Causal Thinking

LAsBEST LECTURE JUNE 15, 2021

PROF. ERIKA GARCIA

Objectives

At the conclusion of this class meeting, students will be able to:

- Define a causal effect
- Explain exchangeability and why it is important for causality
- Define confounding and describe its relevance to the concept of exchangeability
- Use Directed Acyclic Graphs to assess for confounding

Roadmap

Causality

- Causal thinking
- Exchangeability
- Confounding

Directed Acyclic Graphs (DAGs)

Causality

https://www.today.com/health/women-who-stop-drinking-alcohol-improve-mental-health-study-finds-t157931

MIND & BODY

Women who stop drinking alcohol improve mental health, study finds

The growing use of alcohol among women has become a public health concern in recent years.

Quitting drinking may be a better way to go when it comes to feeling calm and peaceful. Getty Images

Women who quit alcohol improved their mental well-being, researchers reported this week in CMAJ (Canadian Medical Association Journal). The study comes as many Americans are trying out an alcohol-free life as part of the “sober-curious” movement.

For the study, researchers analyzed the drinking habits and self-reported levels of mental health of more than 41,000 people.

Men and women who were lifetime abstainers — those who didn’t drink any alcohol at all at any point in their lives — reported the highest levels of mental well-being.

When the drinkers were followed over time, quitting alcohol was linked with a more favorable change in mental well-being among women. Women who stopped drinking approached the highest levels of mental health reported by lifetime abstainers within four years.

TODAY FOOD HOME HEALTH & WELLNESS STYLE PARENTS POP CULTURE SHOP

https://www.today.com/health/women-who-stop-drinking-alcohol-improve-mental-health-study-finds-t157931

MIND & BODY

Women who stop drinking alcohol improve mental health, study finds

The growing use of alcohol among women has become a public health concern in recent years.

Based on this study, does quitting drinking have a casual effect on mental health? Why or why not?

Quitting drinking may be a better way to go when it comes to feeling calm and peaceful. Getty Images

What if instead…

For the study, researchers recruited 41,000 people. Mental health was assessed at enrolment into the study.

Drinkers were randomized to either continue current drinking habits or to quit drinking. There was 100% adherence to the protocol.

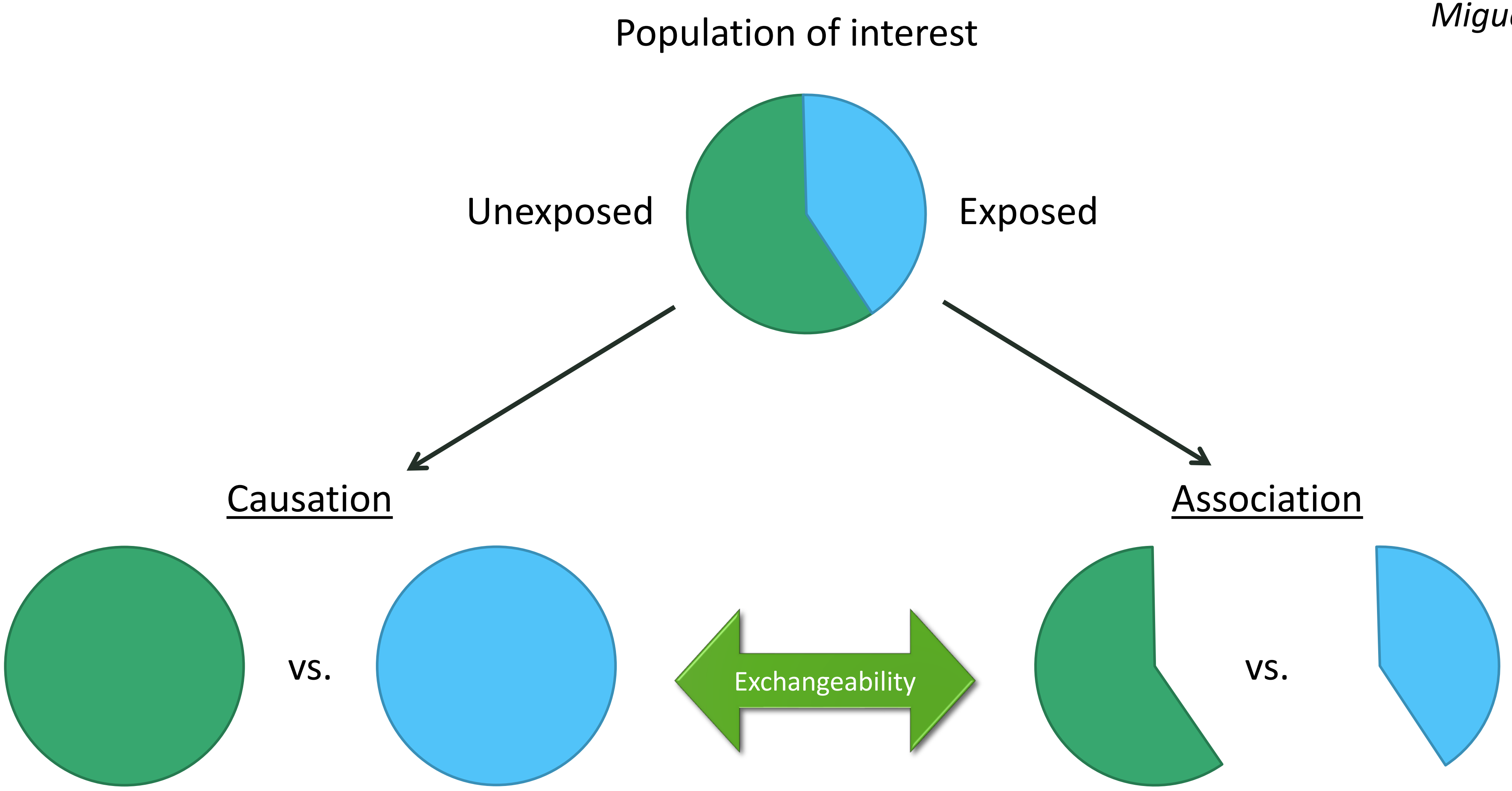
Women in the "alcohol quitting group" had a more favorable change in mental well-being compared with women in the "drinking as usual" group.

Association is not causation

Association: risk difference in two subsets of the population distinguished by individual's actual treatment/exposure value

Causation: risk difference in the entire population under two different treatment values

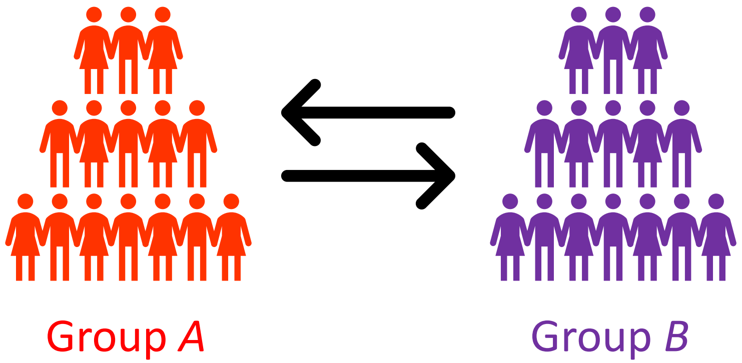
Adapted from slide by
Miguel Hernán



Exchangeability

Subjects in group *A* would have had the same effect/risk as those in group *B* had they received the treatment/exposure of those in group *B*

Implies lack of confounding



Randomization is so highly valued because it is expected to produce exchangeability

