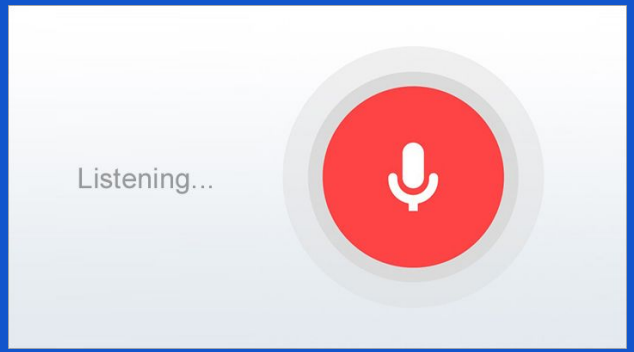
OK Google: Who gets the kidney?



Duncan McElfresh, MS, PhD student

Gabriel Schnickel, MD, MPH
John Dickerson, PhD
Patricia Mayer, MD, MS

ASBH October 18, 2018

Participants

Duncan McElfresh, MS
PhD student, University of Maryland
Department of Computer Science

Gabriel Schnickel, MD, MPH
Associate Professor of Surgery, UCSD School of Medicine
Division of Transplant and Hepatobiliary Surgery

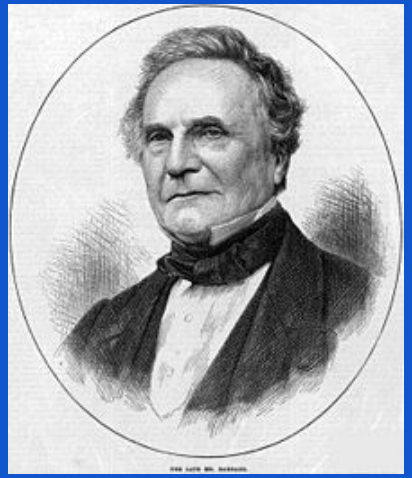
John Dickerson, PhD
Assistant Professor, University of Maryland
Department of Computer Science

Patricia Mayer, MD, MS
Palliative Medicine and Clinical Ethics
Banner Health, Phoenix AZ

No financial disclosures

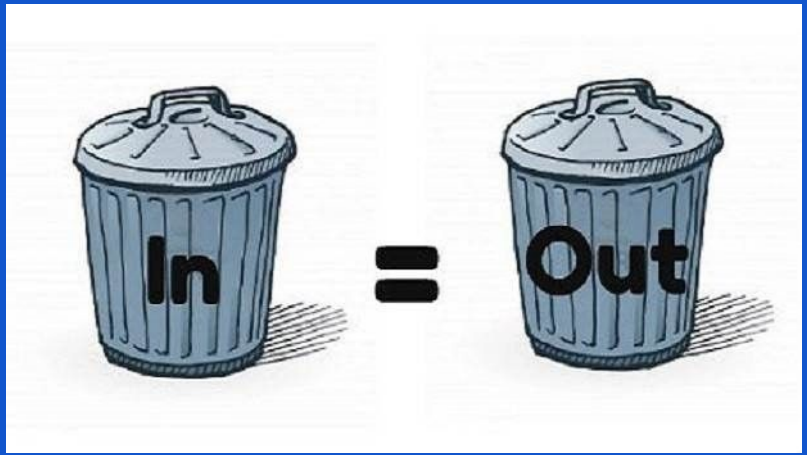
On two occasions I have been asked, “Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?” ... I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a Question.

Charles Babbage (1864)



Translation:

Garbage in, Garbage out.



Outline

Part I: Kidney Transplantation & Exchange

- History of kidney allocation policy
- Intro to kidney exchange

Part II: Artificial Intelligence & Medicine

- Intro to AI
- AI in medicine
- AI in kidney exchange

Part III: AI & Ethics / Building a Better Algorithm

- Challenges of integrating AI & Ethics
- A way forward?

Part I

Kidney Transplantation & Exchange

History: Kidney Transplantation, deceased donors

- Early 60's: kidneys used locally; policies decided by local transplant center
- 1968: Southeast Organ Procurement Foundation (SEOPF) formed to share kidneys in southeast US
- 1977 First computer-based organ matching system (UNOS)
- 1984 UNOS separates from SEOPF
- 1984 Congress passes NOTA and establishes OPTN
- 1986 Federal contract to operate OPTN awarded to UNOS
- 1999 UNOS launches UNET, secure internet-based database system to manage organ allocation

More history

- 2000 OPTN Final Rule - “Equitable allocation of deceased donor organs”
  - Use sound medical judgment
  - Achieve best use of donated organs
  - Avoid wasting organs
  - Avoid futile transplants
  - Promote patient access to transplantation
- 2004 OPTN Kidney Transplant Committee
  - Charged with developing a “new rule” based on above criteria
  - Most allocation was based on waiting time
- 2014 New allocation system implemented
  - Yes, it took a decade

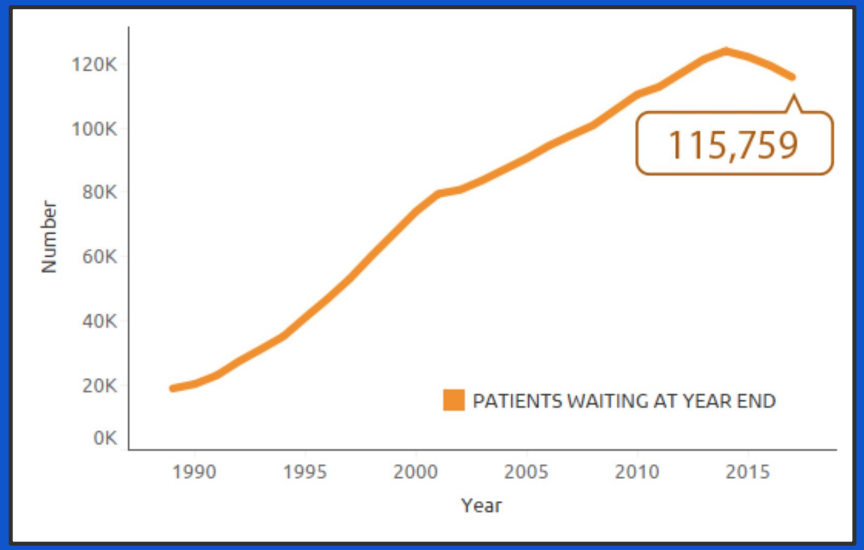
Exchanges: Kidney Paired Donations (KPD)

- 2001: First KPD program in US (Hopkins)
- 2009: Hopkins - first 16 patient multicenter Domino Chain
- 2010: UNOS begins “pilot” kidney exchange program
  - Using AI-based algorithm to match patients with donors
- 2014: National Kidney Registry sets new record with 70 participant chain

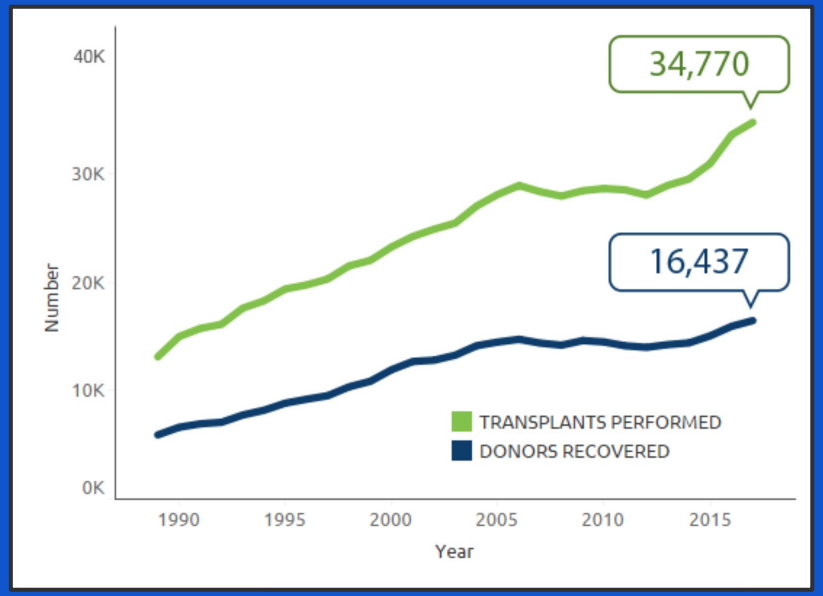
- National exchanges: South Korea (‘91), Netherlands (‘05), Canada (‘09),
- There are MANY exchanges in the US, and they don’t all work together
  - UNOS, NKR, APD, NCDEC, Private hospitals (ex Johns Hopkins)

