Lecture will start at 9:30

Assignments reminder

Keep doing your PMIRO+Q

Would be nice if you did the mid-term course evaluation

Your third coding assignment is due Friday, March 15th by 11:59pm.

Your project description will be due April 4th (8am)

Climate Change in the News

Jaguar Ending Production of Gas Cars Entirely before New EVs Arrive

Production for Jaguar's internal-combustion vehicles—the F-Pace, E-Pace, and XF—will end in June in preparation for the arrival of three new electric vehicles.

BY JACK FITZGERALD   PUBLISHED: MAR 4, 2024

MICHAEL SIMARI | CAR AND DRIVER

- Jaguar will end production of internal combustion cars later this year.

- According to a report by Road & Track, the manufacturer is planning to hold a supply of its current lineup of gas-powered cars until the arrival of its next-generation electric vehicles.

- The existing lineup will be replaced in the coming years by three models on a new platform named JEA (Jaguar Electric Architecture,) the first being a four-seat electric GT car.

Lecture

Climate Change content: finances

Machine learning content: recommender systems, genetic algorithms
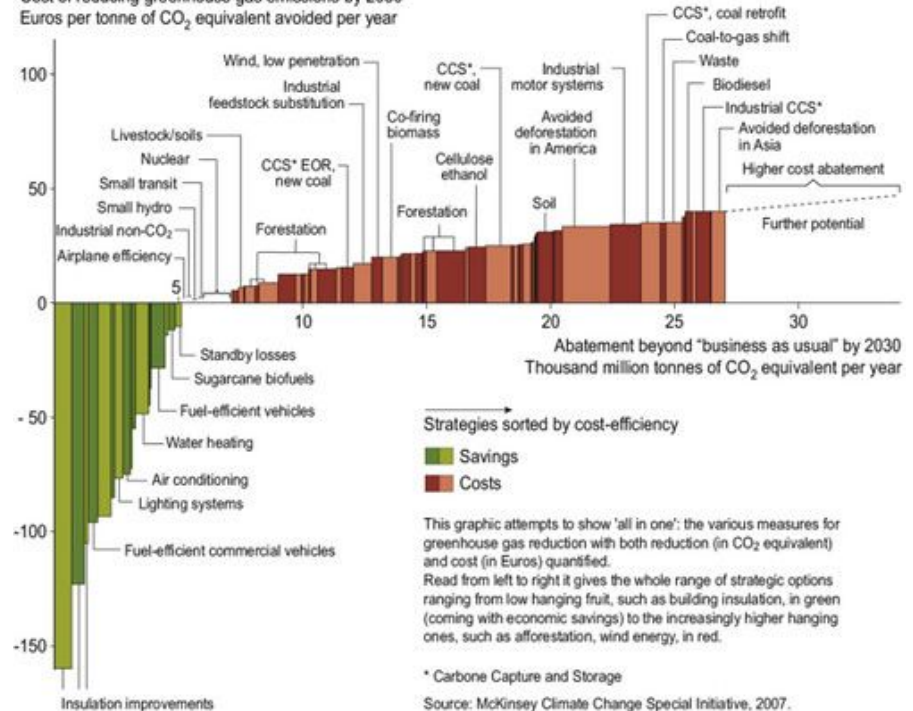
Project Assignment

Addressing climate change takes money

Some methods of reducing GHGs are actually financially beneficial immediately (such as increasing energy efficiency), but others will cost a significant amount of money upfront.

Strategic options for climate change mitigation
Global cost curve for greenhouse gas abatement measures

But the effects of climate change are even more expensive
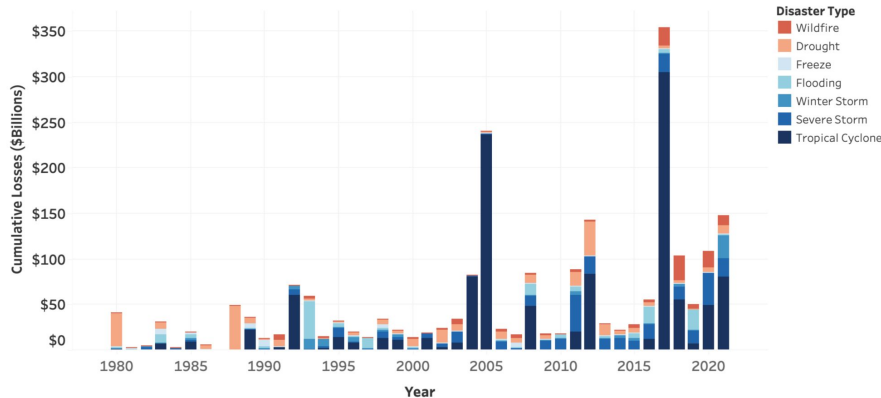
$2.2 trillion in losses since 1980 for the US

https://e2.org/reports/cost-of-climate-change/

Press releases

Deloitte Report: Inaction on Climate Change Could Cost the US Economy $14.5 Trillion by 2070

The U.S. economy could gain $3 trillion over the next 50 years if it accelerates towards a path of low-emissions growth

And over the next 50 years, nearly 900,000 jobs could disappear each year due to climate damage

Where should that money come from?

Free Market

Corporations

Carbon Tax

Carbon Credits/Offsets

Free Market

Consumers "vote with their wallet" and choose to buy sustainable options rather than products associated with high emissions

Will consumers make sustainable choices?

Exhibit 1

Products that make environmental, social, and governance-related claims have achieved disproportionate growth.

Retail sales growth, US, CAGR 2018–22, %

Products without ESG¹-related claims	4.7
Products with ESG-related claims	6.4

+1.7 *percentage points*

¹Environmental, social, and governance.
Source: NielsenIQ

McKinsey & Company

Some research suggests they might

Searches for Sustainable Goods Have Increased Rapidly

There is growing interest in researching and buying sustainable products online.

- Global Google searches for topics related to sustainable products increased by around **130%** between 2017 and 2022.
- Searches made in the US followed a similar trend, increasing by **117%** over the same time period.

Sales of Carbon Labeled Products Doubled in One Year

Many consumers are looking to reduce their carbon footprint and they appear to have identified the emissions associated with the goods that they buy as a key factor in achieving this.