Confounding

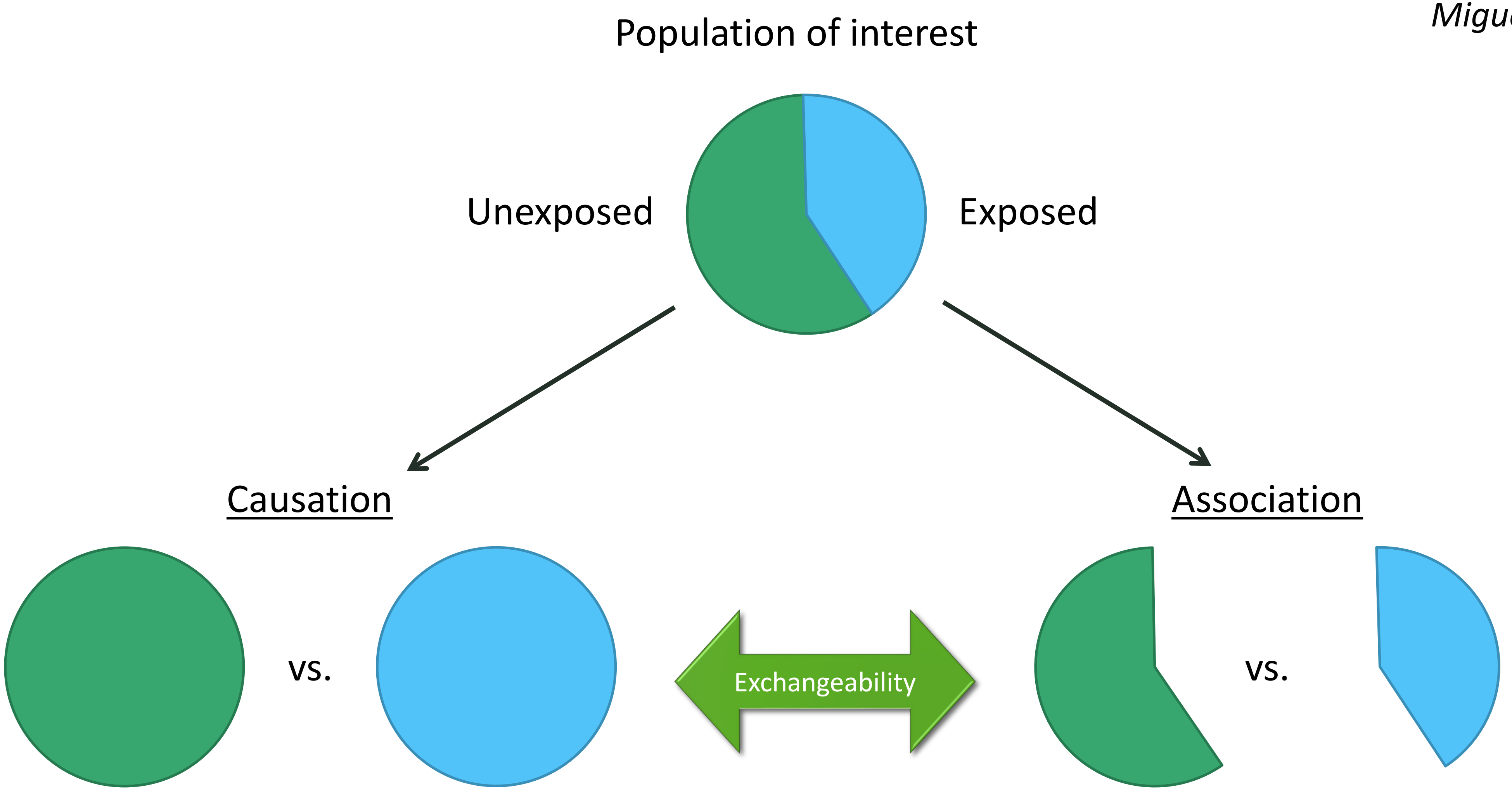
From Latin *confundere*, to mix together

The distortion of a measure of the effect of an exposure on an outcome due to the association of the exposure with other factors that influence the occurrence of the outcome (*A Dictionary of Epidemiology, 5th Ed.)*

Can bias effect estimates—a major concern in observational studies

If confounding is present, you do not have exchangeability

Adapted from slide by
Miguel Hernán



Causation ≠ Association then there is confounding

The research assistants made a mistake

Study participants were randomized into either group A or B

Original treatment assignments:

- Group A were assigned to <u>continue</u> current alcohol drinking habits
- Group B were assigned to <u>quit</u> drinking alcohol

But, the instructions were misinterpreted and instead:

- Group A were assigned to <u>quit</u> drinking alcohol
- Group B were assigned to <u>continue</u> current alcohol drinking habits

❖ How would this reversal of treatment assignment impact the study's results?

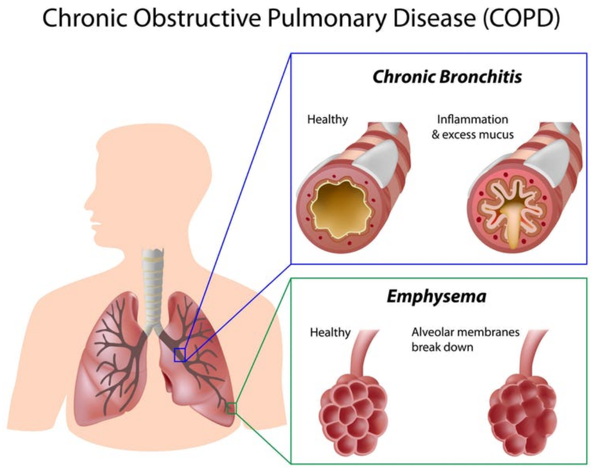
In an observational study (asking if they carry a lighter), how might those participants who carry a lighter differ from those who do not carry a lighter?

Smoking

Carry a lighter

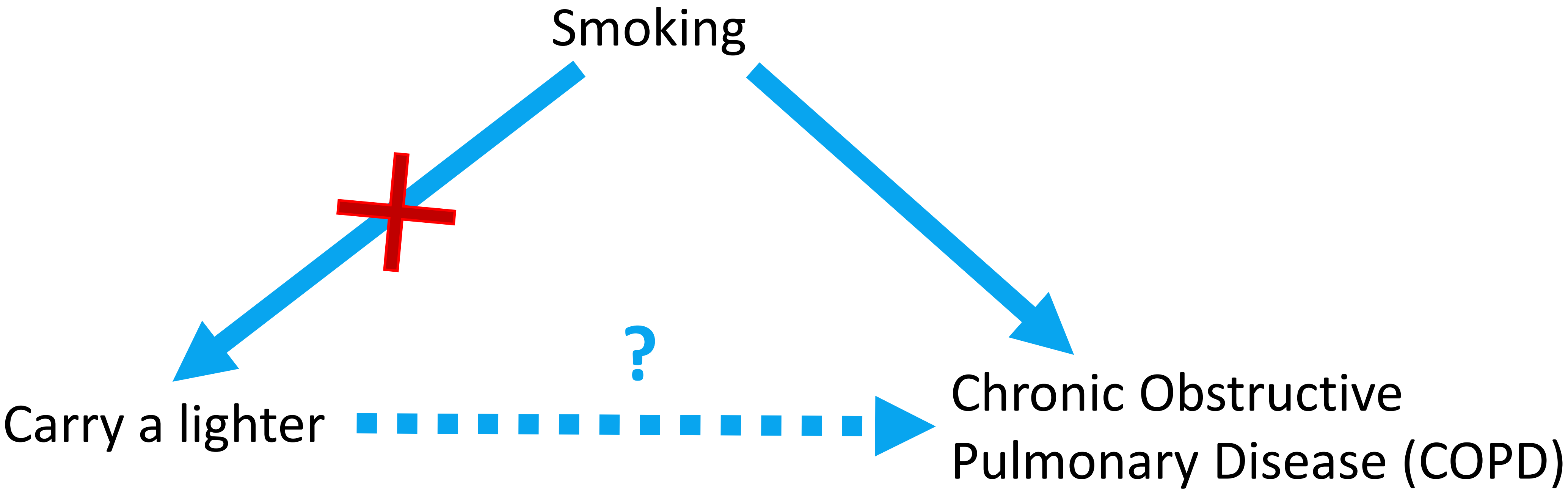
?

Chronic Obstructive Pulmonary Disease (COPD)



Smoking may confound the relation between carrying a lighter and risk of COPD

In an experimental study with randomized treatment assignment (randomly assign whether person carries a lighter; 100% adherence), how might those participants who carry a lighter differ from those who do not carry a lighter?



Smoking not likely to confound the relation between carrying a lighter and risk of COPD

Review

1. Define a causal effect
2. Explain exchangeability and why it is important for causality
3. Define confounding and describe its relevance to the concept of exchangeability

Directed Acyclic Graphs

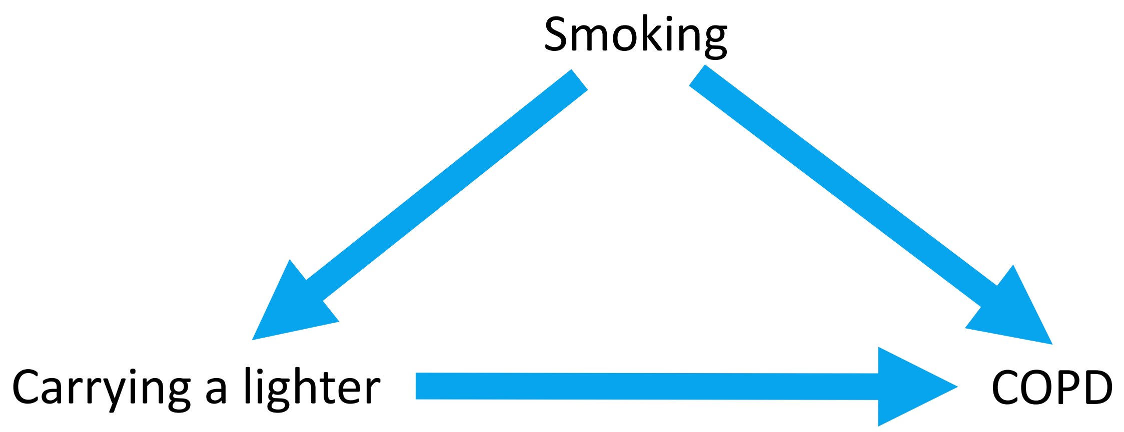
AKA DAGS

Causal Diagrams as a Tool in Epi Research

Summarization of causal links using graphs/diagrams has long been used as a tool in causal analysis