Kidney Donation in the US

Patients in Need of an Organ

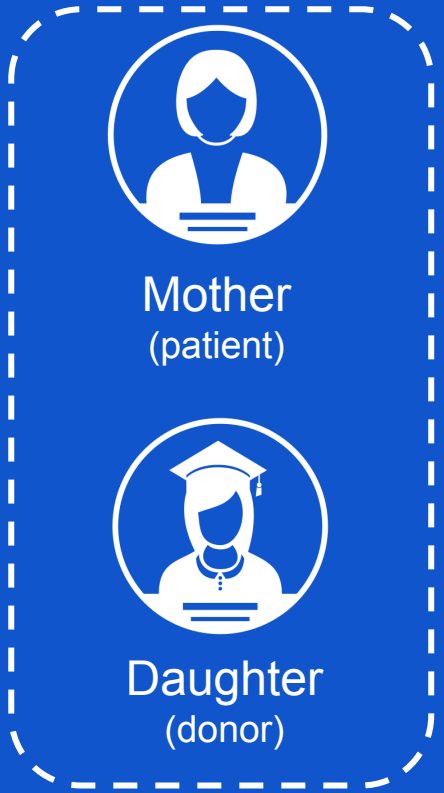


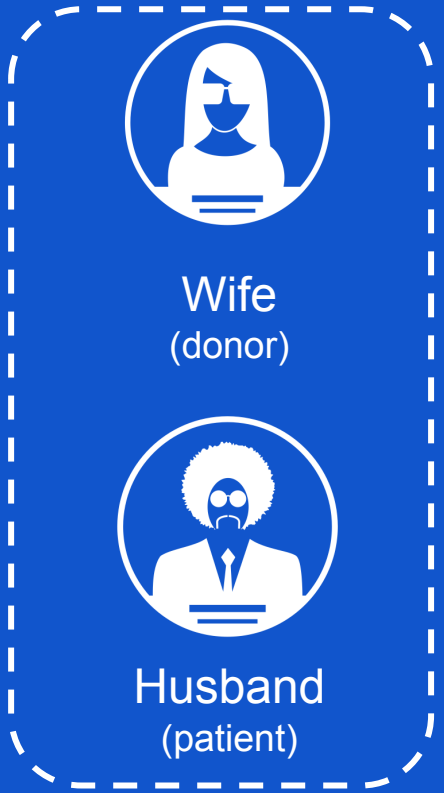
Transplants



Images: https://optn.transplant.hrsa.gov/

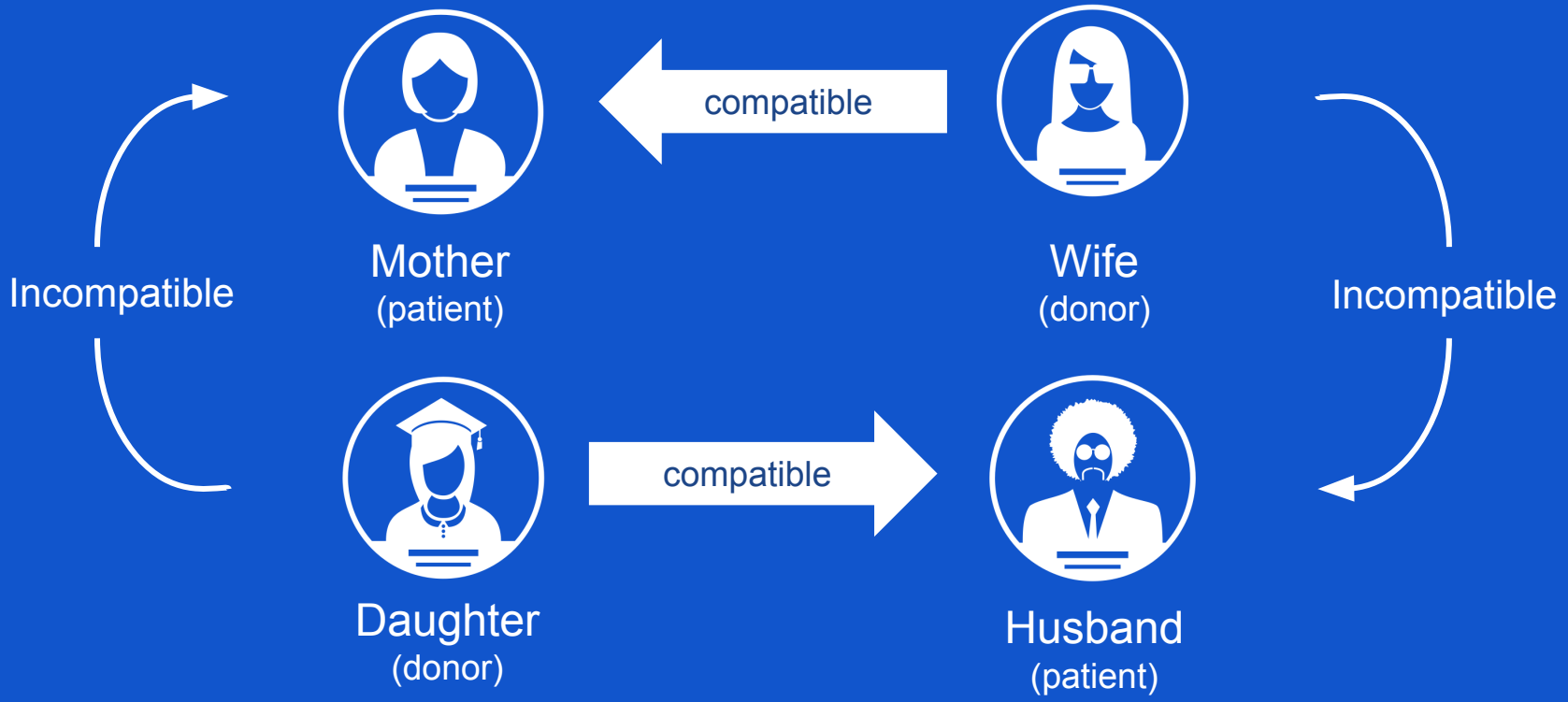
Kidney Exchange





Kidney Exchange

Kidney Exchange



Part II

Artificial Intelligence & Medicine

What is Artificial Intelligence?

In popular culture:

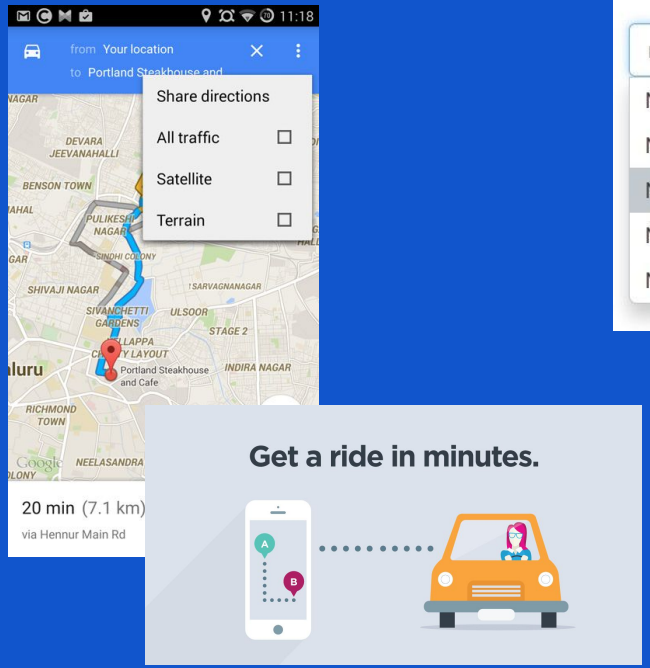
AI is whatever hasn't been done yet. (the "AI effect")

For us:

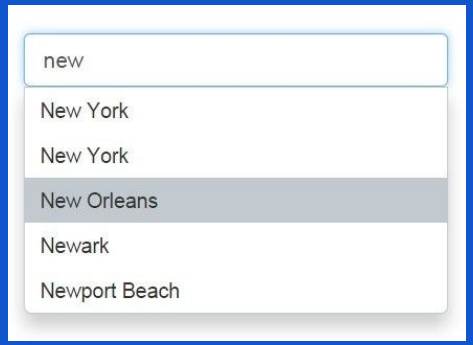
AI is an algorithmic system that makes decisions or takes actions on behalf of a human.

What is Artificial Intelligence?

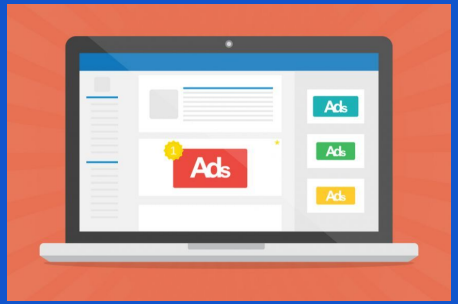
Planning & Optimization



Natural Language Processing

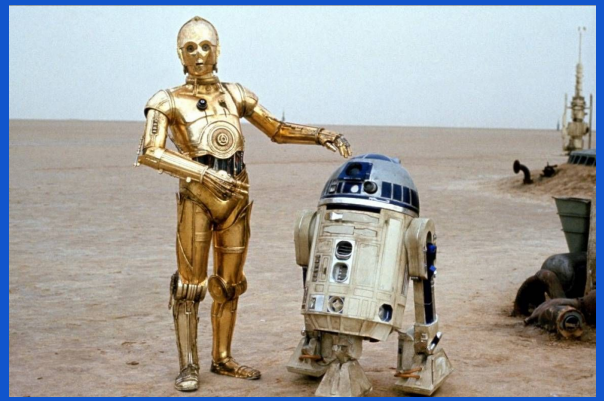


Recommender Systems



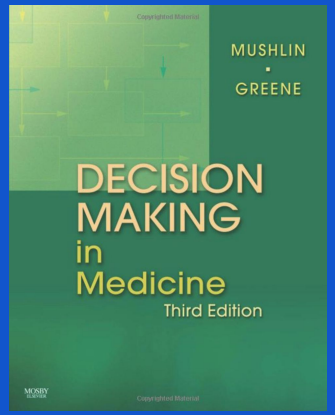
Also Artificial Intelligence...