- Carbon Labeled products (such as those with 1% For the Planet or Climate Neutral Certification) enjoyed more than **$3.4 Billion** worth of sales in 2021 - double that of the previous year.

https://theroundup.org/environmentally-conscious-consumer-statistics/

Can we leave it to the consumer to fund our climate change response?
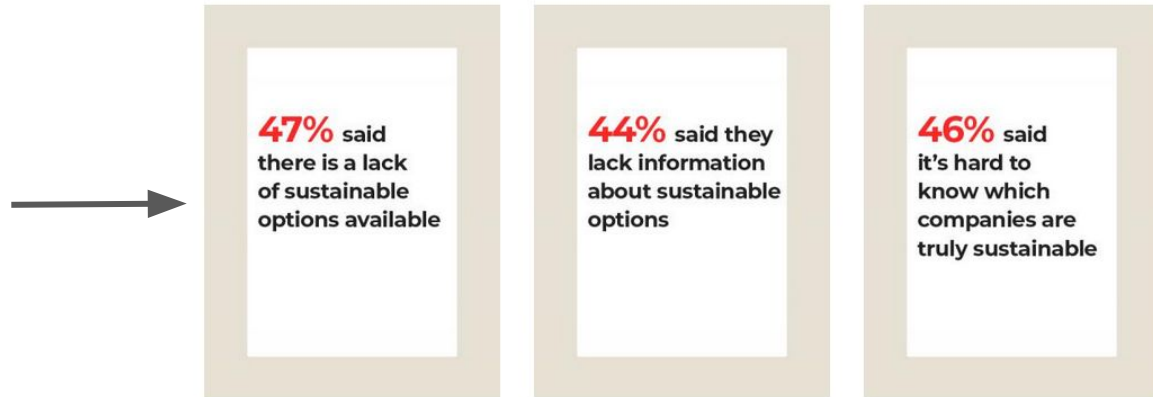
Probably not, due to....

Can we leave it to the consumer to fund our climate change response?

Probably not, due to....

Sustainable travel a key priority for Australian travellers

Sustainability and responsibility are no longer nice-to-haves, they're non-negotiables for travellers. **A massive 89% of respondents** said they were likely to choose sustainable travel options for their next trip and want to know their holidays aren't just good for them but good for local communities and the planet, too.

However, our research shows that operators still have work to do when it comes to communicating sustainability messages to customers, with almost half of respondents identifying three primary barriers to travelling sustainably.

47% said there is a lack of sustainable options available

44% said they lack information about sustainable options

46% said it's hard to know which companies are truly sustainable

Can we leave it to the consumer to fund our climate change response?

Probably not, due to....

The need to fund collective infrastructure projects

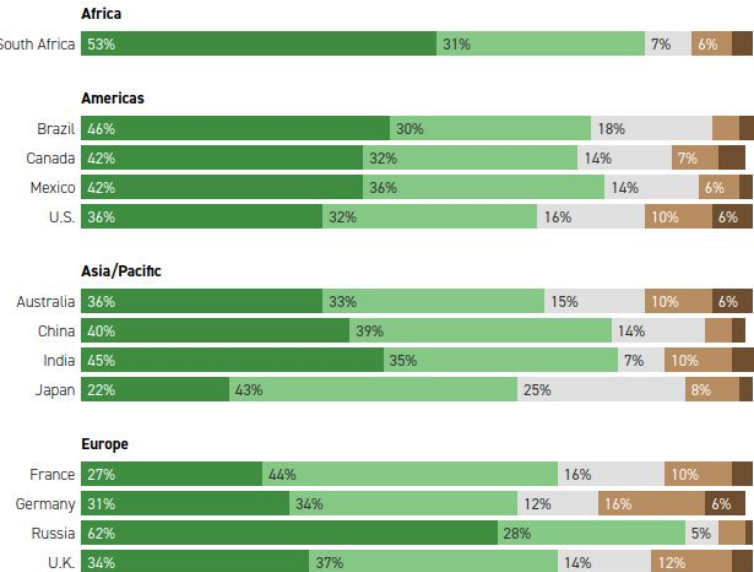# People believe fossil fuel companies should pay

A POLITICO Morning Consult Global Sustainability Poll asked people in 13 countries who should pay — governments, taxpayers, consumers, other countries, or the private sector. In every country but one — India — respondents **singled out companies**.

Respondents in every country surveyed were united **against increasing costs to taxpayers or consumers**. In the U.S., 15 percent of adults said climate change costs should be borne by consumers through higher prices. Eighteen percent said taxpayers should pay a lot of the cost.

Consumers want fossil fuel company accountability

Should fossil fuel companies be held responsible for the impacts their products have on the environment?

■ Yes, definitely ■ Yes, probably ☐ Don't know/no opinion ■ No, probably not ■ No, definitely not

Africa
South Africa	53%	31%	7%	6%

Americas
Brazil	46%	30%	18%	
Canada	42%	32%	14%	7%
Mexico	42%	36%	14%	6%
U.S.	36%	32%	16%	10% 6%

Asia/Pacific
Australia	36%	33%	15%	10% 6%
China	40%	39%	14%	
India	45%	35%	7%	10%
Japan	22%	43%	25%	8%

Europe
France	27%	44%	16%	10%
Germany	31%	34%	12%	16% 6%
Russia	62%	28%	5%	
U.K.	34%	37%	14%	12%

Totals may not add to 100 due to rounding. Poll in field Dec. 16-22, 2021. Margin of error is 3 percentage points.
Source: POLITICO/Morning Consult
Ryan Heath / POLITICO

https://www.politico.com/news/2022/02/09/climate-change-expensive-who-should-pay-00005198

Taking oil companies to court to pay for climate change

Grist

Donate ≡

Big Oil faces a flood of climate lawsuits – and they're moving closer to trial

A quarter of Americans now live in cities and states taking companies to court over lying to the public.

It's been six years since cities in California started the trend of taking Big Oil to court for deceiving the public about the consequences of burning fossil fuels. The move followed investigations showing that Exxon and other companies had known about the dangers of skyrocketing carbon emissions for decades, but publicly downplayed the threat. Today, around 30 lawsuits have been filed around the country as cities, states, and Indigenous tribes seek to make the industry pay for the costs of climate change.