Encode our assumptions—they display assumptions about the web of causation

Help researchers in the selection of factors to control for in a study in order to reduce confounding



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology* 10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

Directed: A $\longrightarrow$ Y

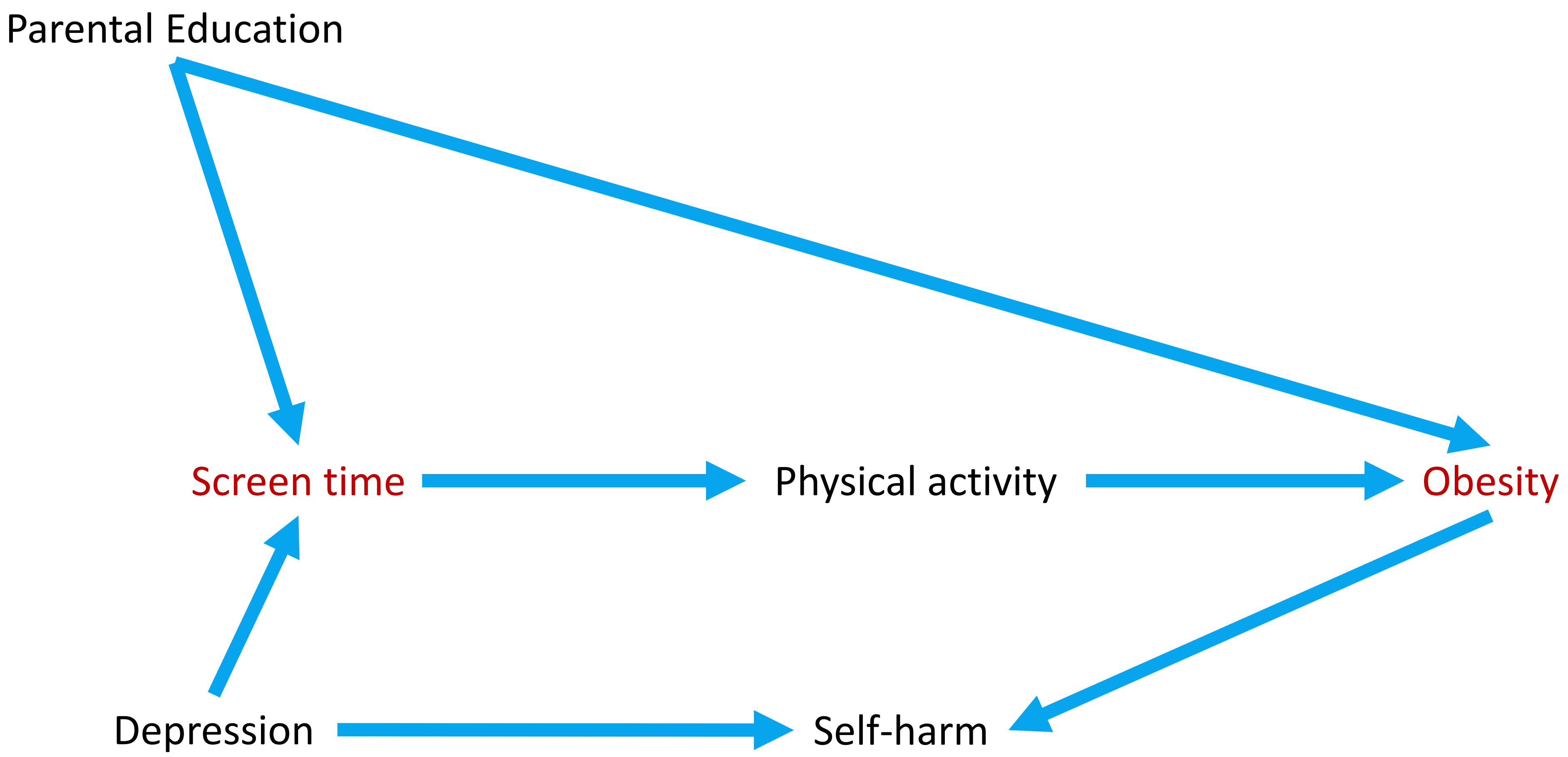
Acyclic: Cannot contain a feedback loop where a variable causes itself

Graph

In a DAG, causal relationships are represented by arrows between variables, pointing from cause to effect

- No arrow between two variables implies no causal relation between those two factors (also an assumption)

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology* 10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology* 10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

2 variables can be connected by a “path” between them

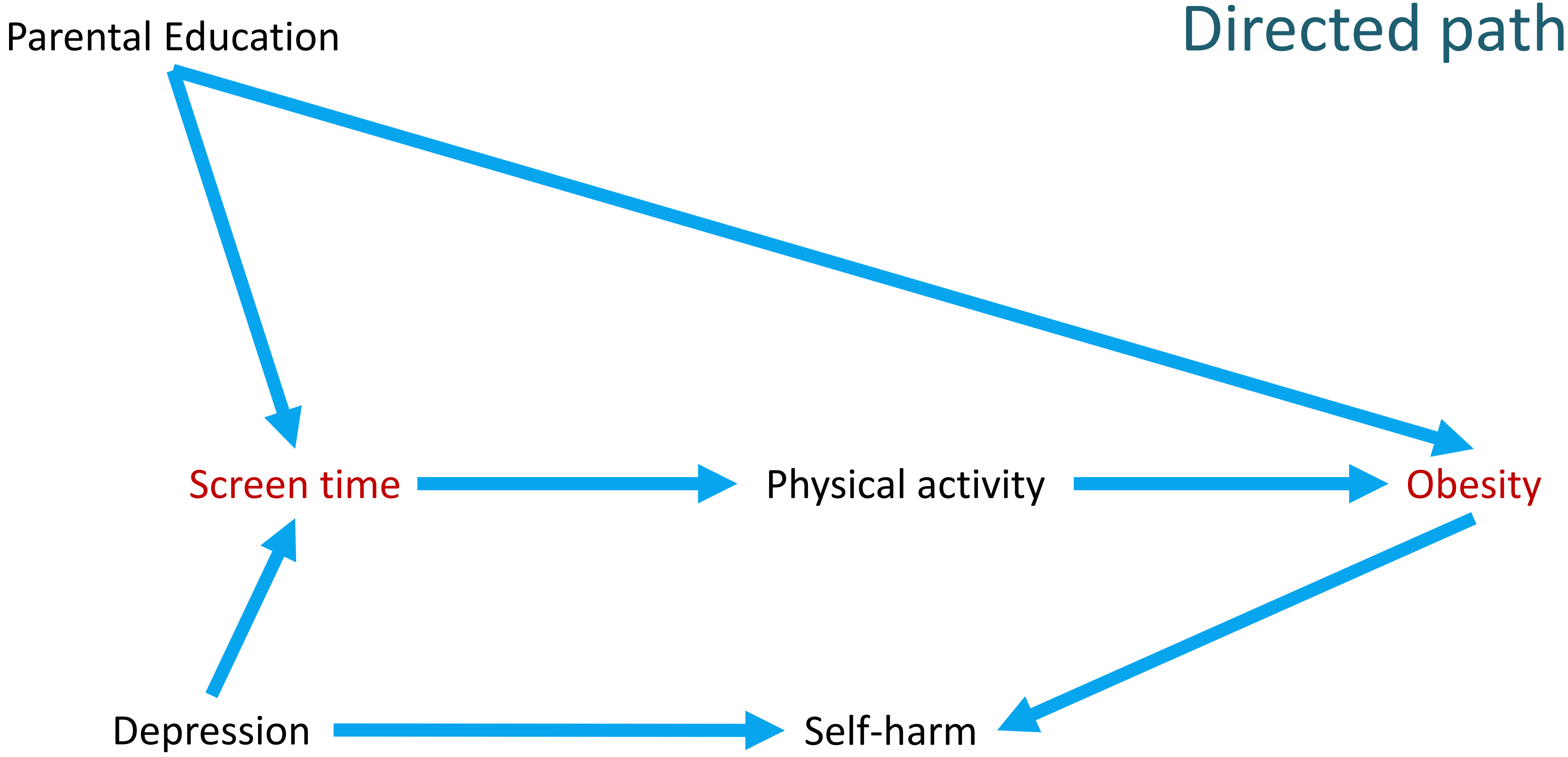
- Path: unbroken route traced along arrows connect two variables

Variables and arrows can be combined into 3 main types of paths:

- **Directed paths**: Traced through a sequence of arrows, always entering an arrow though the tail and leaving through the head. Arrow points out of X and leads to Y. Reflects a causal relationship.