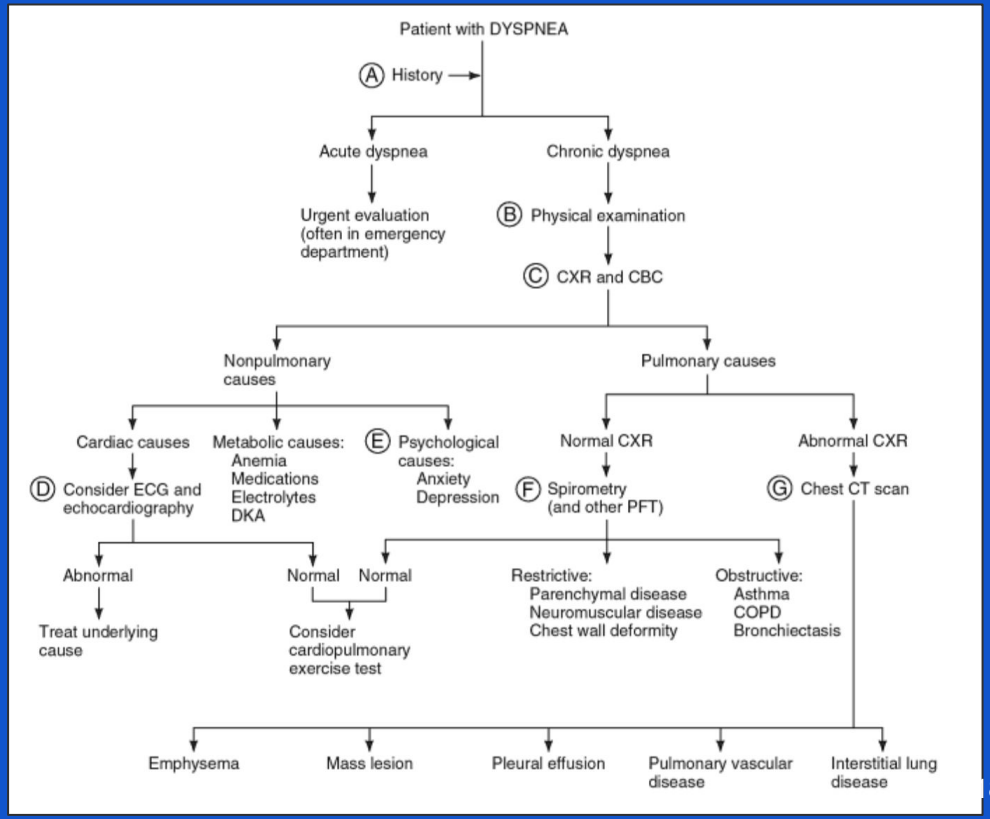
Artificial General Intelligence **&** **Machine Consciousness**



Algorithms & AI In Medicine

- ***Decision support tools***
- Automatic Alerts
- Machine Learning





Algorithms & AI In Medicine

- Decision support tools
- ***Automatic Alerts***
- Machine Learning

Sepsis Alert Algorithm

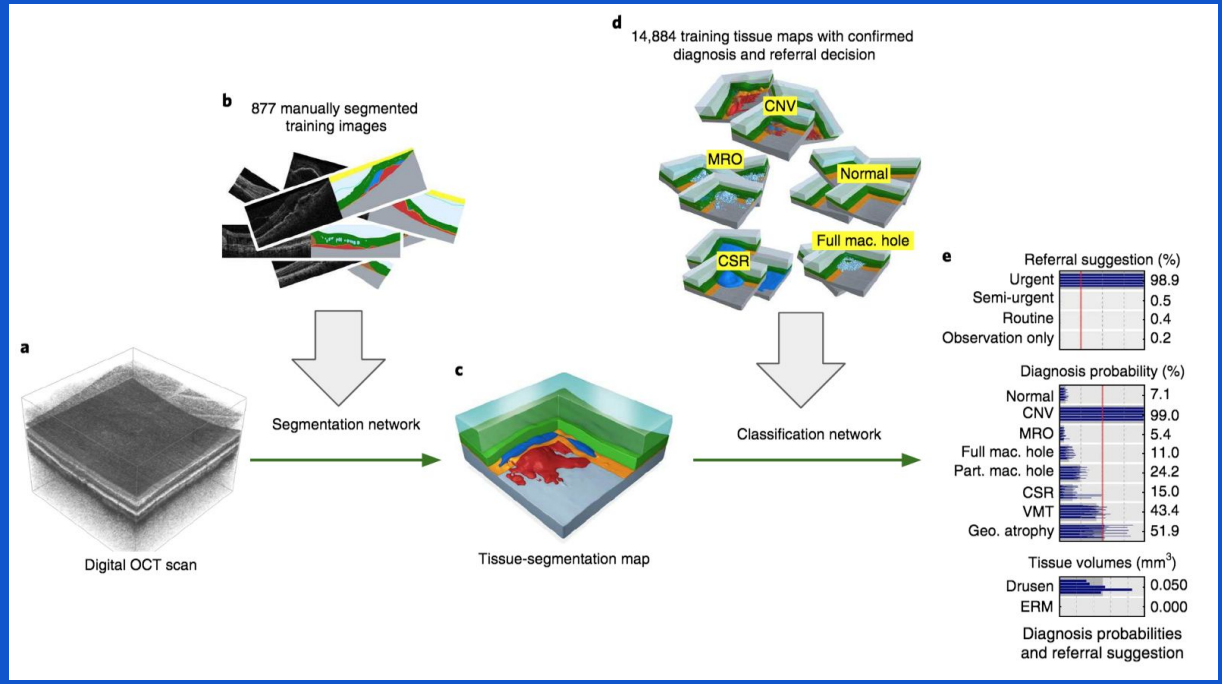
If: Suspected Infection **and** 2 or more of:

- Temp >38 or <36
- Heart rate >90
- Resp. rate >20
- Systolic BP <90 mmHg
- Sa02 <93% on RA without chronic lung disease
- Glucose >8 mmol/L without diabetes
- Confusion/unresponsiveness

Then: Issue Sepsis Alert

Algorithms & AI In Medicine

- Decision support tools
- Automatic Alerts
- ***Machine Learning***




ARTICLES
https://doi.org/10.1038/s41591-018-0107-6
nature medicine

Clinically applicable deep learning for diagnosis and referral in retinal disease

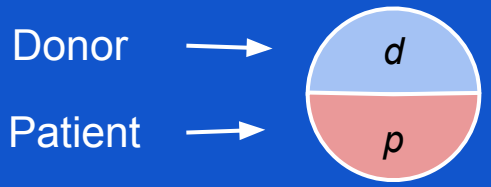
Jeffrey De Fauw[1], Joseph R. Ledsam[1], Bernardino Romera-Paredes[1], Stanislav Nikolov[1], Nenad Tomasev[1], Sam Blackwell[1], Harry Askham[1], Xavier Glorot[1], Brendan O'Donoghue[1], Daniel Visentin[1], George van den Driessche[1], Balaji Lakshminarayanan[1], Clemens Meyer[1], Faith Mackinder[1], Simon Bouton[1], Kareem Ayoub[1], Reena Chopra[2,3], Dominic King[1], Alan Karthikesalingam[1], Cían O. Hughes[1,2], Rosalind Raine[3], Julian Hughes[2], Dawn A. Sim[2], Catherine Egan[2], Adnan Tufail[2], Hugh Montgomery[2,3], Demis Hassabis[1], Geraint Rees[2,3], Trevor Back[1], Peng T. Khaw[2], Mustafa Suleyman[1], Julien Cornebise[1,3,4], Pearse A. Keane[2,4*] and Olaf Ronneberger[1,4*]

Medical Imaging Data → Machine learning model → Diagnosis

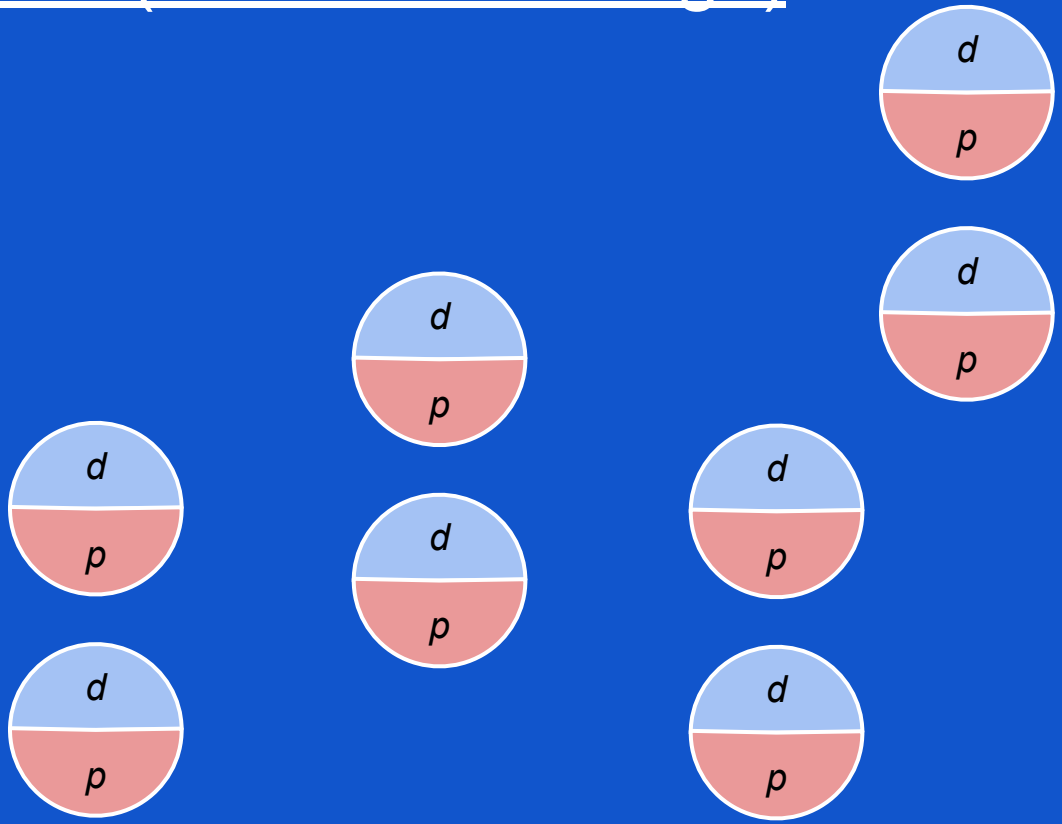
Algorithms & AI In Medicine

- Algorithms (and AI) are common in medicine
- Usually easy to interpret:
  - Decision support
  - Automatic alerts
  - Diagnosis prediction
- What about kidney exchange?