Last September, the state of California demanded that oil companies fund efforts to recover from extreme weather. In December, the Makah and Shoalwater Bay tribes along the coast of Washington state became the first Native American tribes to take oil companies to court over the costs of responding to climate-related risks from rising seas, flooding, and ocean acidification. Meanwhile, Hoboken, New Jersey, and a collection of cities in Puerto Rico have added racketeering lawsuits to the mix, alleging that oil companies engaged in a conspiracy of deception.
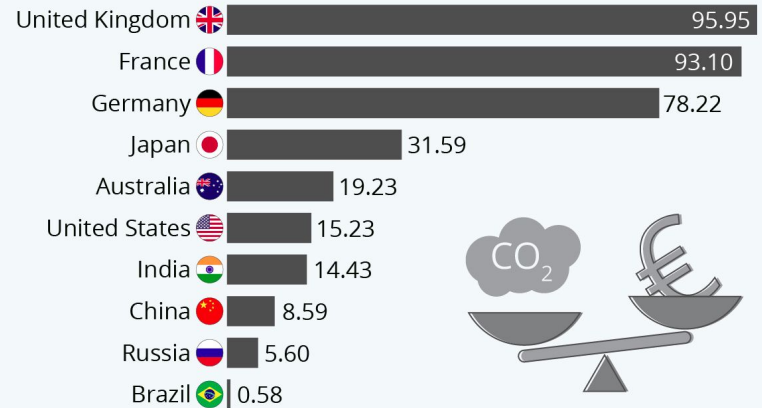
Carbon tax

According to the EPA, tax-based regulatory systems provide incentives for polluters to find cost-effective solutions to emissions control.

Firms will either pay the tax or, if it is cheaper, they will reduce emissions to avoid the tax.

How the World Puts a Price on Carbon

Average carbon prices in selected countries in 2021 (EUR per tonne of CO_2)

Country	Price
United Kingdom	95.95
France	93.10
Germany	78.22
Japan	31.59
Australia	19.23
United States	15.23
India	14.43
China	8.59
Russia	5.60
Brazil	0.58

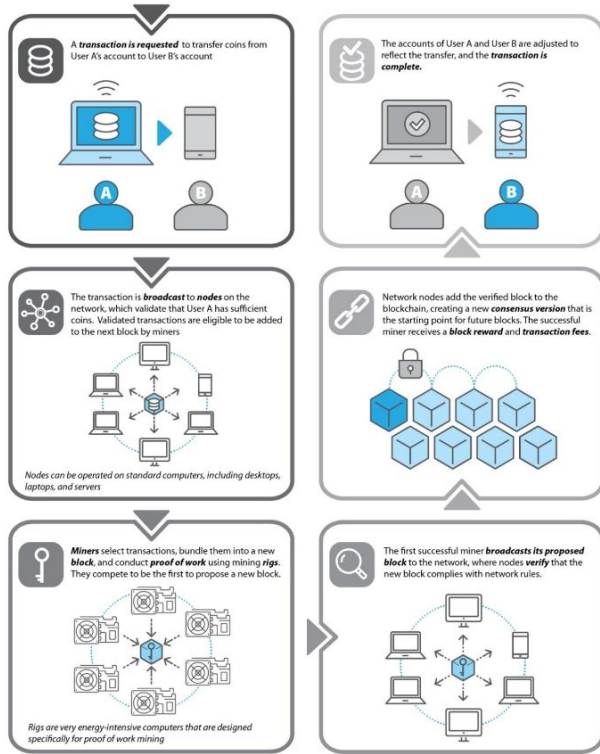Based on taxes applicable on 1 April 2021.
Source: OECD

statista

Offsets and carbon credits

Blockchain-based carbon credit tracking

The blockchain creates a public ledger that can be used to verify that an entity has bought or sold carbon credits.

Most blockchains run on "proof of work"

This is a problem because...

Figure 1.1: Understanding Proof of Work Blockchain in Crypto-Asset Mining. Adapted from Kilroy Blockchain.[33]

Proof of Work is a huge waste of energy

The Real-World Costs of the Digital Race for Bitcoin

Bitcoin mines cash in on electricity — by devouring it, selling it, even turning it off — and they cause immense pollution. In many cases, the public pays a price.

Texas was gasping for electricity. Winter Storm Uri had knocked out power plants across the state, leaving tens of thousands of homes in icy darkness. By the end of Feb. 14, 2021, nearly 40 people had died, some from the freezing cold.

Meanwhile, in the husk of a onetime aluminum smelting plant an hour outside of Austin, row upon row of computers were using enough electricity to power about 6,500 homes as they raced to earn Bitcoin, the world's largest cryptocurrency.

The computers were performing trillions of calculations per second, hunting for an elusive combination of numbers that Bitcoin's algorithm would accept. About every 10 minutes, a computer somewhere guesses correctly and wins a small number of Bitcoins worth, in recent weeks, about $170,000. Anyone can try, but to make a business of it can require as much electricity as a small city.

Crypto mining requires way too much energy

Any one proposing a blockchain-based carbon credit system or crypto-funded climate company will need to address energy issues
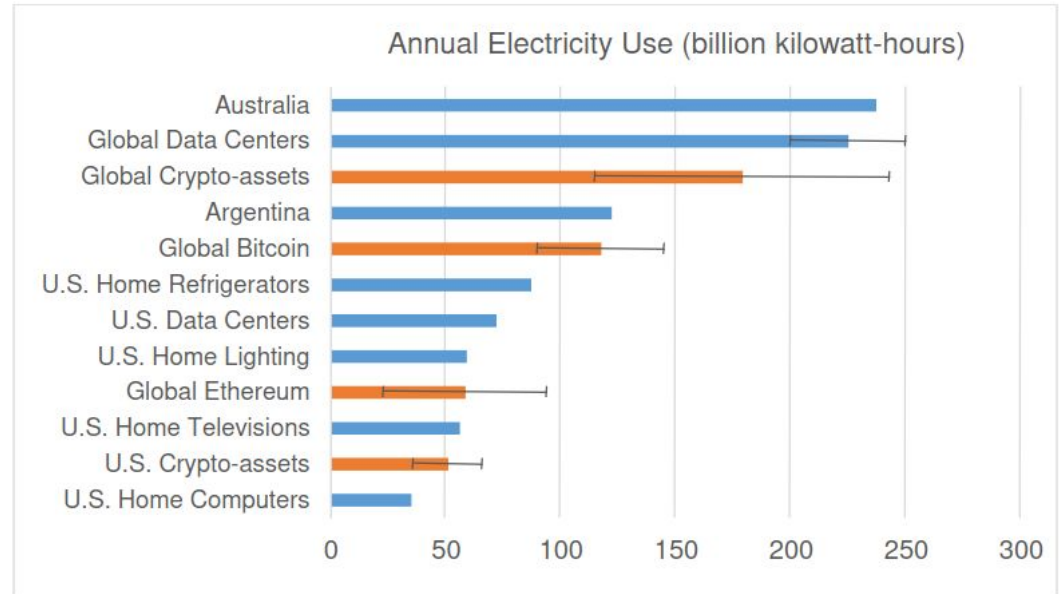

Annual Electricity Use (billion kilowatt-hours)