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology* 10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

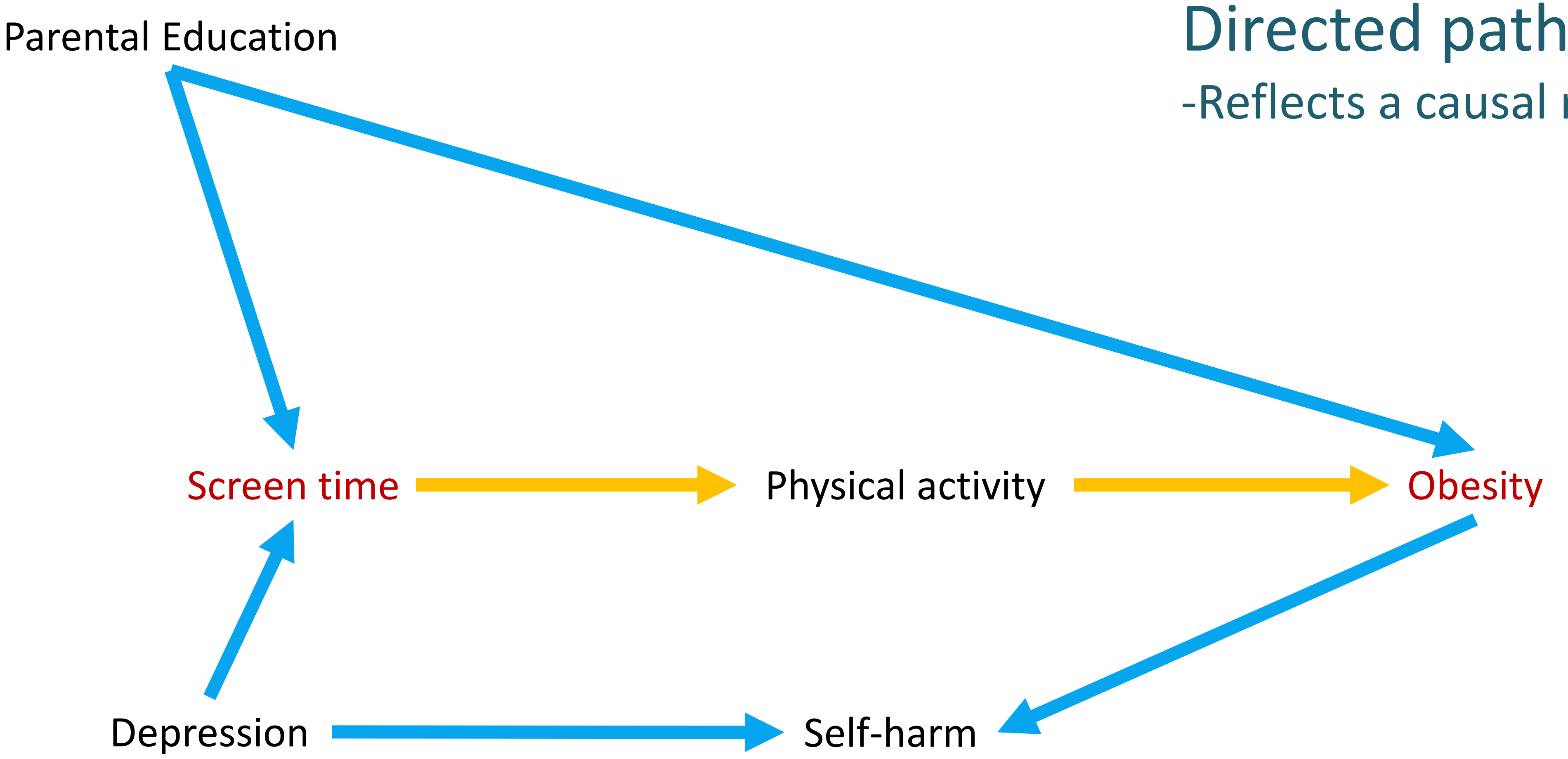
Directed path?



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology* 10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed path?

-Reflects a causal relationship



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

2 variables can be connected by a “path” between them

- Path: unbroken route traced along arrows connect two variables

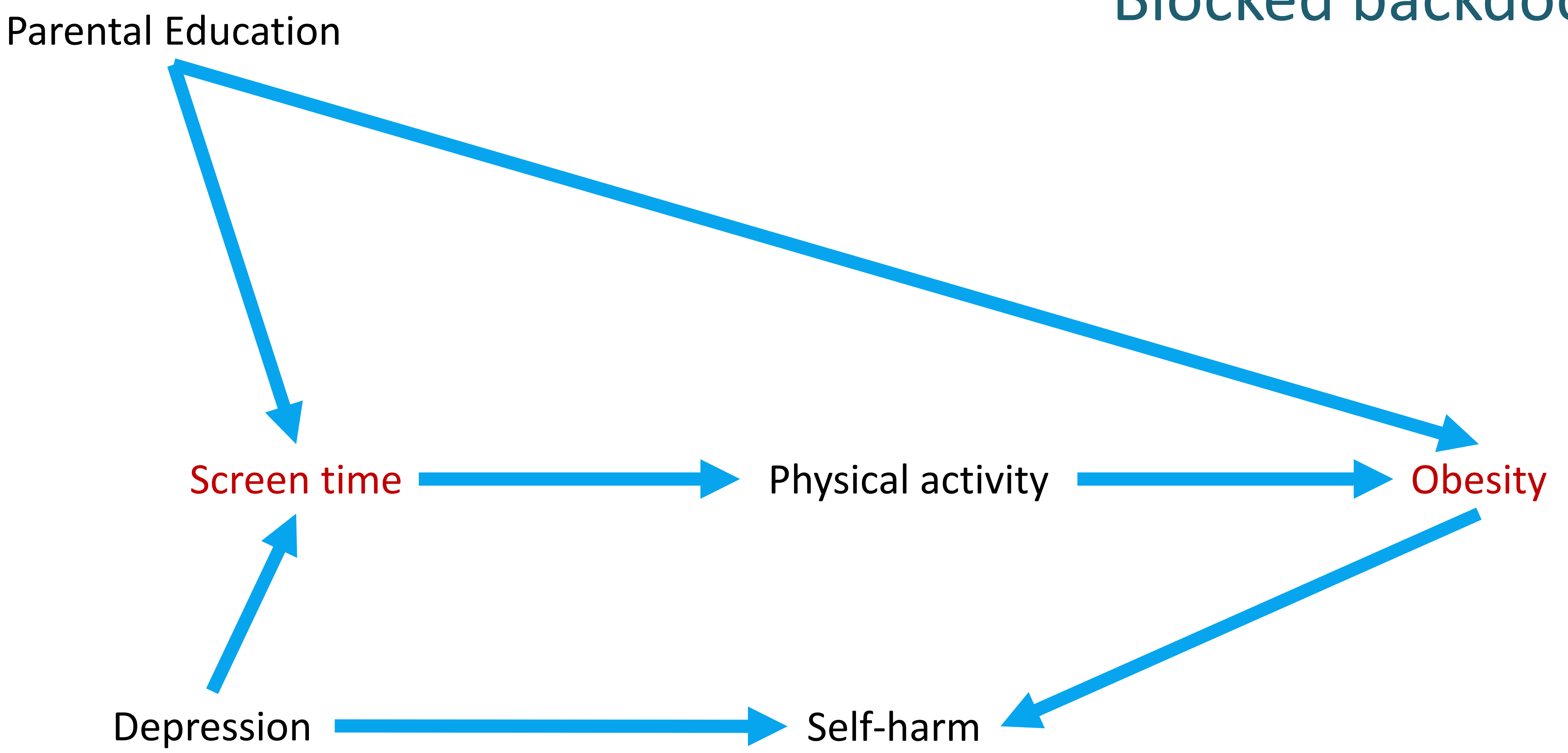
Variables and arrows can be combined into 3 main types of paths:

- **<u>Directed paths</u>**: Traced through a sequence of arrows, always entering an arrow though the tail and leaving through the head. Arrow points out of X and leads to Y. Reflects a causal relationship.

- **<u>Backdoor paths</u>**: A path that connects X to Y if it has an arrowhead pointing to X
  - **<u>Closed/Blocked</u>**: The path has one or more colliders (a variable that you enter and exit through arrowheads). There is <u>no association between X and Y transmitted though the collider</u>.

