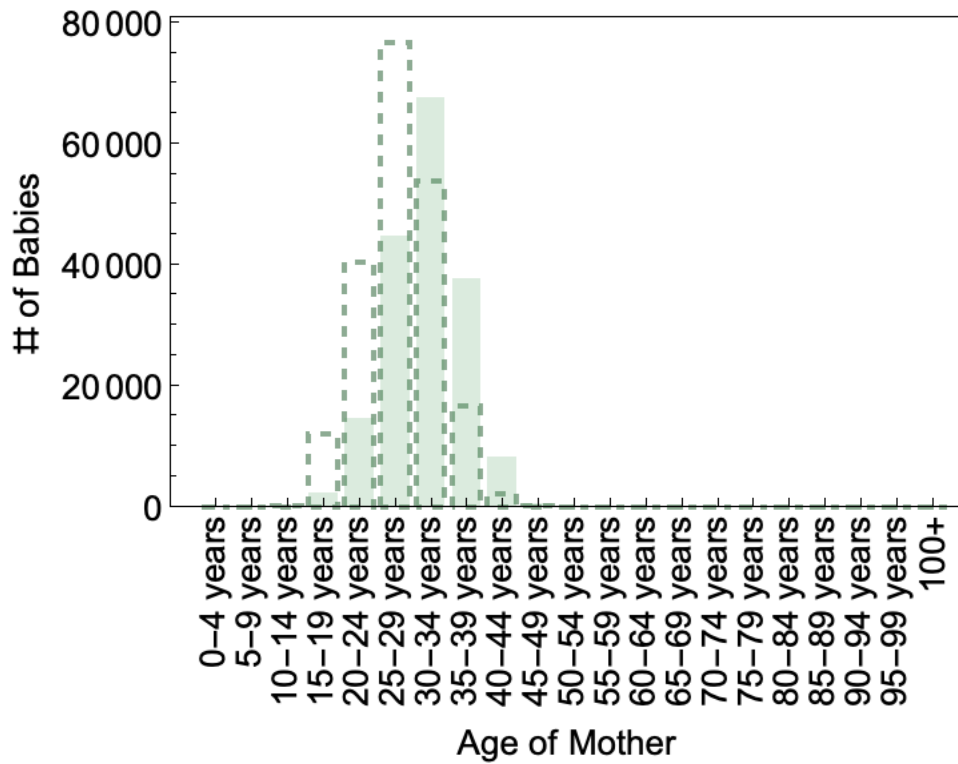
Here $\vec{f}_{10} =$

Here $\vec{f}_{20} =$

Fecundity:

Let's compare the fecundity in 2023 to the fecundity in 1991.

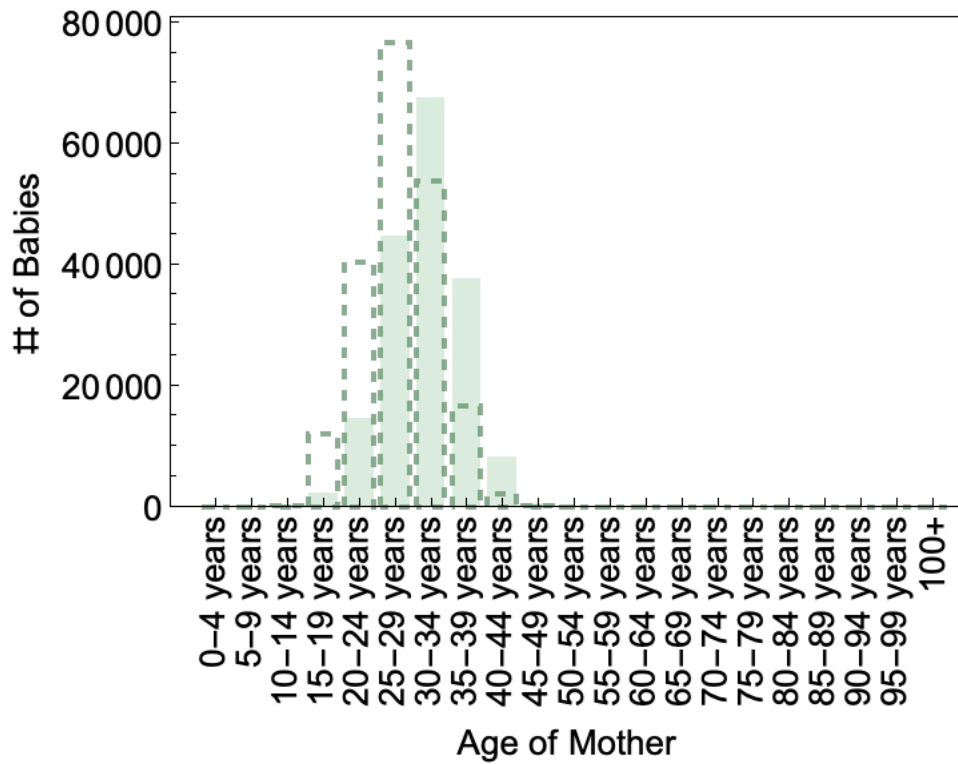
Q: How many female babies were born each year in 1991?