Kidney Transplant (Without Exchange)



Kidney Transplants (Without Exchange)

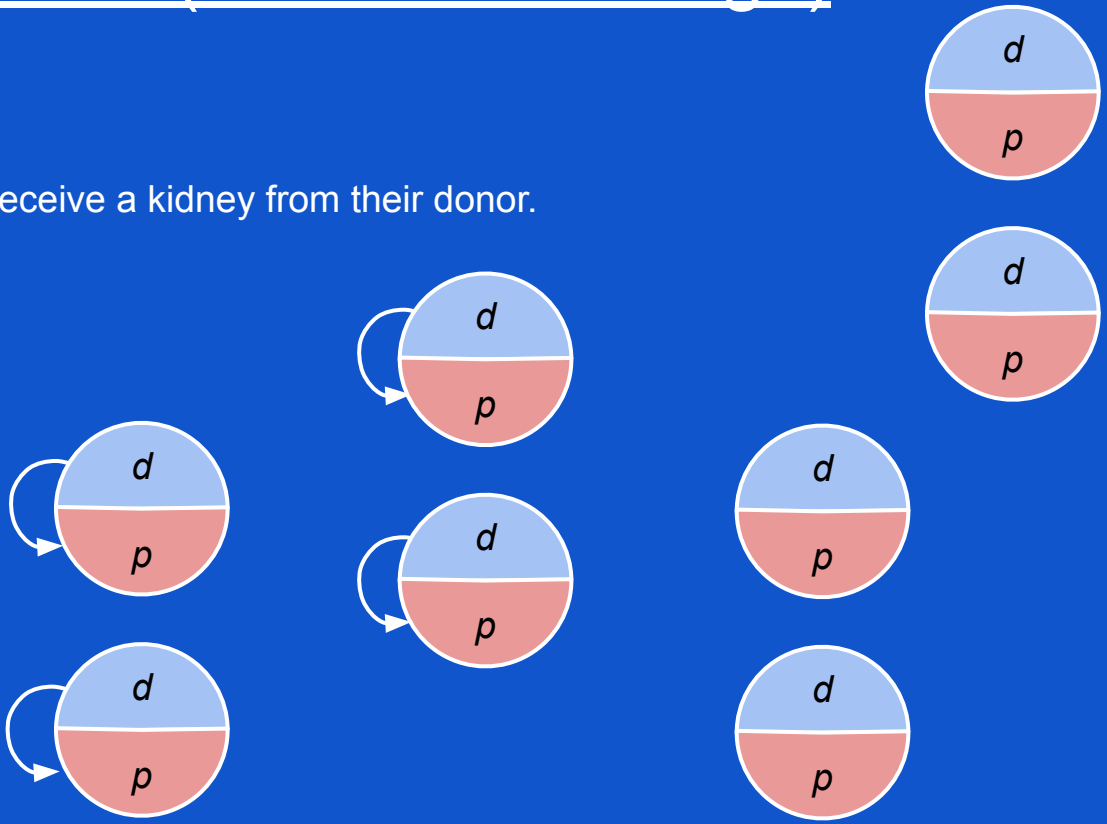


Kidney Transplants (Without Exchange)

Without Exchange

Roughly 50% of patients can receive a kidney from their donor.

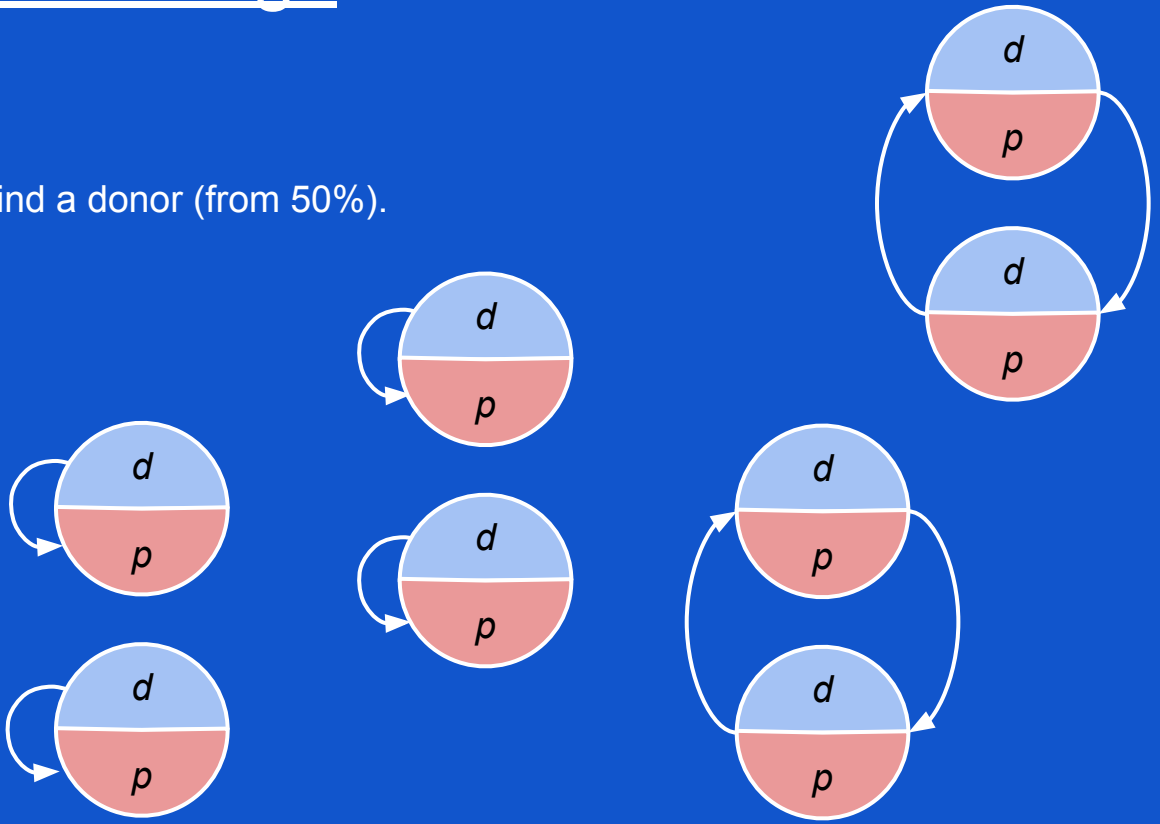
(The rest are incompatible.)



Paired Kidney Exchange

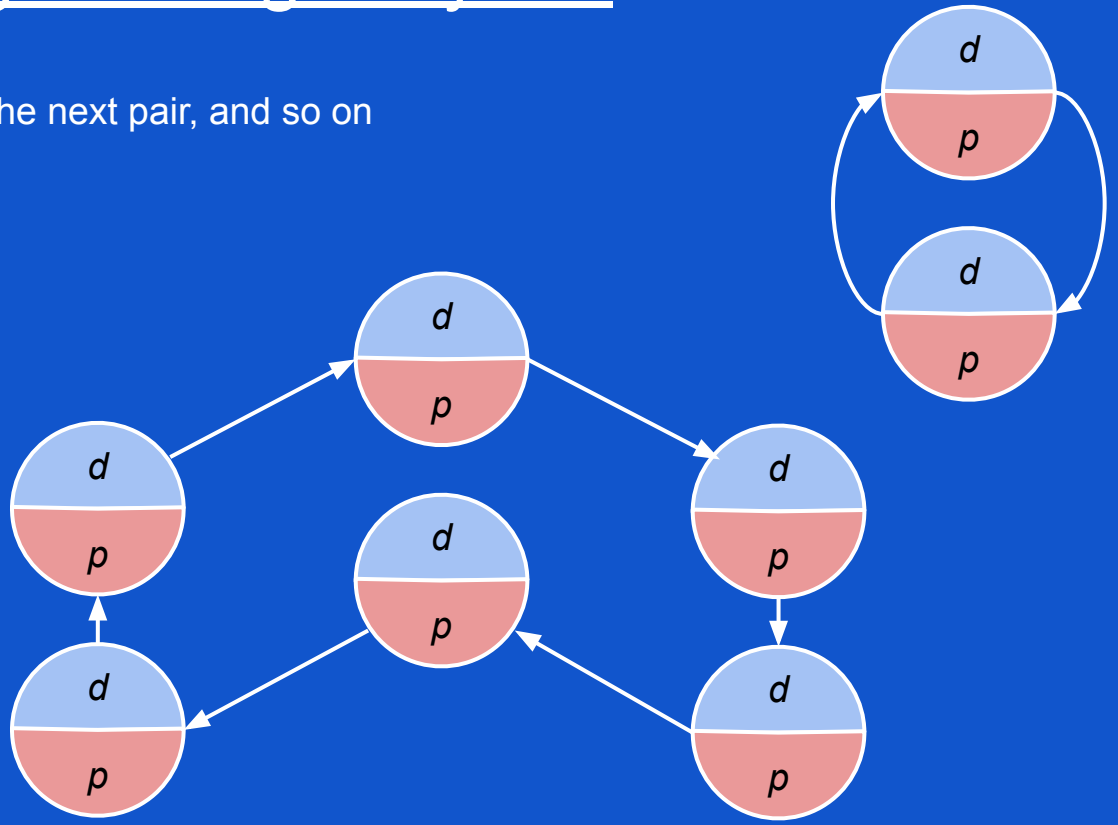
Two pairs exchange donors.