Australia	
Global Data Centers	
Global Crypto-assets	
Argentina	
Global Bitcoin	
U.S. Home Refrigerators	
U.S. Data Centers	
U.S. Home Lighting	
Global Ethereum	
U.S. Home Televisions	
U.S. Crypto-assets	
U.S. Home Computers	

0   50   100   150   200   250   300

Figure 2.1: Comparison of Annual Electricity Use of Several Examples and the Best Estimates for Crypto-assets, as of August 2022, with error bars representing the best range of values.[80,81]

Crypto mining and the popularization of AI are driving up energy use in unprecedented ways

The Washington Post
Democracy Dies in Darkness

BUSINESS

Amid explosive demand, America is running out of power

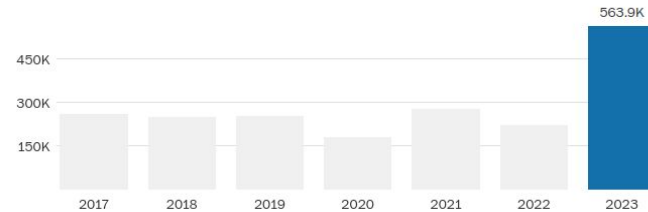AI and the boom in clean-tech manufacturing are pushing America's power grid to the brink. Utilities can't keep up.

By Evan Halper

March 7, 2024 at 6:05 a.m. EST

Projected new energy demand in North America doubles

9-year growth forecast of demand for new electricity, in gigawatt hours

Data covers U.S., Canada and part of Baja California, Mexico.

Source: North American Electric Reliability Corp. Long Term Reliability Assessment

A major factor behind the skyrocketing demand is the rapid innovation in artificial intelligence, which is driving the construction of large warehouses of computing infrastructure that require exponentially more power than traditional data centers. AI is also part of a huge scale-up of cloud computing. Tech firms like Amazon, Apple, Google, Meta and Microsoft are scouring the nation for sites for new data centers, and many lesser-known firms are also on the hunt.

The proliferation of crypto-mining, in which currencies like bitcoin are transacted and minted, is also driving data center growth. It is all putting new pressures on an overtaxed grid — the network of transmission lines and power

Machine Learning requires energy

Very large models (like ChatGPT) can use an enormous amount of energy for training.

This week's paper explicitly measures their compute-related emissions
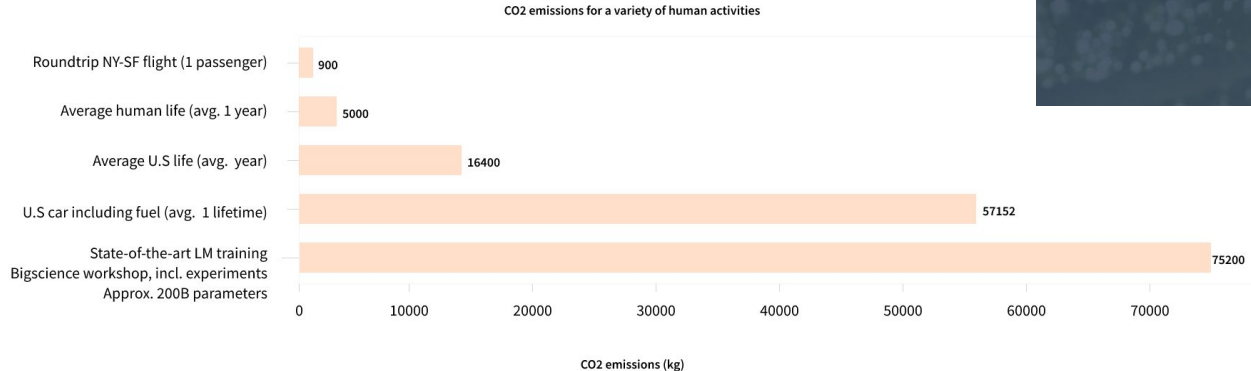
ML CO₂ IMPACT

Machine Learning has a carbon footprint.

We've made a tool to help you estimate yours:

1 Compute your GPU's carbon emissions

2 Push for more transparency in our field by including the results in your publication (research paper, blog post etc.)

COMPUTE YOUR ML CARBON IMPACT

CO2 emissions for a variety of human activities

Activity	CO2 emissions (kg)
Roundtrip NY-SF flight (1 passenger)	900
Average human life (avg. 1 year)	5000
Average U.S life (avg. year)	16400
U.S car including fuel (avg. 1 lifetime)	57152
State-of-the-art LM training Bigscience workshop, incl. experiments Approx. 200B parameters	75200

CO2 emissions (kg)

How can we get people to switch to better products?

Build a recommender system

A system or algorithm that recommends products or posts to a user based on knowledge of that user. These algorithms can be built in many different ways

A good recommender system might help people switch to more eco-friendly products

Recommendation problems can be complex

We don't want to recommend just *any* eco-friendly products. We want to recommend products that:

Aren't too expensive

Are similar to what a person normally wants

Lower emissions without other side effects like increased water use

Etc.

One way to say this: we have *multiple objectives*

How can we write a loss function when we have multiple objectives?

Lecture 2:

The loss function tells the network what we want it to do

If we want to train a model on a regression problem, for example, we may use Mean Squared Error as the loss function.

Also known as "cost" or "objective" function. Higher values mean the model is performing poorly.

When we have the "correct answer" that we can train the network with, this is known as "supervised learning"

Mean **Error** **Squared**

$$\text{MSE} = \frac{1}{n} \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$$

Correct answer

Output of the model

Haltakov

How can we write a loss function when we have multiple objectives?

One option: "scalarization"

I.e., turn the multiple objectives into a single scalar value by computing a weighted sum of them.

E.g.,

   Total Loss = a*CO2_term + b*Cost_term + ...

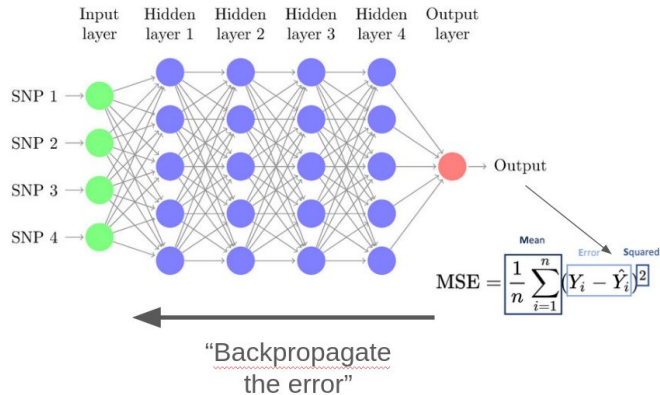Pros: can treat it like a normal loss/optimization function

Cons: need to decide on the weights

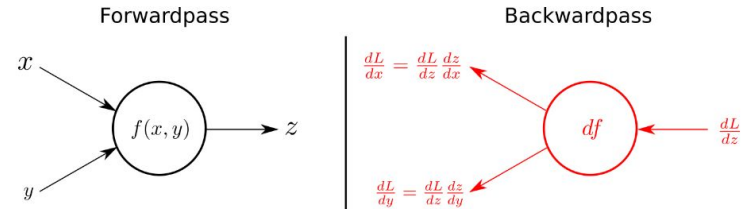# How can we write a loss function when we have multiple objectives?