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

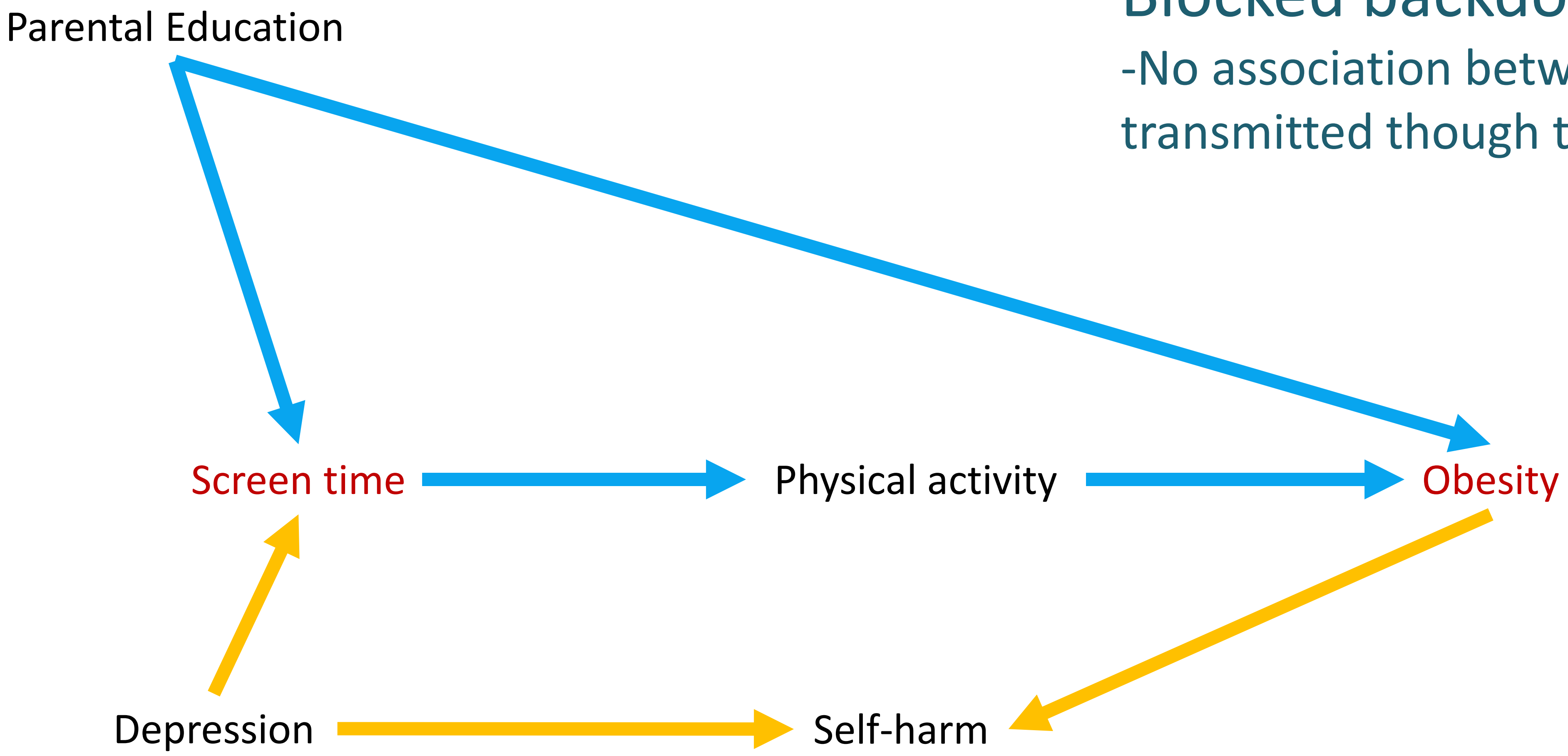
Blocked backdoor path?



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Blocked backdoor path?

-No association between X and Y transmitted though the collider



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

2 variables can be connected by a "path" between them

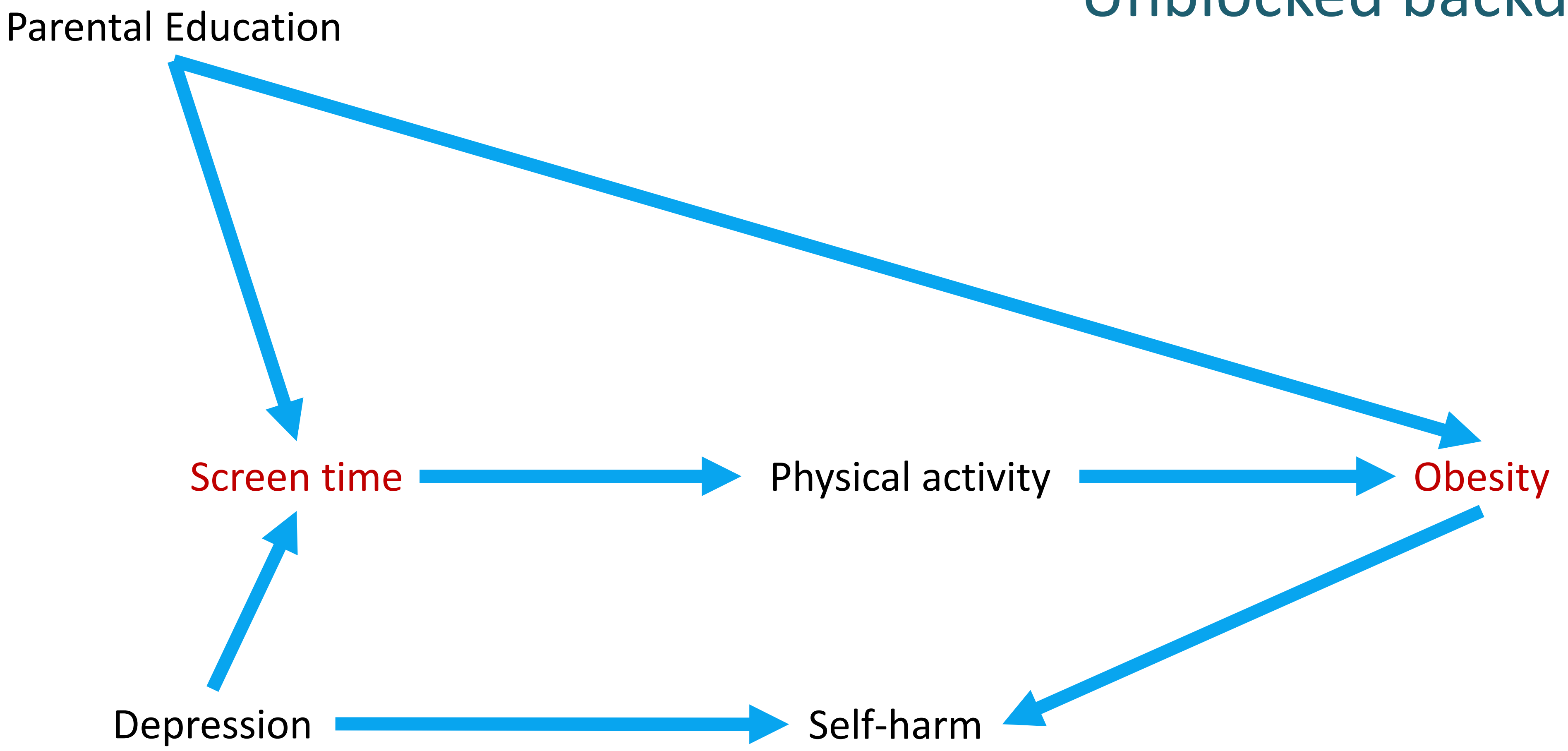
- Path: unbroken route traced along arrows connect two variables

Variables and arrows can be combined into 3 main types of paths:

- **Directed paths**: Traced through a sequence of arrows, always entering an arrow though the tail and leaving through the head. Arrow points out of X and leads to Y. Reflects a causal relationship.
- **Backdoor paths**: A path that connects X to Y if it has an arrowhead pointing to X
  - **Closed/Blocked**: The path has one or more colliders (a variable that you enter and exit through arrowheads). There is no association between X and Y transmitted though the collider.
  - **Open/Unblocked**: There are no colliders on the path. The two variables share the same cause. This path is open, but the association is non-causal. Represents the basic structure of confounding.