Roughly 75% of patients can find a donor (from 50%).



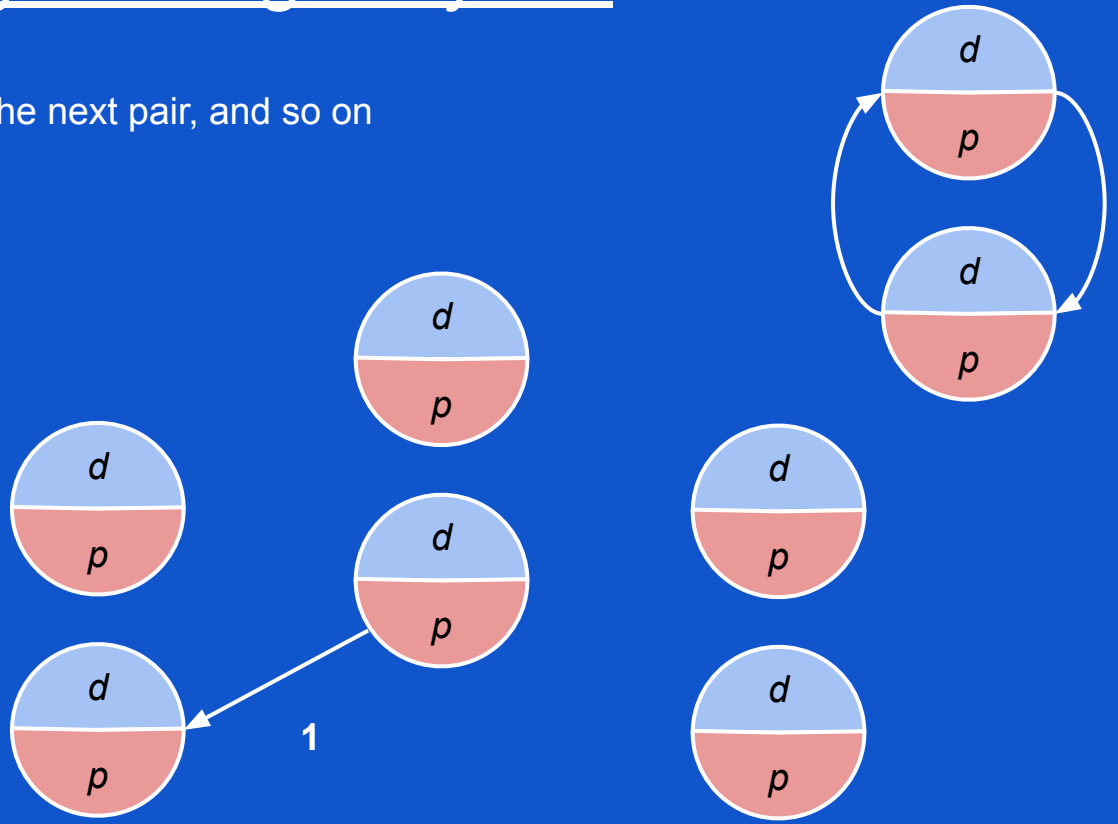
Kidney Exchanges: Longer Cycles

Every pair in a cycle donates to the next pair, and so on



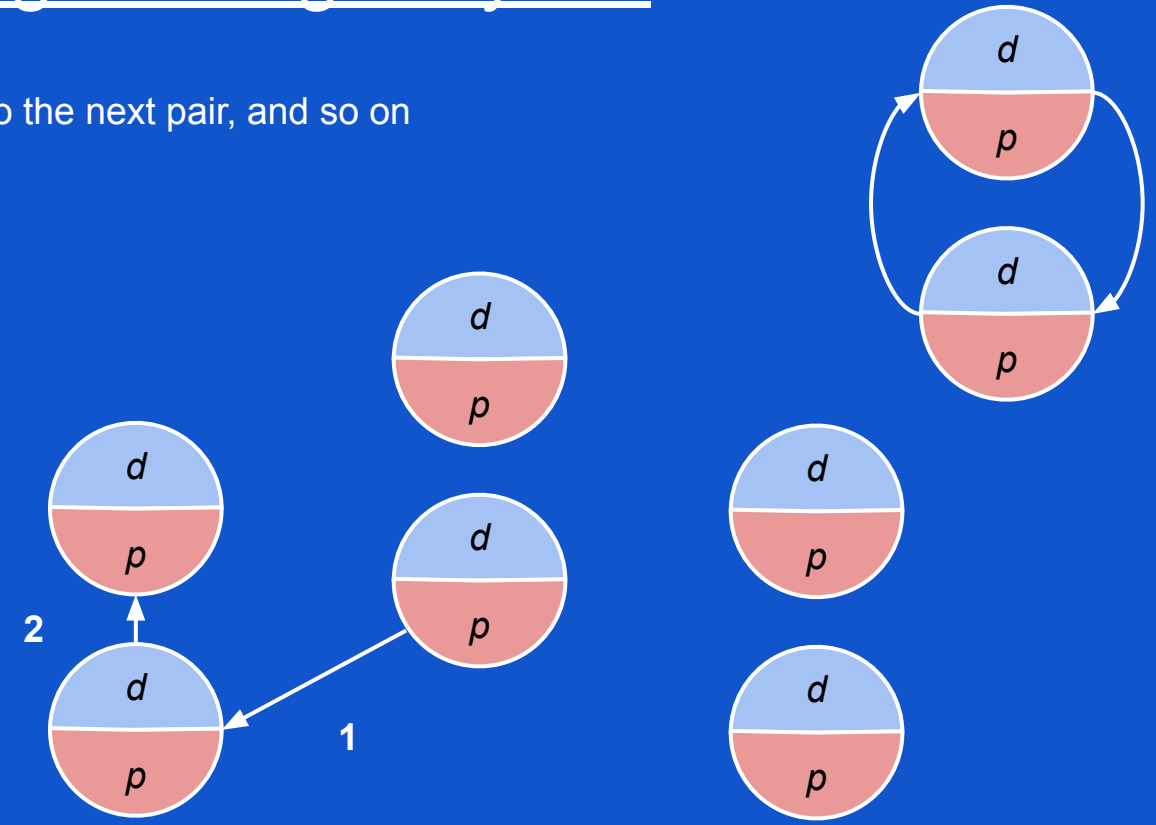
Kidney Exchanges: Longer Cycles

Every pair in a cycle donates to the next pair, and so on



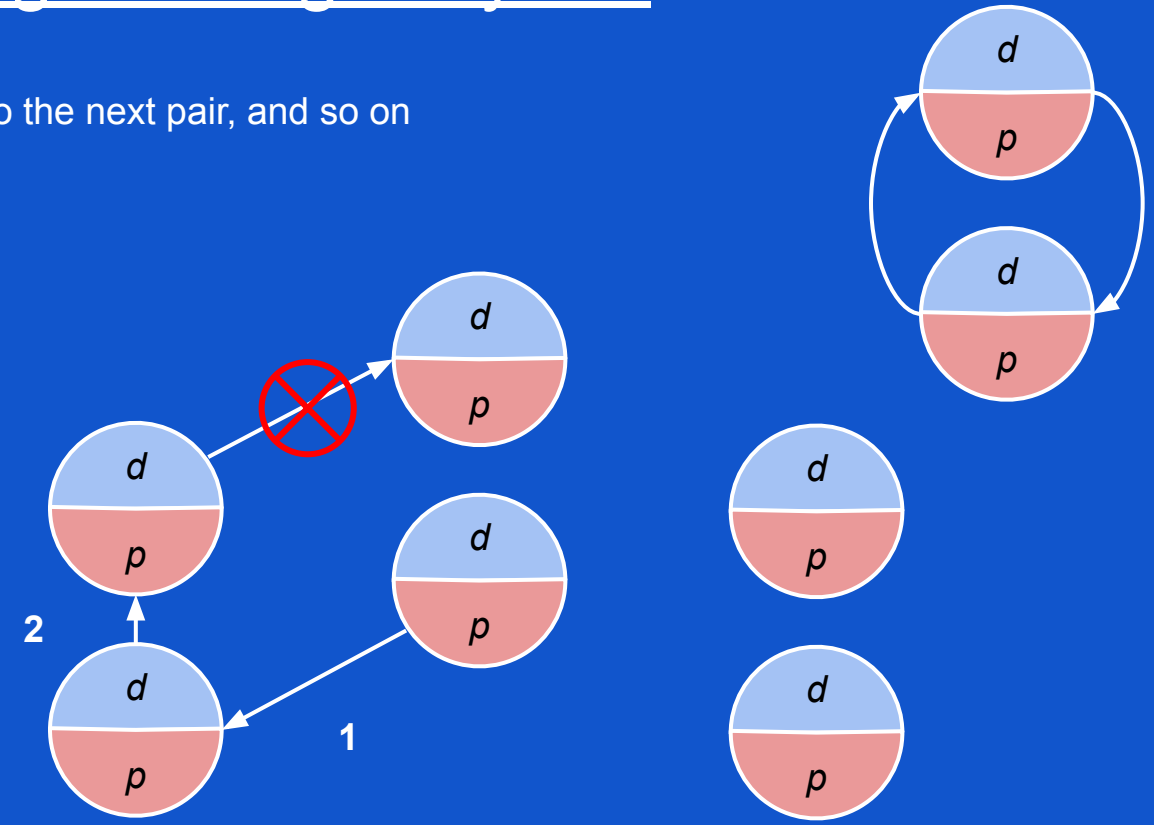
Kidney Exchanges: Longer Cycles

Every pair in a cycle donates to the next pair, and so on



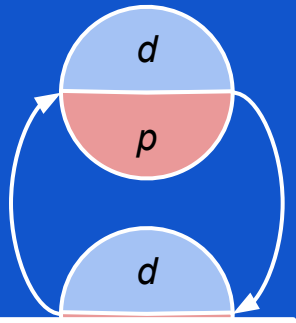
Kidney Exchanges: Longer Cycles

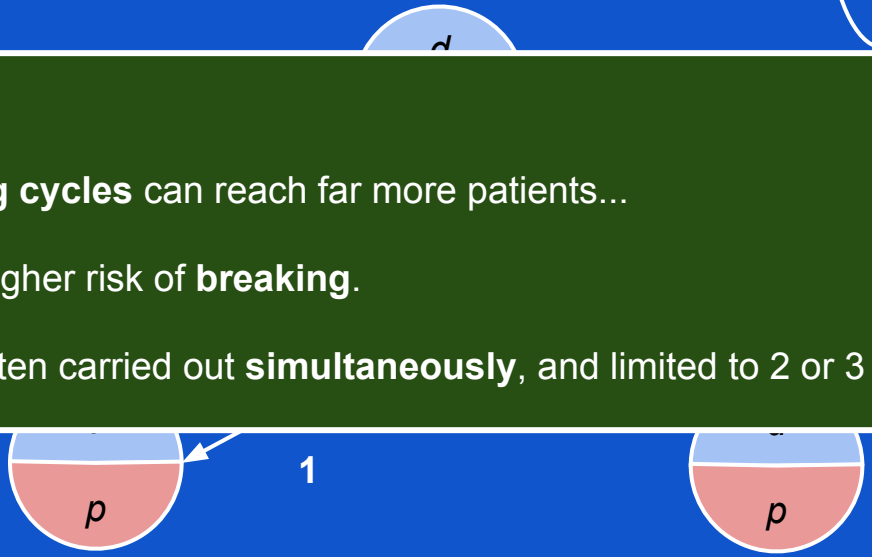
Every pair in a cycle donates to the next pair, and so on



Kidney Exchanges: Longer Cycles

Every pair in a cycle donates to the next pair, and so on





Implications

In real exchange pools, **long cycles** can reach far more patients...

But long cycles have a far higher risk of **breaking**.