But why does the loss function need to be a single function anyway?

Lecture 2:

How do we use the loss function to learn the right weights?

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$$

"Backpropagate the error"

Backpropagation algorithm

Forwardpass

Backwardpass

x

$f(x,y)$ → z

y

$\frac{dL}{dx} = \frac{dL}{dz}\frac{dz}{dx}$

df

$\frac{dL}{dz}$

$\frac{dL}{dy} = \frac{dL}{dz}\frac{dz}{dy}$
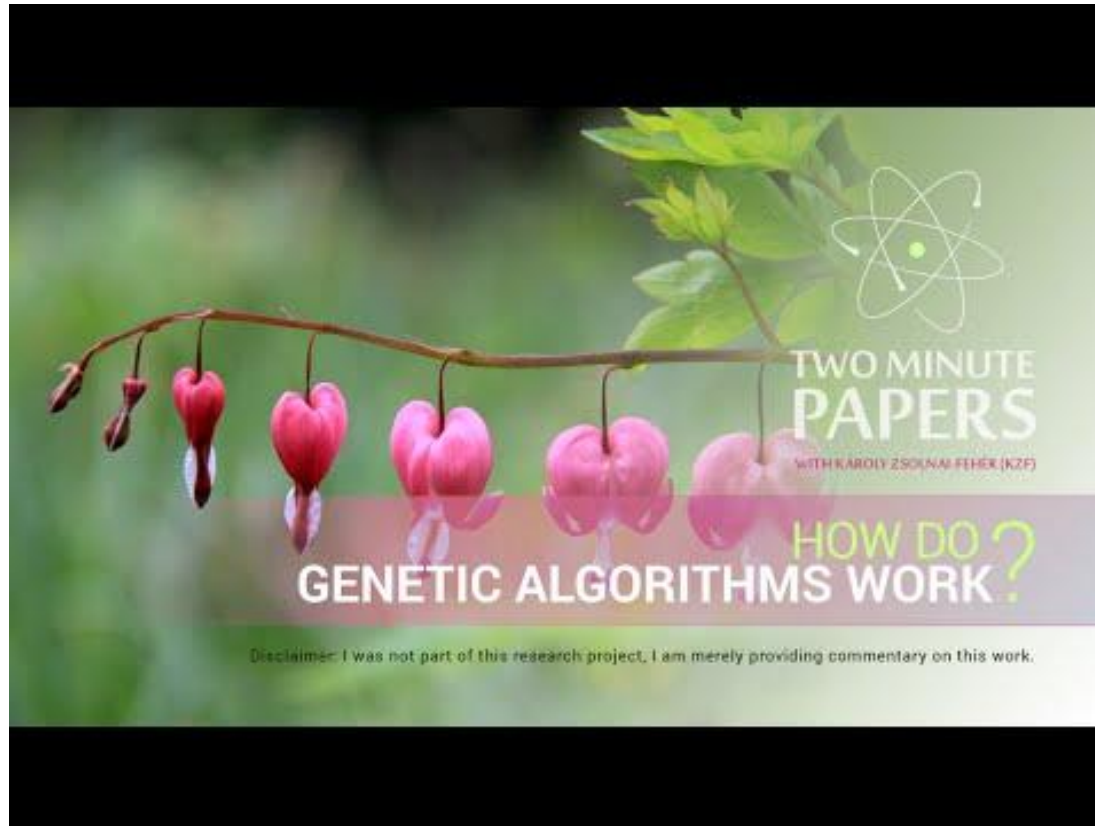
Kratzert

By applying the chain rule for derivatives, we can calculate exactly in which direction a weight should change in order to make the loss function decrease

For backpropagation, we need a single differentiable function
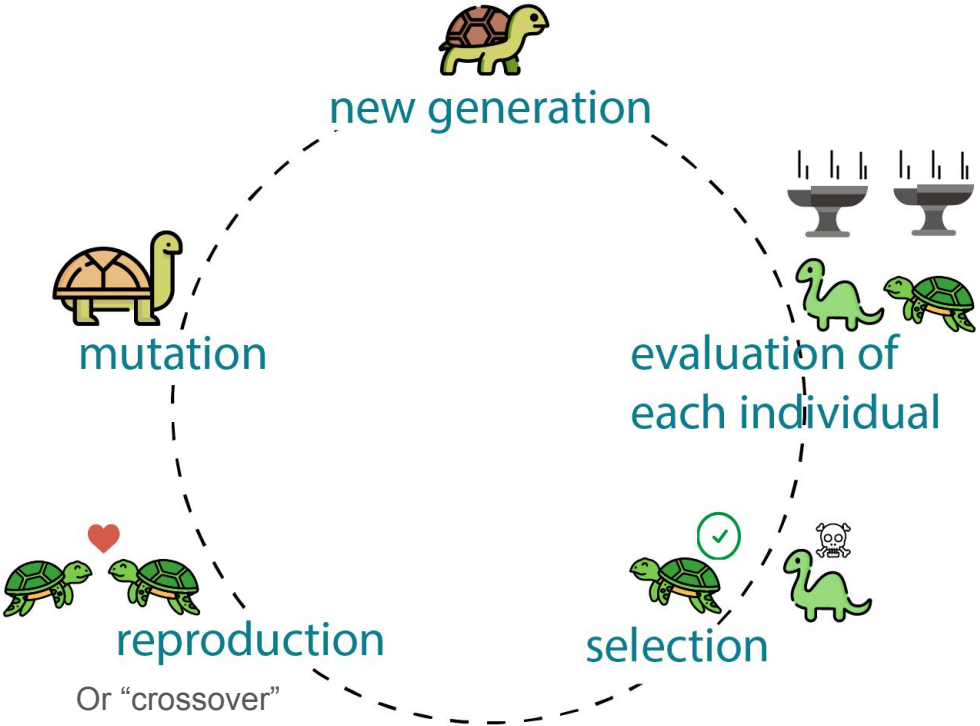
Evolutionary/Genetic Algorithms

Evolutionary/Genetic Algorithms

new generation

mutation

reproduction

Or "crossover"

evaluation of each individual

selection

Where does something like a loss function go?