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

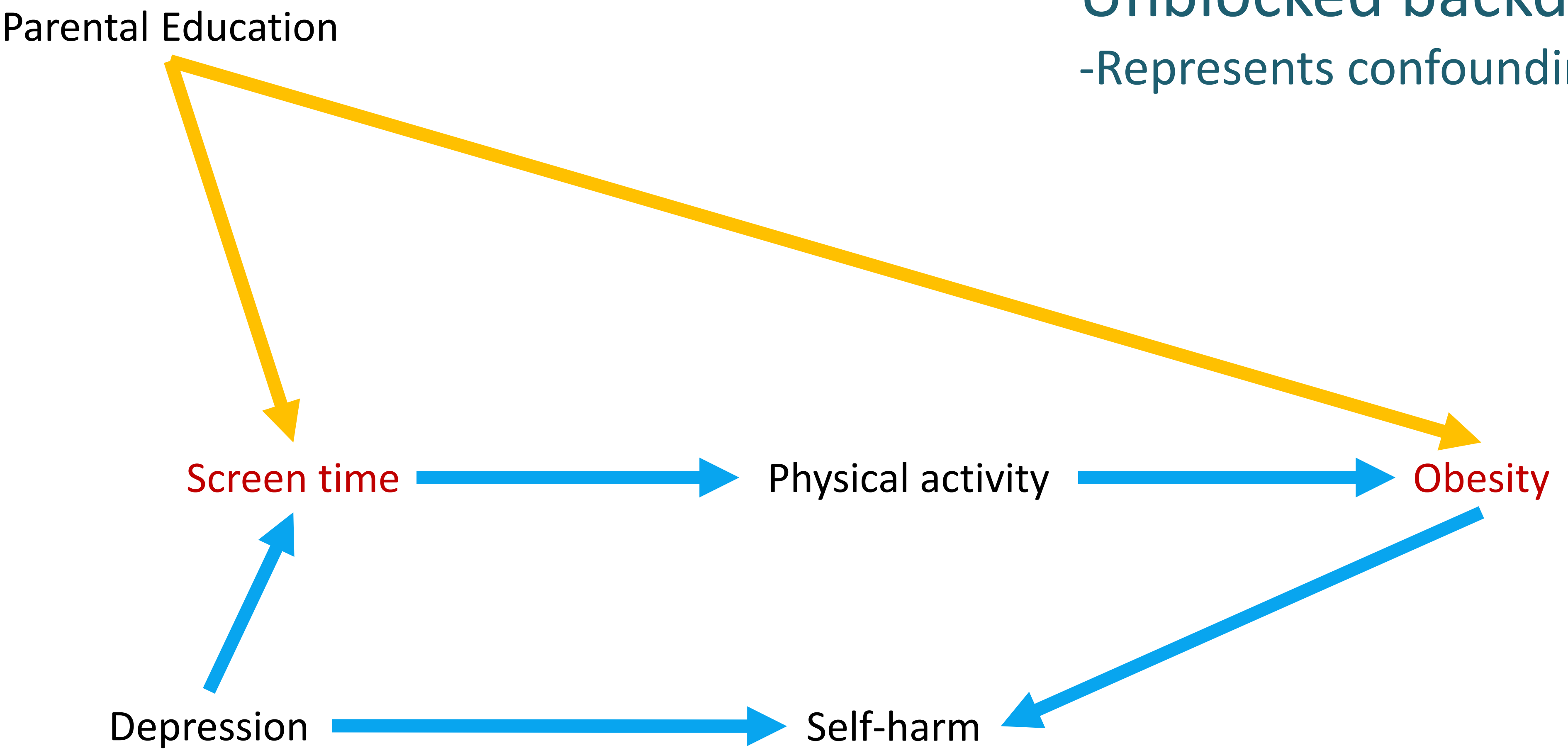
Unblocked backdoor path?



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Unblocked backdoor path?

-Represents confounding



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology* 10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

2 variables can be connected by a “path” between them

- Path: unbroken route traced along arrows connect two variables

Variables and arrows can be combined into 3 main types of paths:

- **Directed paths**: Traced through a sequence of arrows, always entering an arrow though the tail and leaving through the head. Arrow points out of X and leads to Y. Reflects a causal relationship.

- **Backdoor paths**: A path that connects X to Y if it has an arrowhead pointing to X
  - **Closed/Blocked**: The path has one or more colliders (a variable that you enter and exit through arrowheads). There is no association between X and Y transmitted though the collider.
  - **Open/Unblocked**: There are no colliders on the path. The two variables share the same cause. This path is open, but the association is non-causal. Represents the basic structure of confounding.

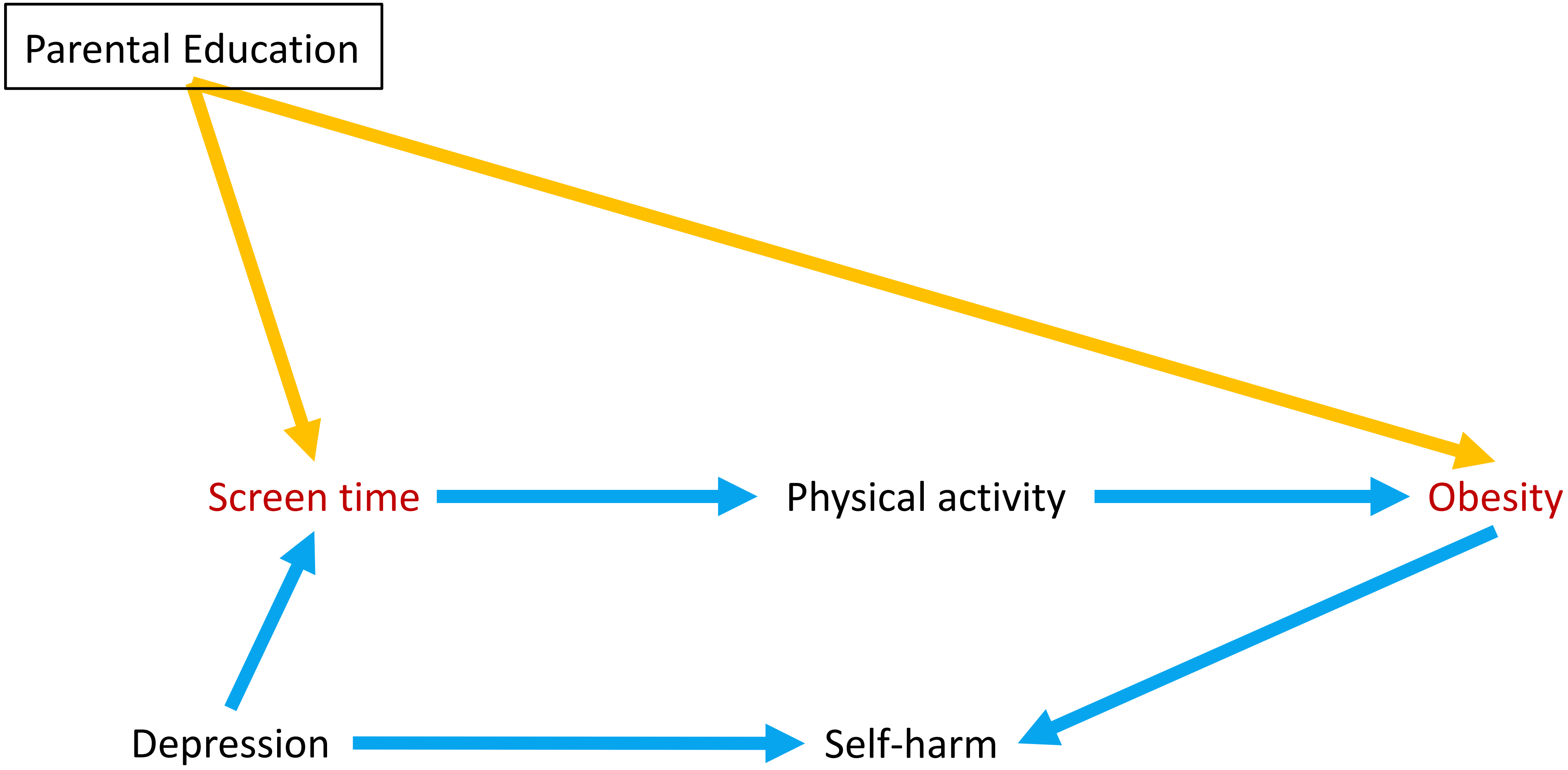
Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

Researchers can change the status of a backdoor path from open to closed, or vice versa, by acting on (conditioning on, or controlling for) a variable (a confounder)

- Through study design or statistical adjustments such as restriction, stratification, matching, standardization, or multivariable regression