To reduce risk, cycles are often carried out **simultaneously**, and limited to 2 or 3 transplants.

Kidney Exchanges: Chains

NDDs can increase overall number of transplants (by 5-6%) by donating to an *exchange* rather than the *waiting list*.

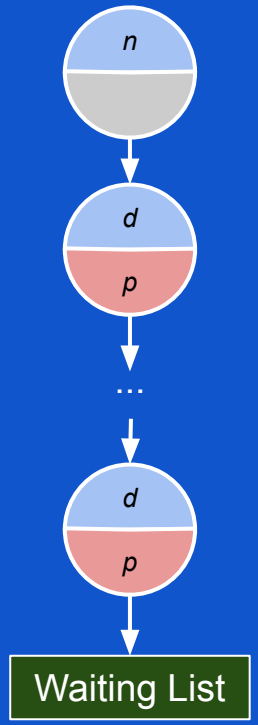
DPD:

- Often simultaneous
- In practice, limited to 3-4 transplants

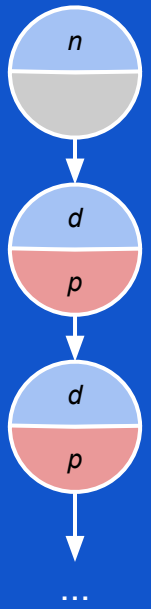
NEAD:

- First reported chain had 10 transplants over 8 months
- Unlimited length (in theory)

Domino Paired Donation (DPD)

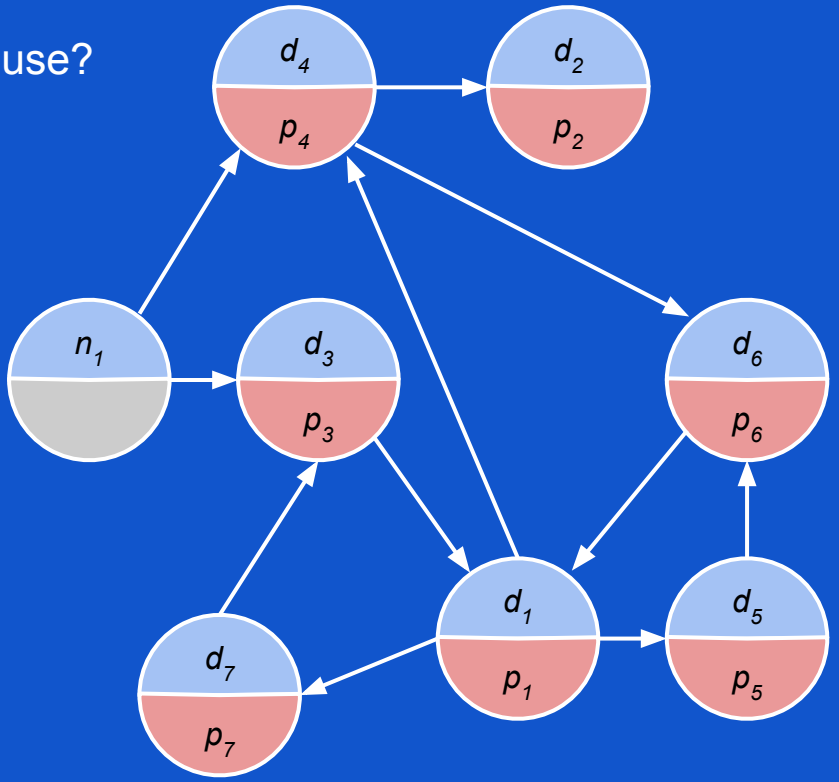


Non-simultaneous extended altruistic donor (NEAD)



The Kidney Exchange Problem

Q: How do we decide which cycles & chains to use?



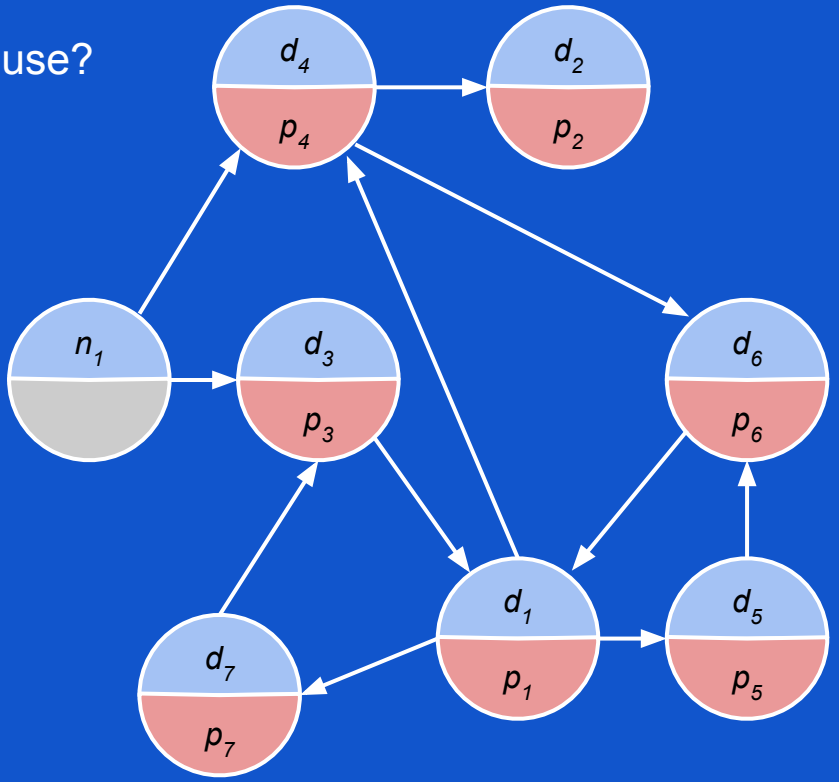
The Kidney Exchange Problem

Q: How do we decide which cycles & chains to use?

A: Algorithms

1) Exchanges set a *matching policy.*

2) Computer scientists design an algorithm to implement the policy.