In evolutionary algorithms, each individual needs to be evaluated according to a "fitness" function, and those that fall below a fitness threshold don't get to be part of the next generation ('selection').

This fitness function can be anything we like!

https://www.generativedesign.org

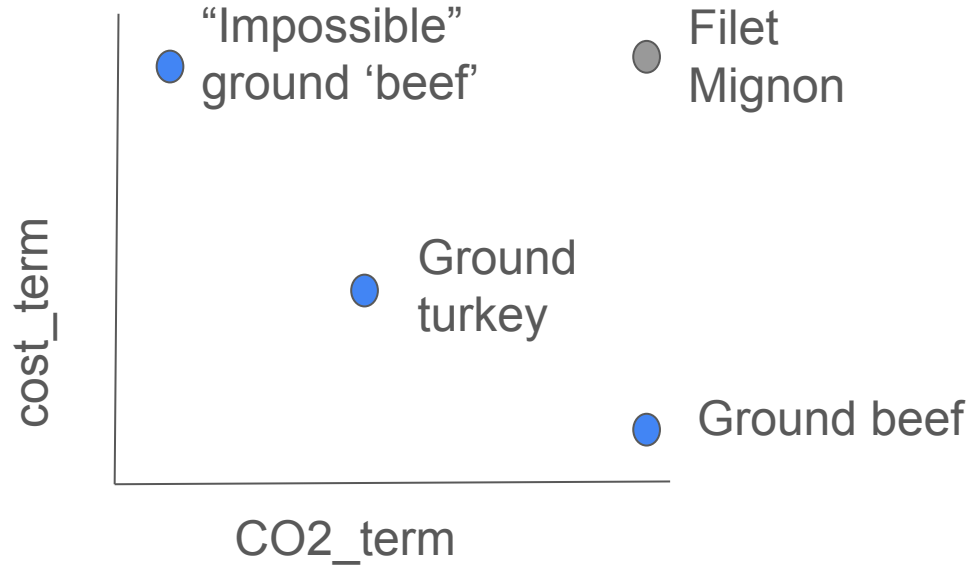# What kind of fitness function and selection problem can we use for multi-objective problems?

1. Represent fitness as an objective *vector* (e.g. [CO2_term, cost_term, ...]
2. Apply "non-dominated sorting"
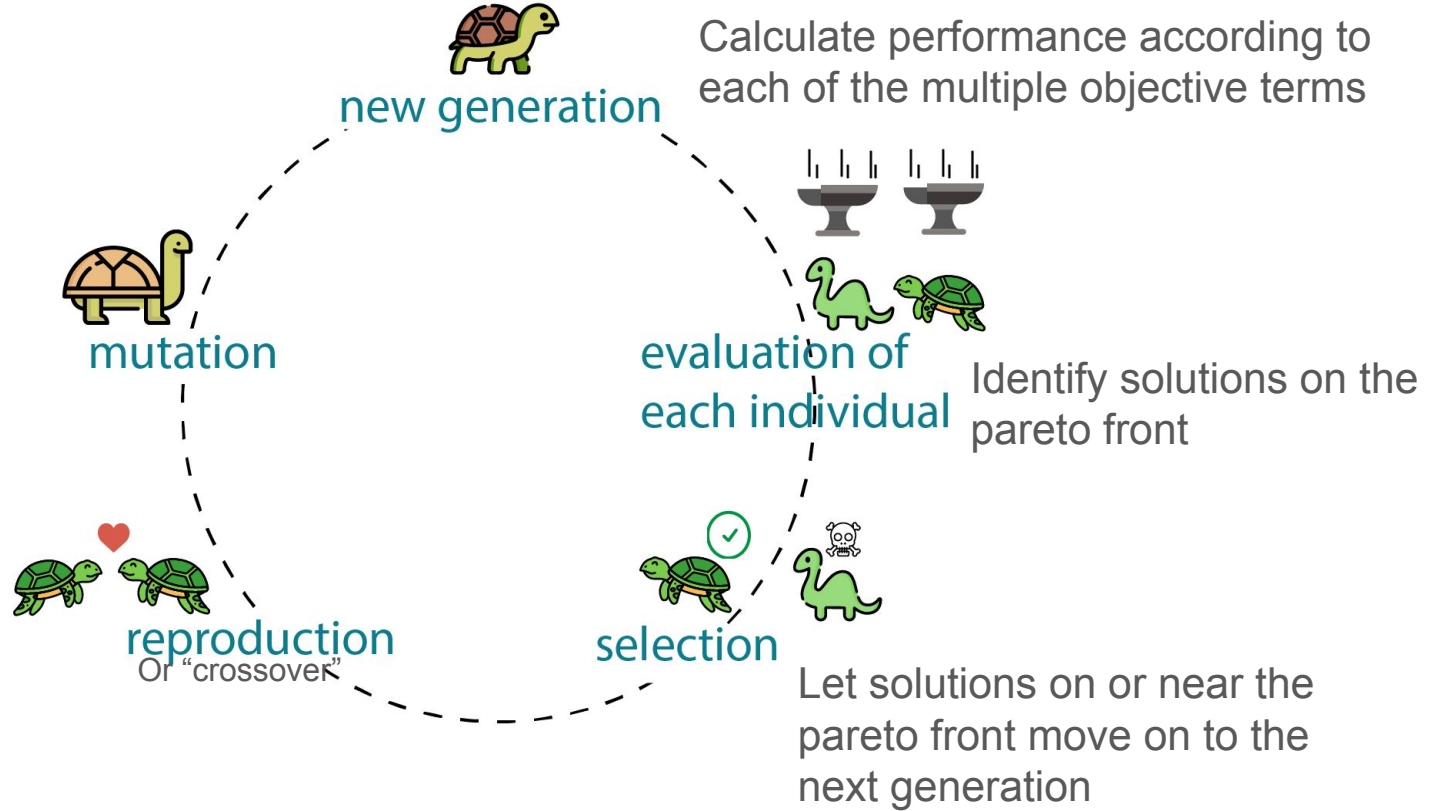3. Select the solutions on the "Pareto Front"

I.e., get the solutions that are the best you can do for one term without sacrificing the others