Q: Are moms getting older or younger over time?

Fecundity:

Let's compare the fecundity in 2023 to the fecundity in 1991.



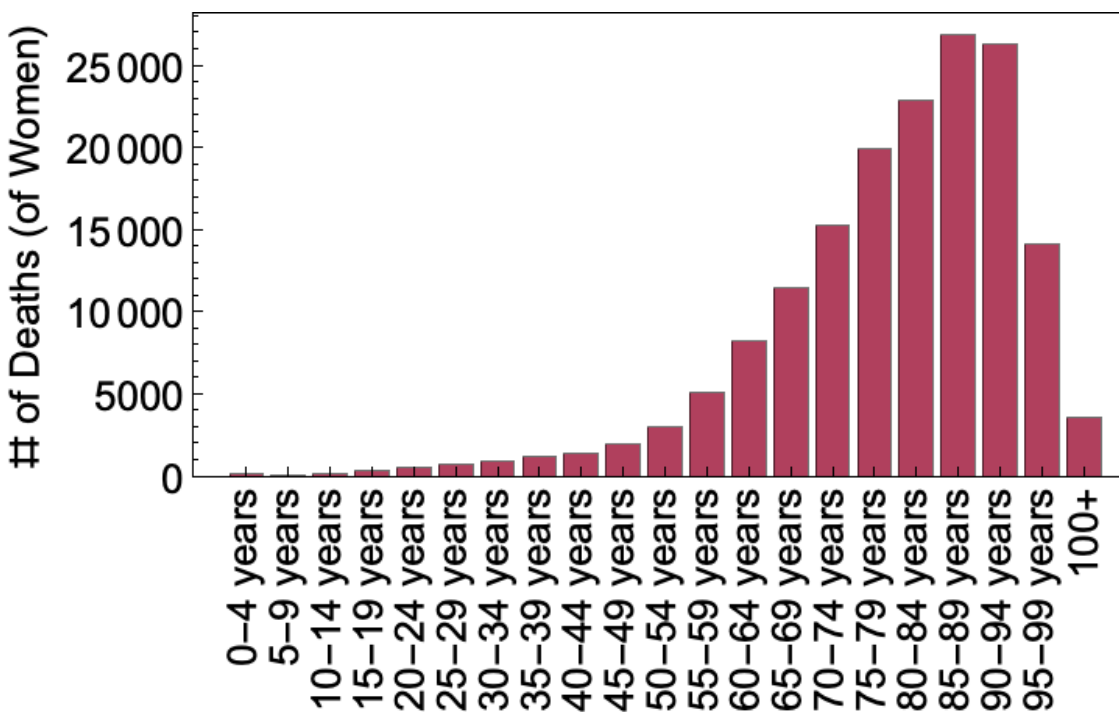
Q: Is the number of babies being born each year increasing or decreasing? Give the answer in the percentage increase/decrease.