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

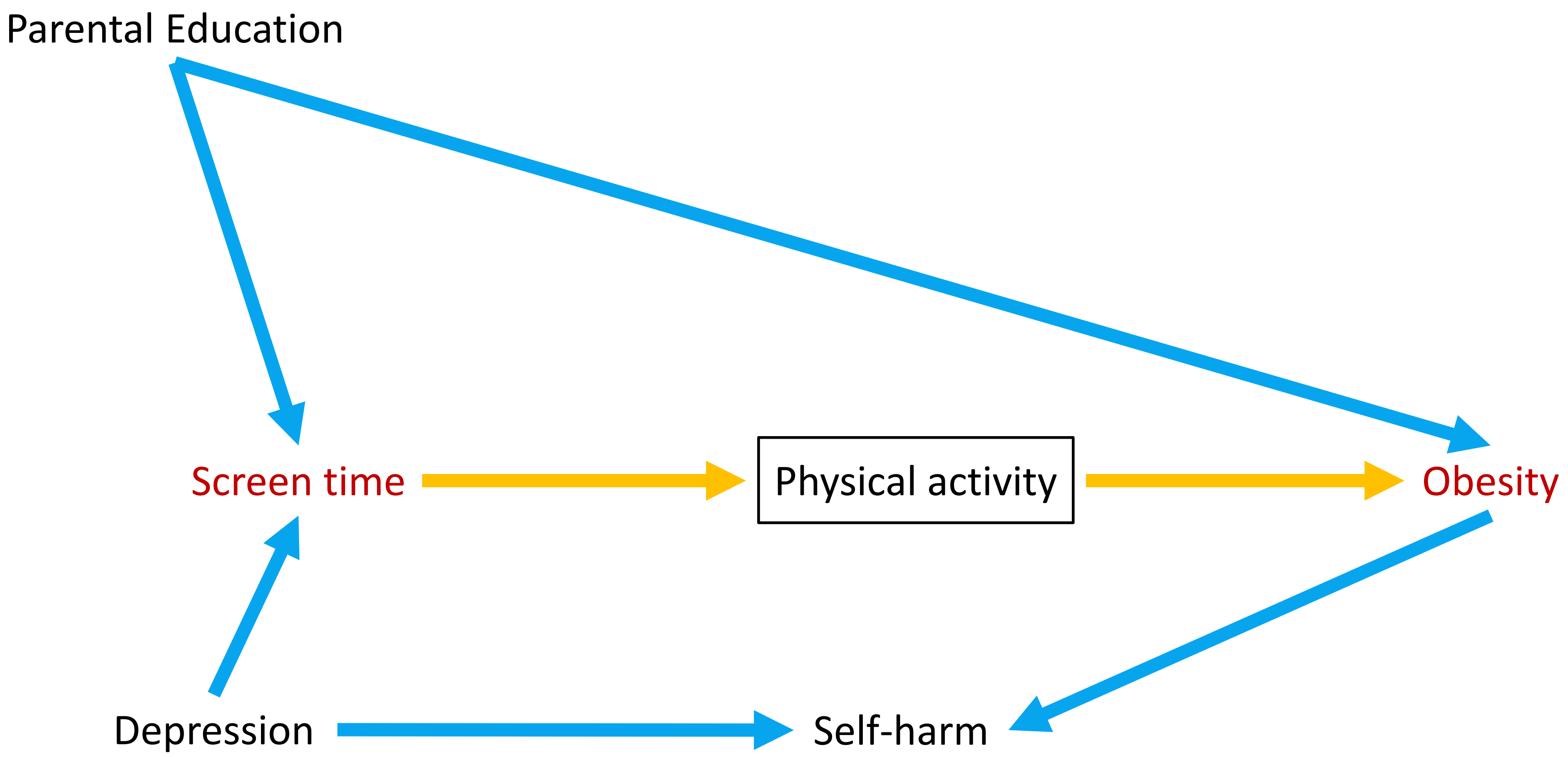
Directed Acyclic Graphs (DAGs)

Researchers can change the status of a backdoor path from open to closed, or vice versa, by acting on (conditioning on, or controlling for) a variable (a confounder)

- Through study design or statistical adjustments such as restriction, stratification, matching, standardization, or multivariable regression

Conditioning on a variable in a directed path between two variables (a mediator/intermediate) closes this path, and could lead to an incorrect estimate of the true overall association between the variables

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

Directed Acyclic Graphs (DAGs)

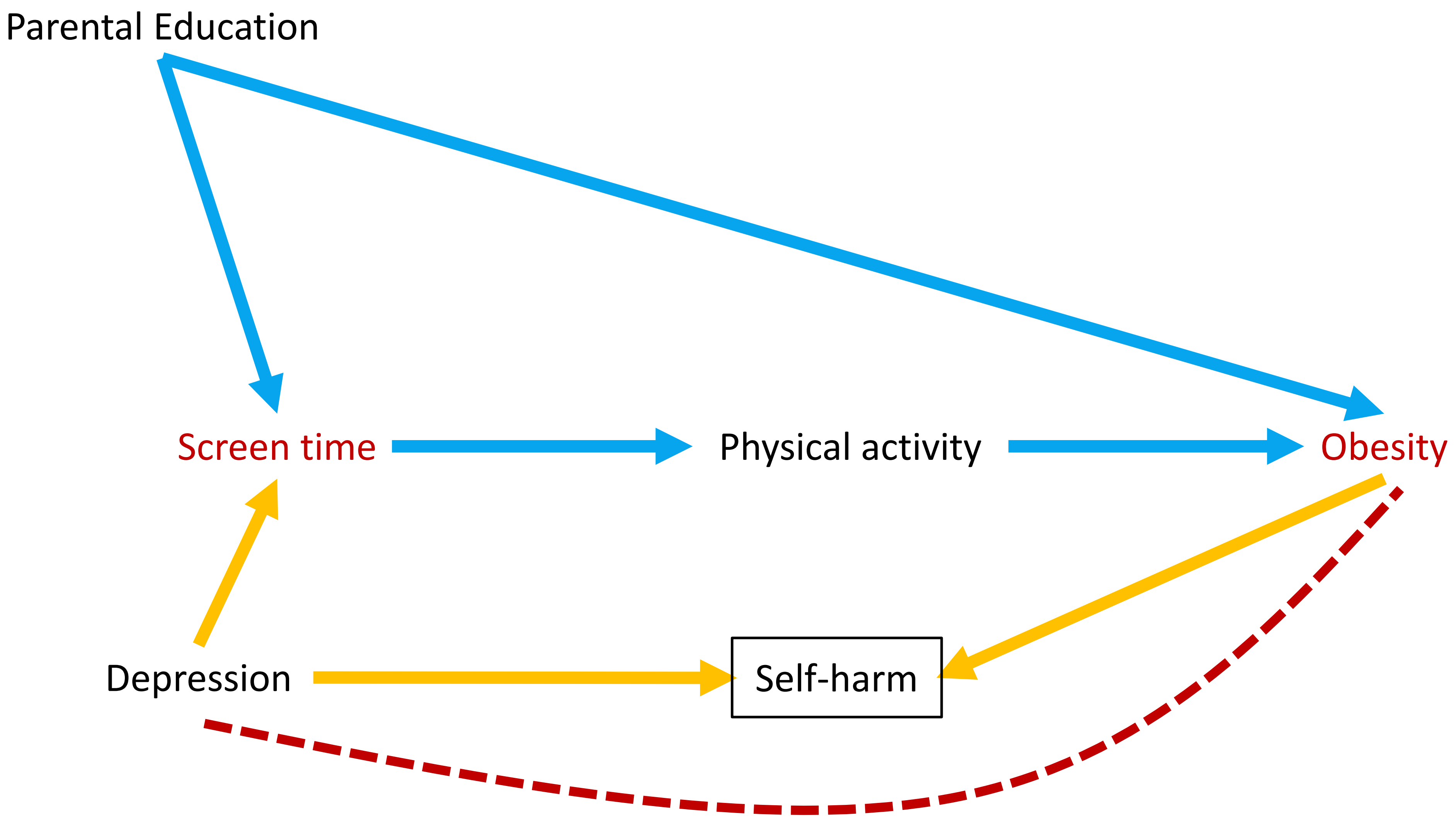
Researchers can change the status of a backdoor path from open to closed, or vice versa, by acting on (conditioning on, or controlling for) a variable (a confounder)

- Through study design or statistical adjustments such as restriction, stratification, matching, standardization, or multivariable regression

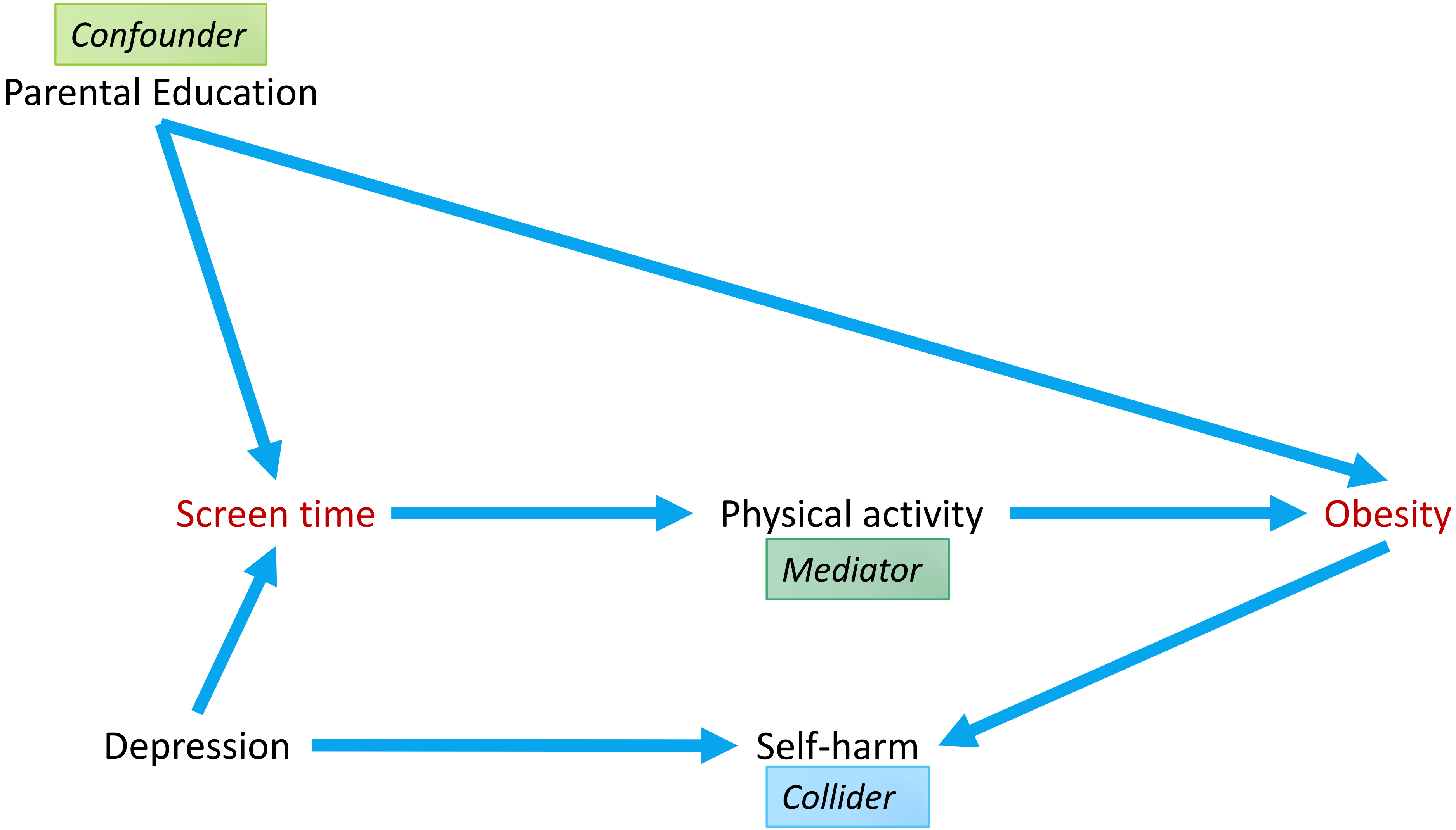
Conditioning on a variable in a directed path between two variables (a mediator) closes this path, and could lead to an incorrect estimate of the true overall association between the variables