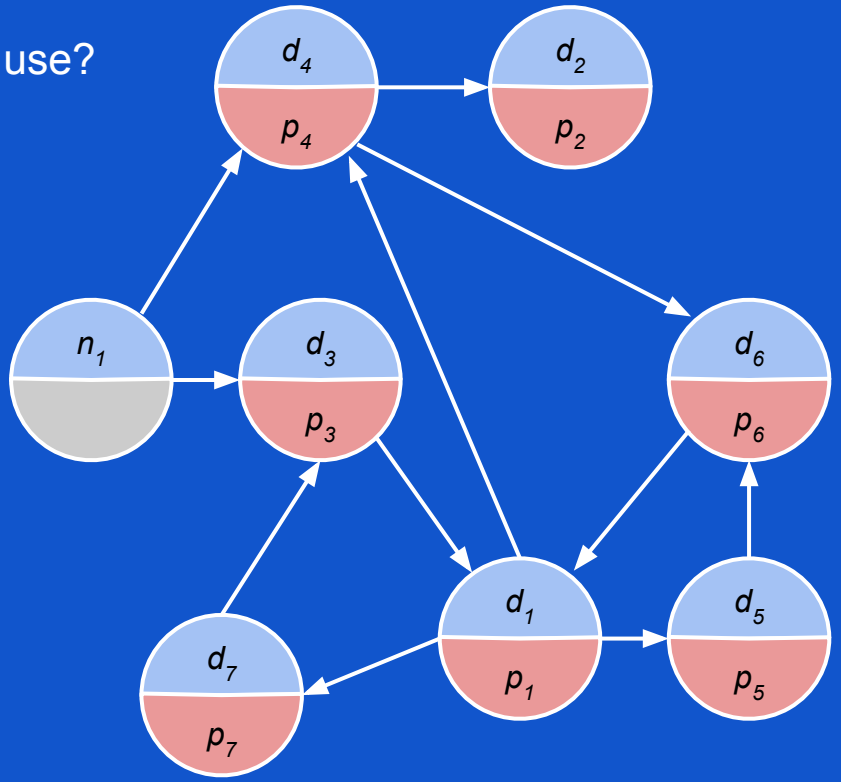
The Kidney Exchange Problem

Q: How do we decide which cycles & chains to use?

A: Algorithms

General Policy Principles

Efficiency / Utilitarianism	Donor kidneys should do the most good for the most patients.
Prioritarianism	Some patients should be prioritized over others.
Egalitarianism	All participants should have equal access to donor kidneys.



Policy Examples & Corresponding Principles

Utilitarian Policy:

- Maximize total number of transplants
- Maximize expected life years

Prioritarian Policy:

- Transplant younger patients before older patients
- Transplant sick patients before healthy patients

Egalitarian Policy:

- Lottery (randomly select patients to receive transplants)
- First-come first-served

Policy Example: Priority Points (OPTN/UNOS)

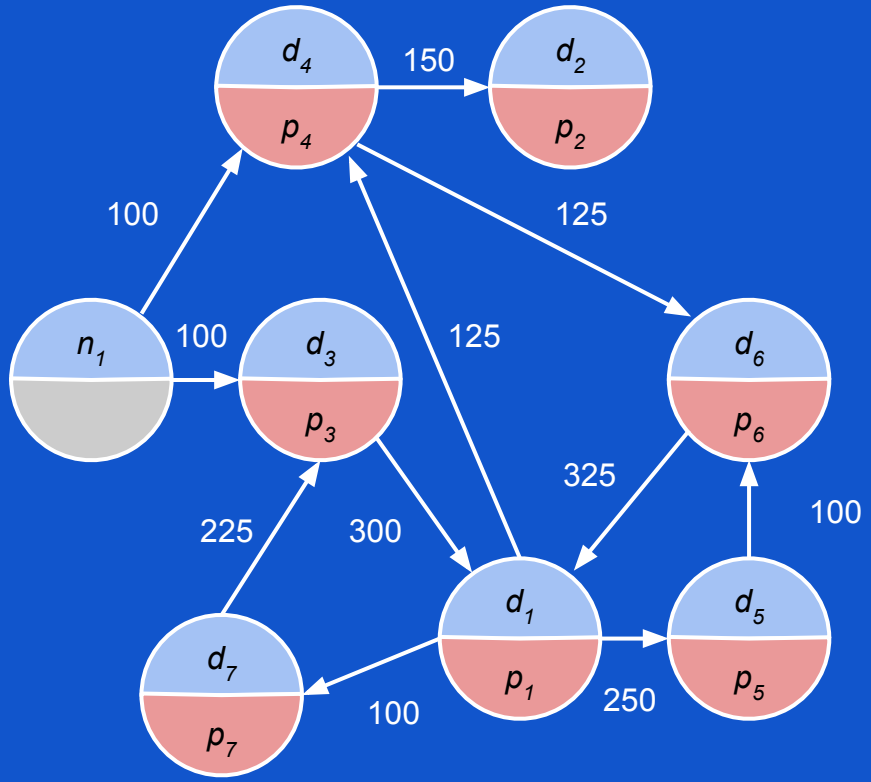
UNOS Matching Policy:

1) Assign a *score* to each transplant

2) Select the cycles & chains to *maximize total score*

This is...

- Computationally hard (NP-hard)
- Practically impossible without an algorithm



Policy Example: Priority Points (OPTN/UNOS)

100 “base points” + ...

Table 13-2: OPTN KPD Prioritization Points

If the:	Then the match will receive:
Candidate is a 0-ABDR mismatch with the potential donor	200 points
Candidate has a CPRA greater than or equal to 80%	125 points
Candidate is a prior living organ donor	150 points
Candidate was less than 18 years old at the time the candidate was registered in the OPTN KPD program	100 points
Candidate and potential donor are registered for the OPTN KPD program in the same region	25 points
Candidate and potential donor are registered for the OPTN KPD program in the same DSA	25 points
Transplant hospital that registered both the candidate and potential donor in the OPTN KPD program is the same	25 points
Potential donor has at least one of the other antibody specificities reported for the candidate	- 5 points

Policy Example: Priority Points (OPTN/UNOS)

100 “base points” + ...

Egalitarianism

Table 13-2: OPTN KPD Prioritization Points

If the:	Then the match will receive:
Candidate is a 0-ABDR mismatch with the potential donor	200 points
Candidate has a CPRA greater than or equal to 80%	125 points
Candidate is a prior living organ donor	150 points
Candidate was less than 18 years old at the time the candidate was registered in the OPTN KPD program	100 points
Candidate and potential donor are registered for the OPTN KPD program in the same region	25 points
Candidate and potential donor are registered for the OPTN KPD program in the same DSA	25 points
Transplant hospital that registered both the candidate and potential donor in the OPTN KPD program is the same	25 points
Potential donor has at least one of the other antibody specificities reported for the candidate	- 5 points

Utilitarianism

Prioritarianism

Utilitarianism(?)

Policy Example: Priority Points (OPTN/UNOS)

Egalitarian, **Prioritarian**, or **Utilitarian?**

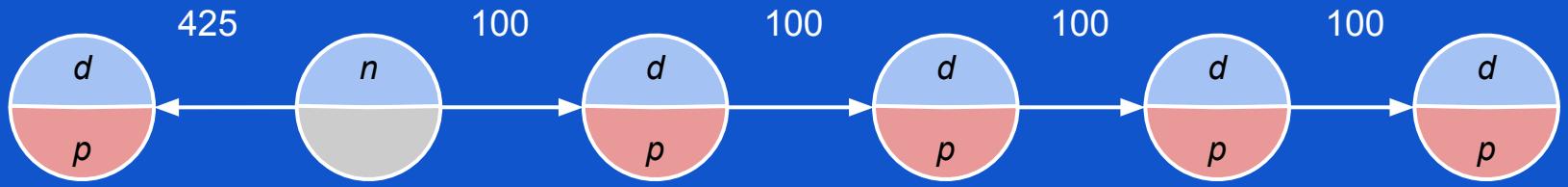
Q: Does maximizing priority points maximize the **overall number of transplants**?

Policy Example: Priority Points (OPTN/UNOS)

Egalitarian, **Prioritarian**, or **Utilitarian?**

Q: Does maximizing priority points maximize the **overall number of transplants**?

A: Not necessarily!



Policy Example: Priority Points (OPTN/UNOS)

Egalitarian, **Prioritarian**, or **Utilitarian?**

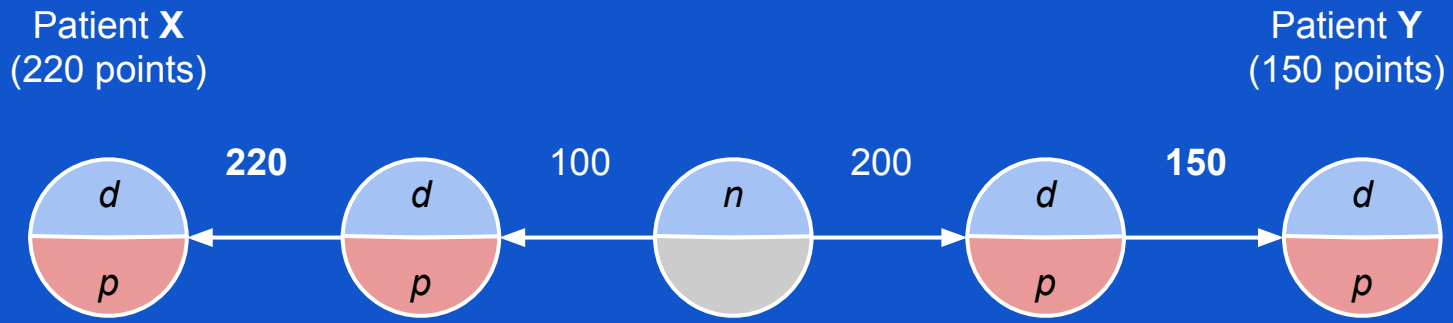
Q: If patient **X** has a higher score than patient **Y**, will **X** receive a kidney before **Y**?

Policy Example: Priority Points (OPTN/UNOS)

Egalitarian, **Prioritarian**, or **Utilitarian?**

Q: If patient **X** has a higher score than patient **Y**, will **X** receive a kidney before **Y**?

A: Not necessarily!