Mortality:

REF_DATE	Age group	VALUE
2023/2024	0 to 4 years	178
2023/2024	5 to 9 years	75
2023/2024	10 to 14 years	145
2023/2024	15 to 19 years	317
2023/2024	20 to 24 years	503
2023/2024	25 to 29 years	731
2023/2024	30 to 34 years	948
2023/2024	35 to 39 years	1181
2023/2024	40 to 44 years	1424
2023/2024	45 to 49 years	1963
2023/2024	50 to 54 years	3009
2023/2024	55 to 59 years	5073
2023/2024	60 to 64 years	8214
2023/2024	65 to 69 years	11 473
2023/2024	70 to 74 years	15 225
2023/2024	75 to 79 years	19 883
2023/2024	80 to 84 years	22 876
2023/2024	85 to 89 years	26 824
2023/2024	90 to 94 years	26 249
2023/2024	95 to 99 years	14 161
2023/2024	100 years and older	3 525

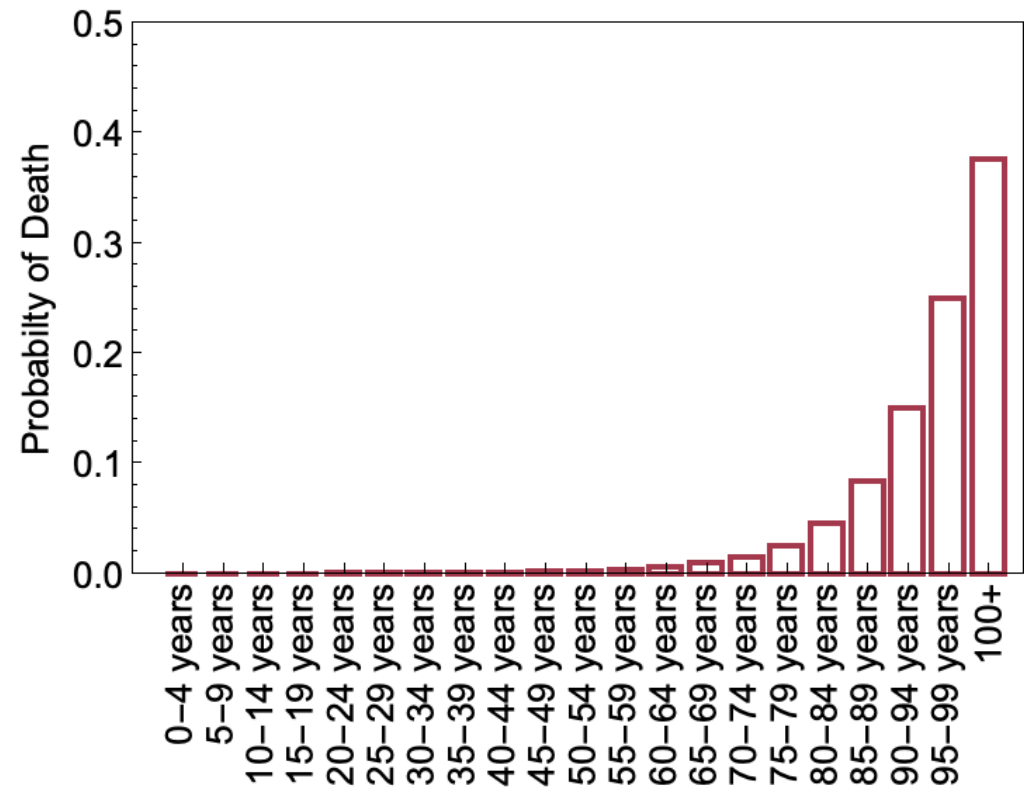
Q: What is the most common age for women to die at in Canada?

Q: Why are there fewer deaths of 100-year-olds than there are of 80-year-olds?



Mortality:

Q: What **proportion** of women over the age of 100 die each year?



Q: If you just turned 100 what is the **probability** that you live to age 101?

Q: If you just turned 100 what is the **probability** that you live to age 102?

Life Expectancy:

Life expectancy = mean age at time of death

An **Average**:

Suppose I have four numbers:

There average is:

Or using **sigma notation**

A **Mean**:

Life Expectancy:

Life expectancy = mean age at time of death

We can calculate life expectancy using **vectors**

Example: A dot product (of 2 vectors)

Putting it All Together

Q: Draw the demographic dynamics as a **flow diagram**.