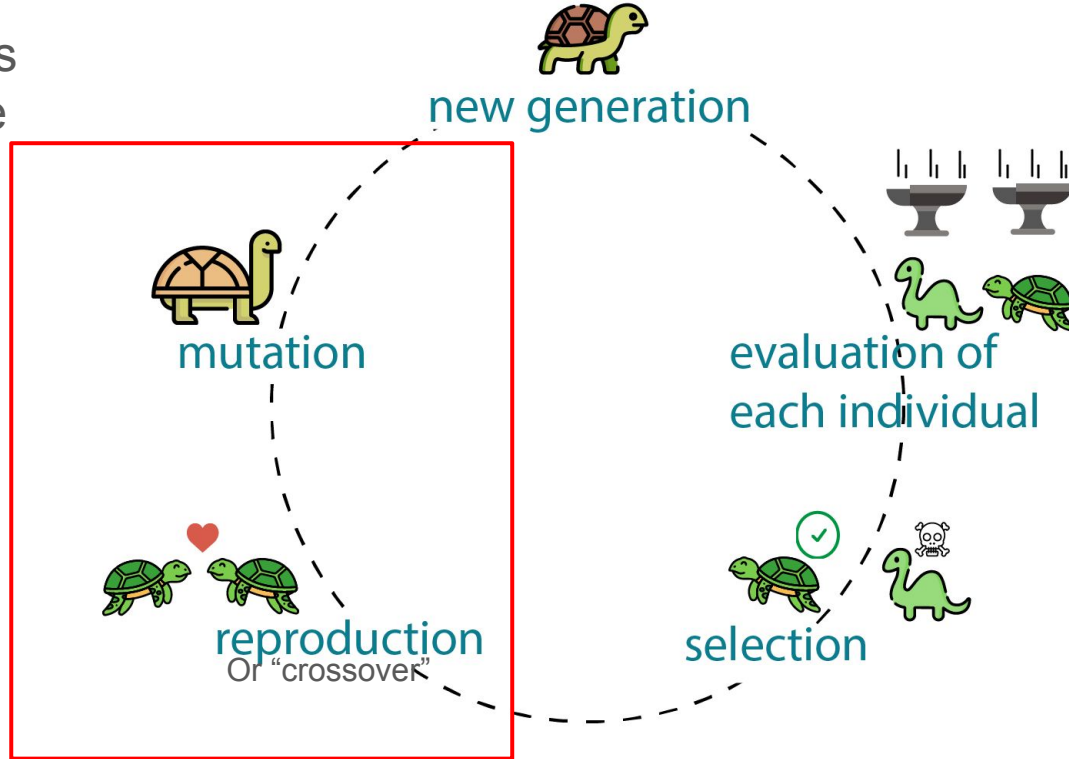# The pareto front is the result of trade-offs in the various objective terms

Trying to minimize:

"Impossible" ground 'beef'

Filet Mignon

Ground turkey

Ground beef

cost_term

CO2_term

NSGA-II

new generation — Calculate performance according to each of the multiple objective terms

evaluation of each individual — Identify solutions on the pareto front

selection — Let solutions on or near the pareto front move on to the next generation

reproduction
Or "crossover"

mutation

These things
can be done
randomly

new generation

mutation

reproduction
Or "crossover"