UNOS Policy - Ethical Implications

UNOS awards points based on the following criteria (plus 100 “base points”):

- Exact HLA match 200 points
- Highly sensitized 125 points
- Prior organ donor 150 points
- Age < 18 100 points
- Geographic proximity 25-75 points

UNOS Policy - Ethical Implications

UNOS awards points based on the following criteria (plus 100 “base points”):

- Exact HLA match 200 points
- Highly sensitized 125 points
- Prior organ donor 150 points
- Age < 18 100 points
- Geographic proximity 25-75 points

Consider two patients:

A) 16 y/o patient awaiting his second kidney, highly sensitized due to prior non-compliance with failure of original graft
(100 + 100 + 125 = **325 points**)

B) 30 y/o non-sensitized prior organ donor.
(100 + 150 = **250 point**s)

Patient A is prioritized over Patient B

Policy Example: Priority Points (OPTN/UNOS)

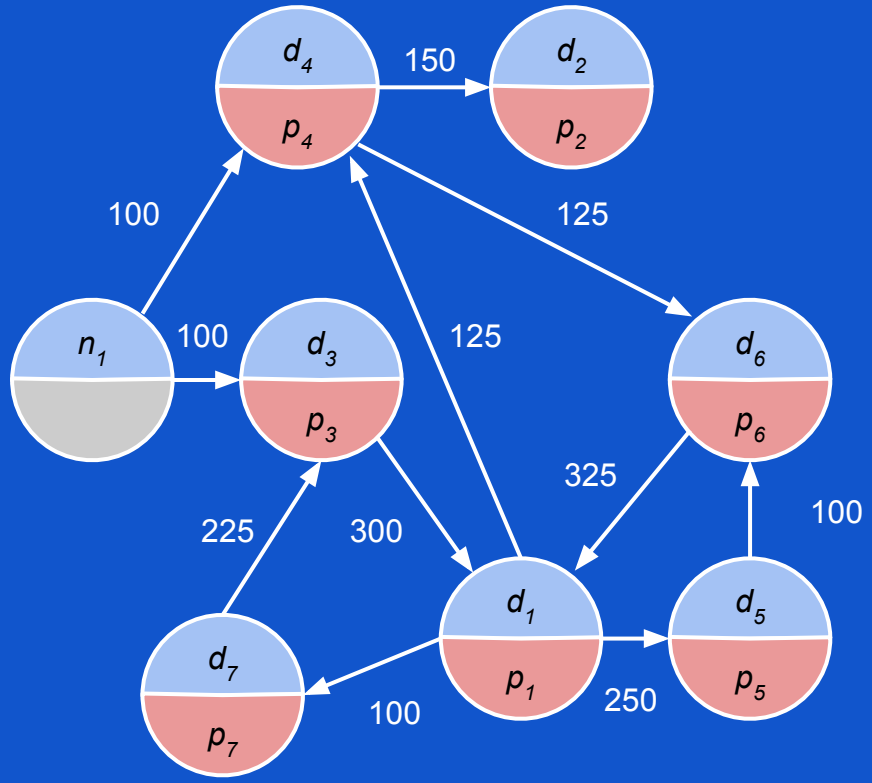
Questions:

Is it fair to maximize priority points?

When, if ever, should we carry out *fewer* than the maximum possible number of transplants?

Can priority points reflect principles of...

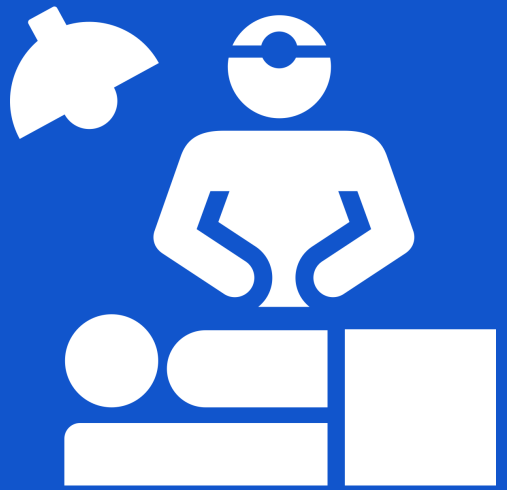
- Utilitarianism?
- Prioritarianism?
- Egalitarianism?



View from the Operating Room

Real people, real stories from the transplant world

- When do I hold out for a better kidney?
- What about gaming the system?
- What risks do I accept?



Part III

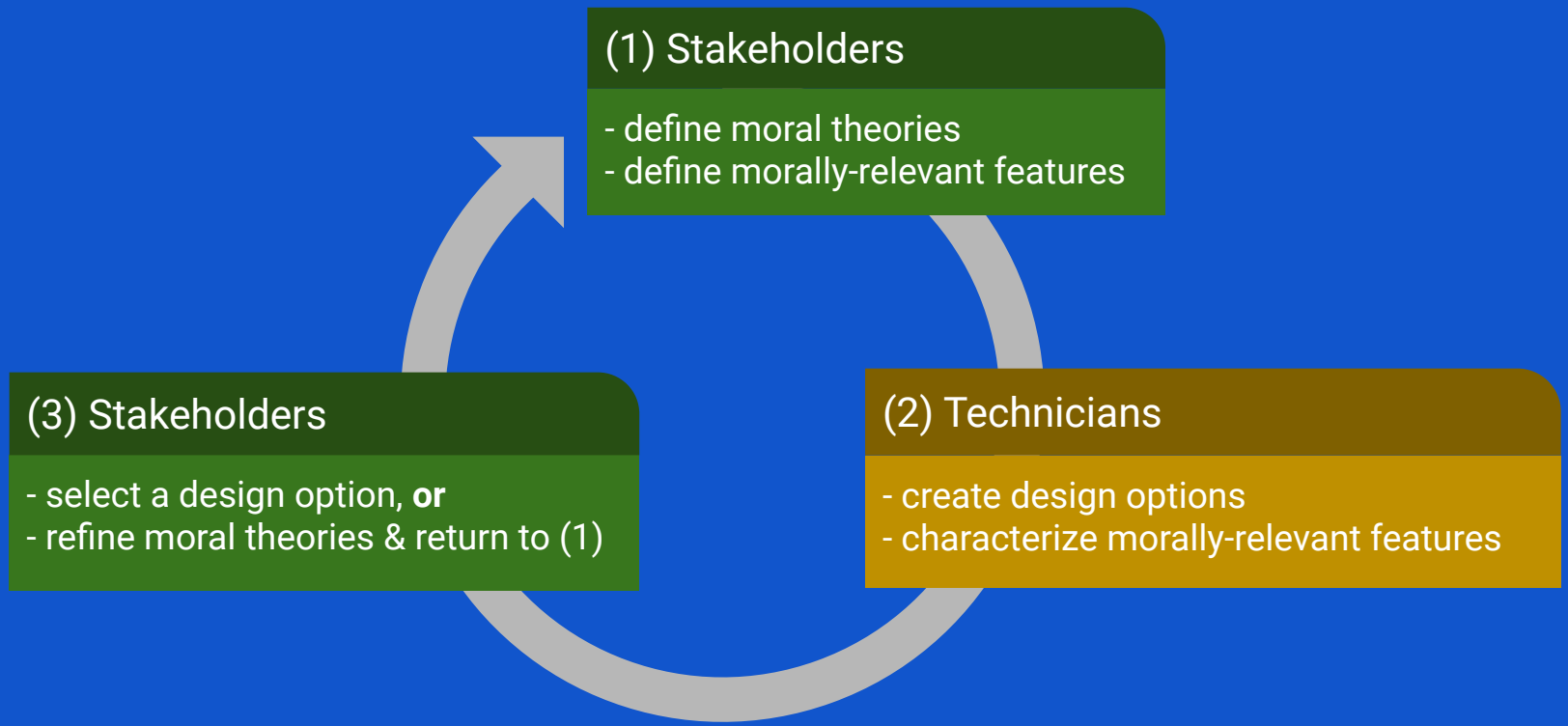
AI & Ethics / Building a Better Algorithm

AI & Ethics: Questions

What are the moral implications of an algorithm's design and use?

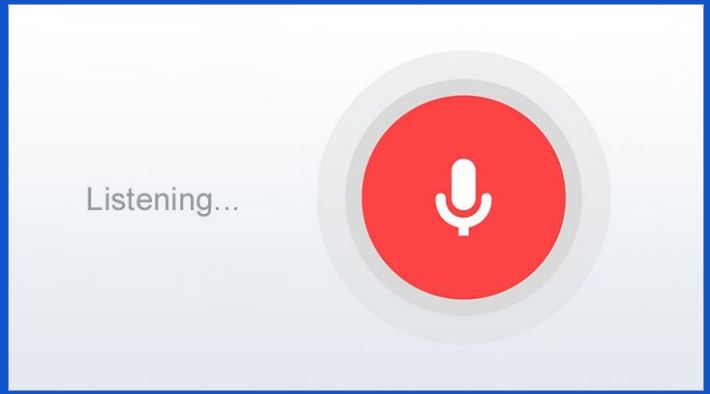
How should competing implications/principles be resolved?

Designing a Better Algorithm



Conclusions

- AI & algorithms are prevalent in medicine
- These algorithms often have ethical implications
- One example: kidney exchange
  - *relies* on AI to match patients and donors
  - unintended consequences
- We can do better
  - Iterative, collaborative process with both technical and ethical experts



Thank you for your attention

Duncan McElfresh: dmcelfre@math.umd.edu

Gabriel Schnickel: gschnickel@uscd.edu
John Dickerson: john@cs.umd.edu
Patricia Mayer: patricia.mayer@bannerhealth.com