The Leslie Matrix:

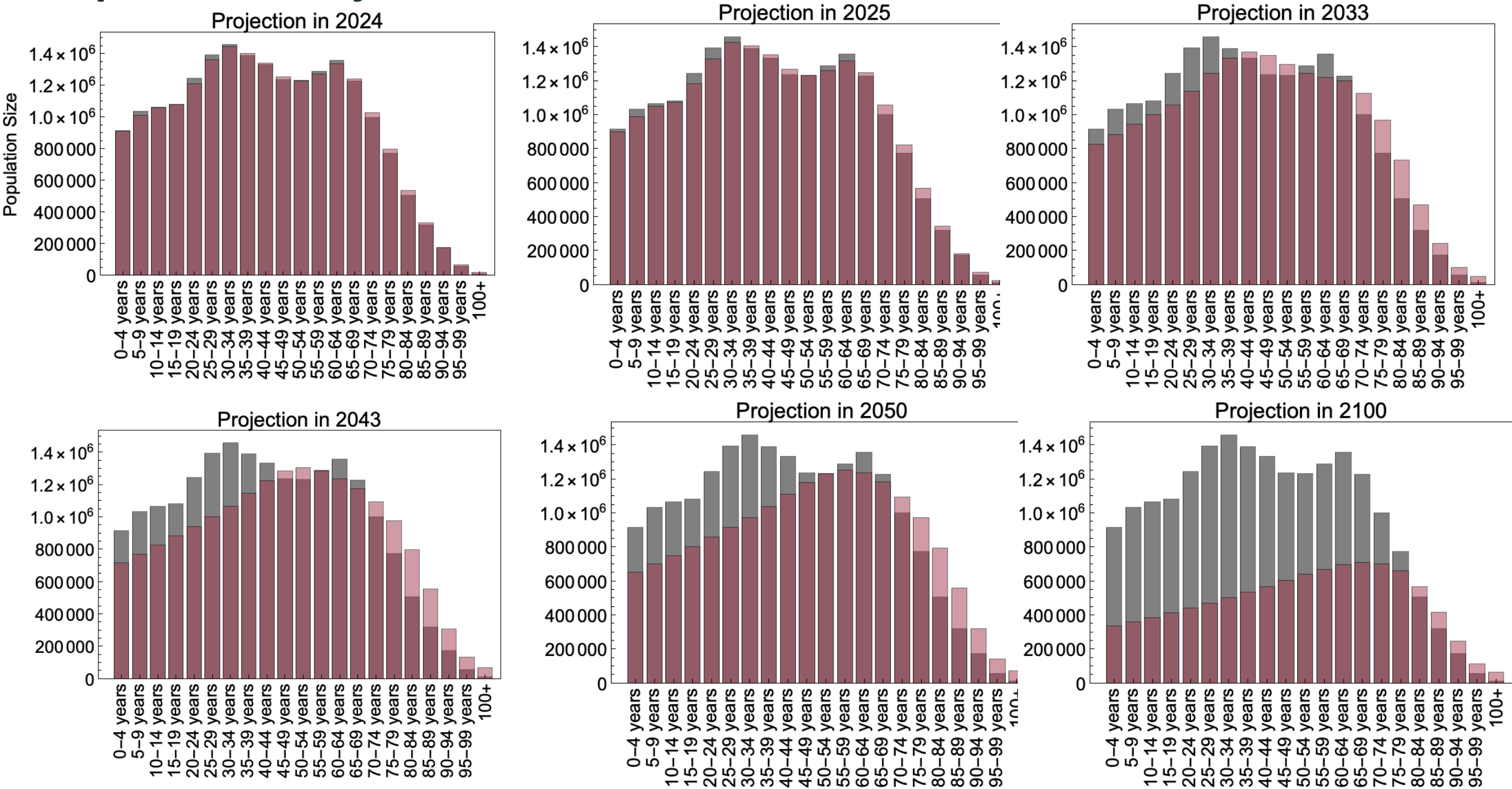
The **Leslie matrix** describes:

Matrix-Vector Multiplication

Example: Multiplying a Matrix and a Vector



Population Projections



Exit Survey

1. If you were to tell a friend about one thing you learned today, what would it be?
2. Is there something that surprised you about the demography of the Canadian population or your own personal demography?
3. Is there a question we talked about today that you still don't understand?
4. What is one new vocabulary word you learned today and what does it mean?
5. What new math skill did you learn today?