evaluation of
each individual
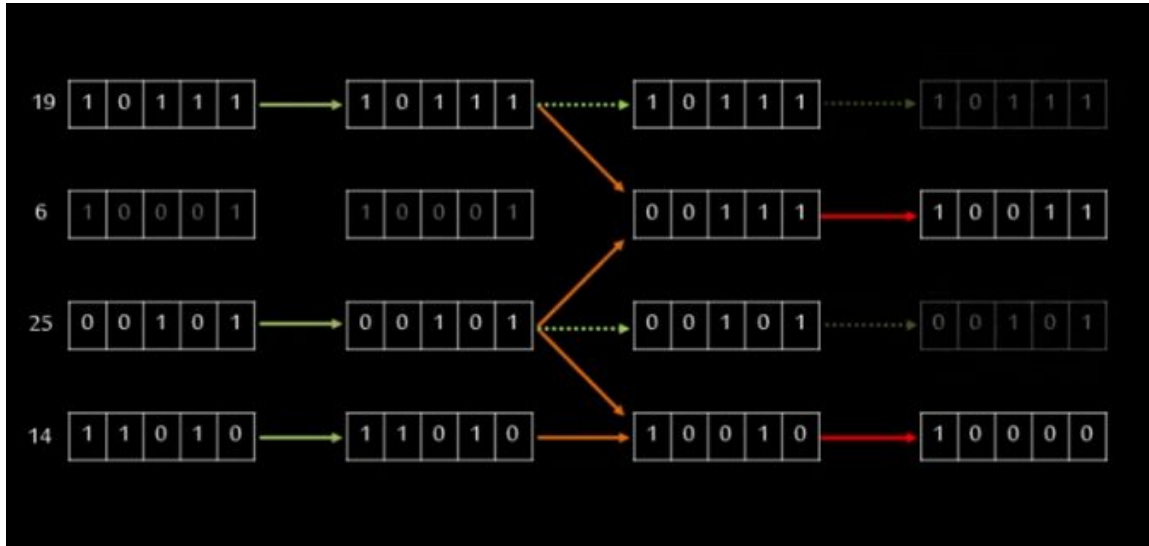
selection

Random pairing and mutation

Randomly pair two solutions that survived the selection phase. Take some of the features from one and some from the other - this makes a new individual (crossover/reproduction). Randomly change some of the features of this individual (mutation) before evaluating it
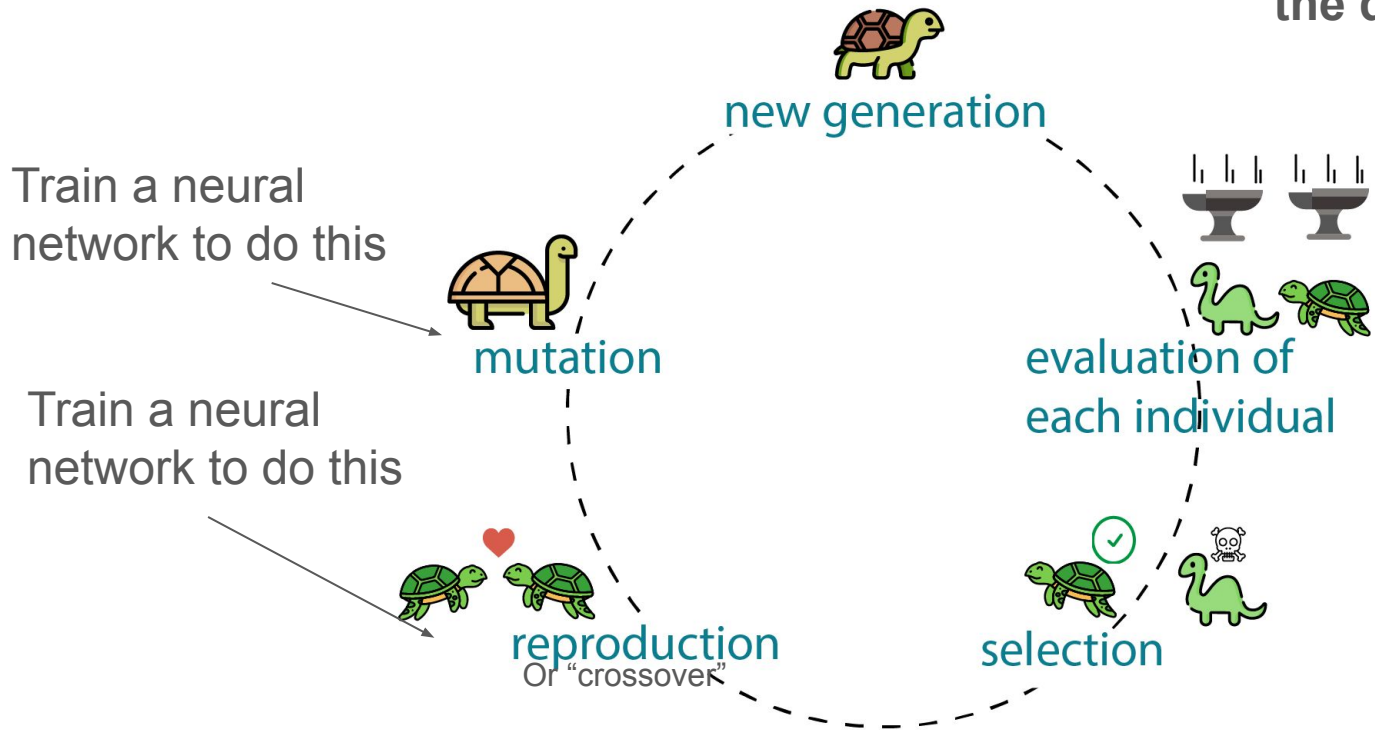
These things can be done randomly

...or we can get fancy about it

new generation

mutation

reproduction
Or "crossover"

evaluation of each individual

selection
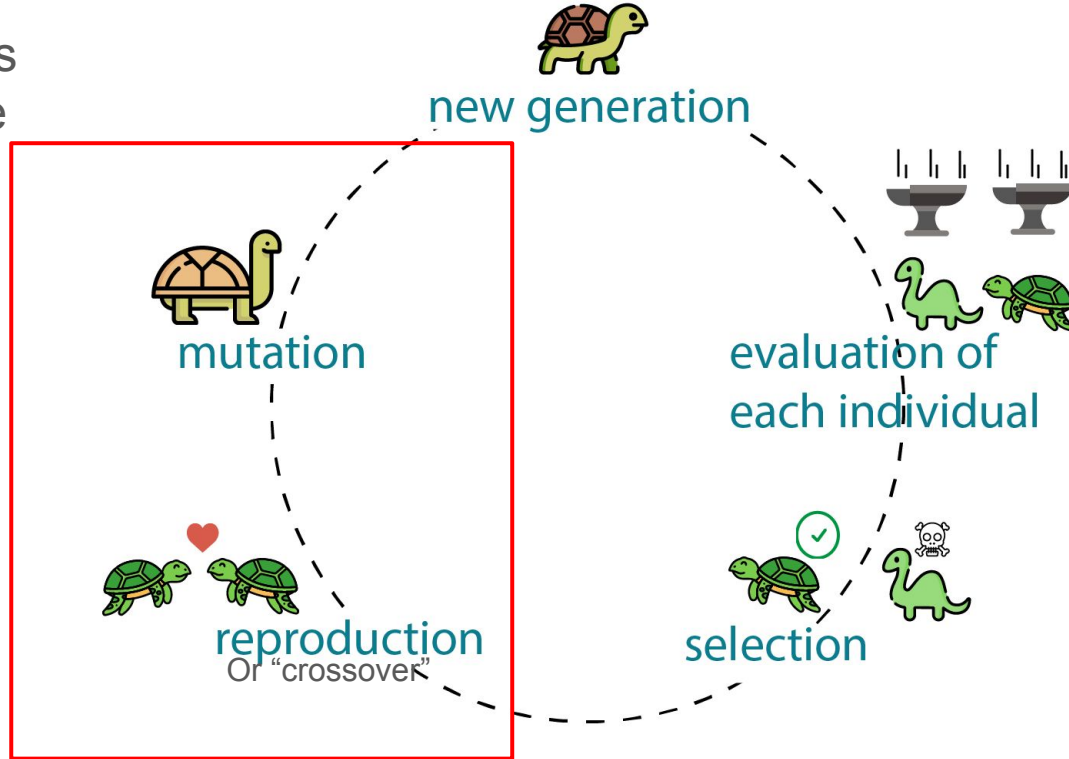
G3A: Gradient Guided Genetic Algorithms

Don't worry about the details of this!

(it's mostly just a bunch of tricks to be able to do backpropagation here)

new generation

Train a neural network to do this

mutation

evaluation of each individual

Train a neural network to do this

reproduction
Or "crossover"

selection

https://www.generativedesign.org

For your reading:

MO-NES is another modified evolutionary algorithm, don't worry about how it works.

In this work, we are trying to find the best 'basket' - which is the set of all items a household buys in a week (so solutions are evaluated based on everything in the basket)

There are more details that may be helpful in the appendix

Project Plan Assignment

Each member of your team should submit the same document to Brightspace by 8:00am on April 4th.

The document should include:

Your team name

The names of all team members

A summary of your project plan (details on next slide)

A statement verifying that you have downloaded, opened, and explored the dataset you plan to use

I will provide feedback about your plan the day after it is due

Project Plan Assignment

Summary: Do a modified PMIRO for your own research.

State the **problem** you will try to solve and how it relates to climate change. Describe the **methods** you will try on the problem and why they are appropriate for the data you have chosen (include the specific data you will be working with). State how your planned work is **substantial** enough for the project. Describe how you will **evaluate** the model for your results. Discuss **issues you anticipate** encountering (will a lot of data cleaning be required, will you need to do a lot of hyperparameter testing, are you working with something you've never used before, etc).

If you do not have a team of *four* members...

Try to form one.

(Use the class slack, e.g.)

If by **March 20th** you still do not have a team of four, **email me**.