Conditioning on a variable in a closed backdoor path (a collider) opens this path and leads to transmission of a non-causal association

Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.



Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

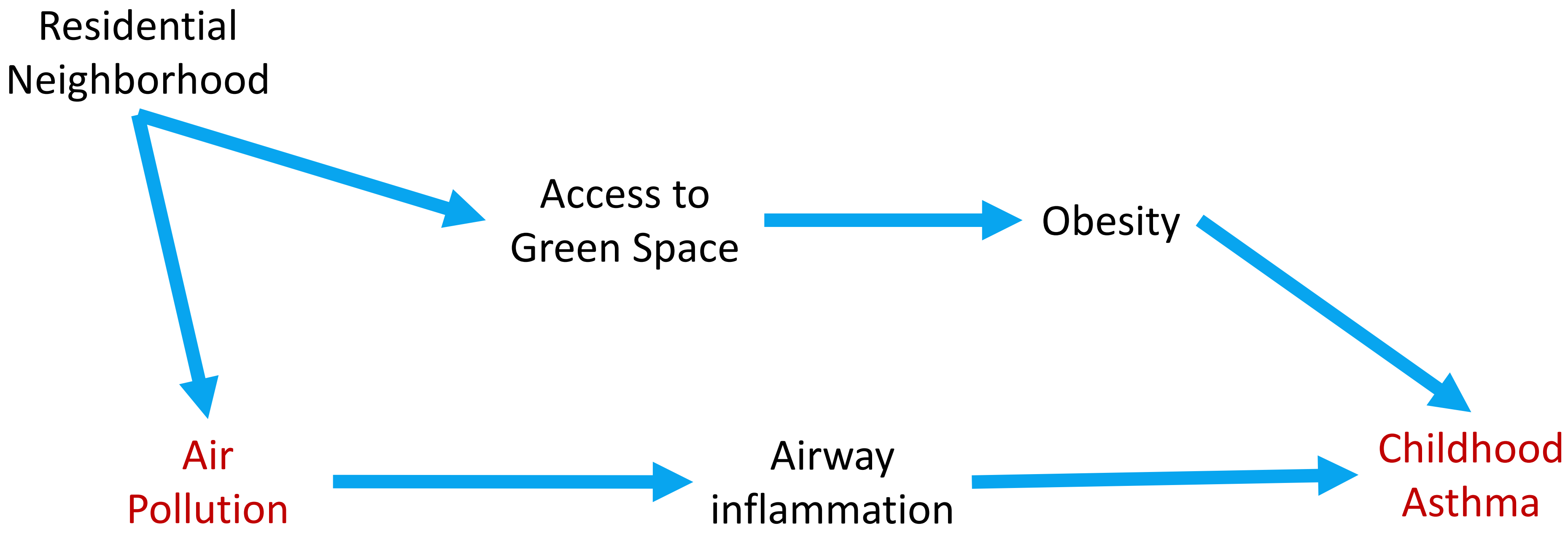


Adapted from Greenland, Sander, Judea Pearl, and James M. Robins. "Causal diagrams for epidemiologic research." *Epidemiology*10 (1999): 37-48.
Williams, Thomas C., et al. "Directed acyclic graphs: a tool for causal studies in paediatrics." *Pediatric research* 84.4 (2018): 487.

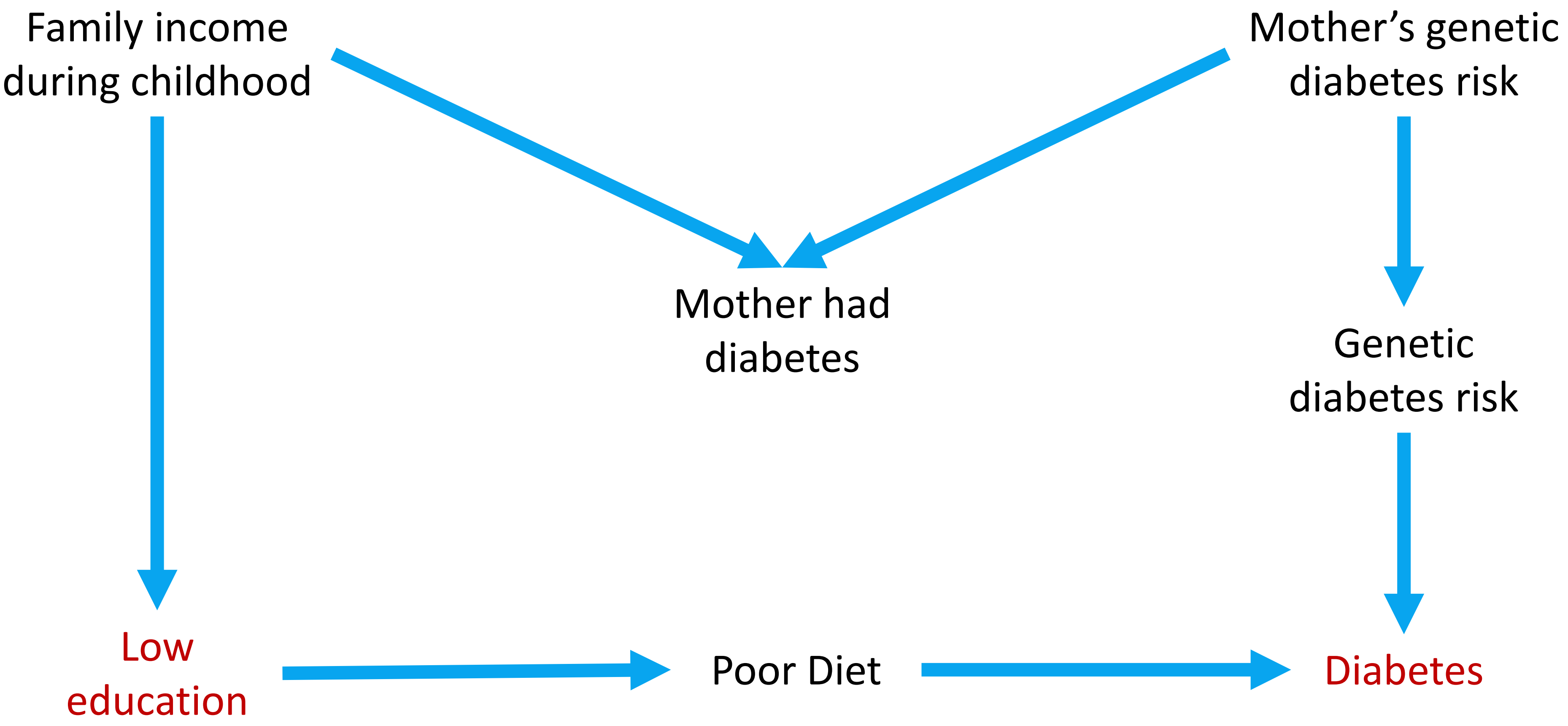
What to do…a cheat sheet

What is it?	What do to?	Why?
Confounder	Control/adjust for it	To reduce confounding in your estimation of the exposure-outcome relation.
Mediator/intermediate	Nothing	It is part of the causal pathway. If you do control for it, then you will block part of the true overall effect and will get an incorrect estimate of the overall exposure-outcome relation.
Collider	Nothing	It is not transmitting any association. If you do control/adjust for it, then you will induce an association and might bias your estimation of the exposure-outcome relation.

- Identify paths from Air Pollution to Childhood Asthma
- Are these directed or backdoor?
  - If backdoor, are they blocked or unblocked?
- What would you control for in a causal analysis?

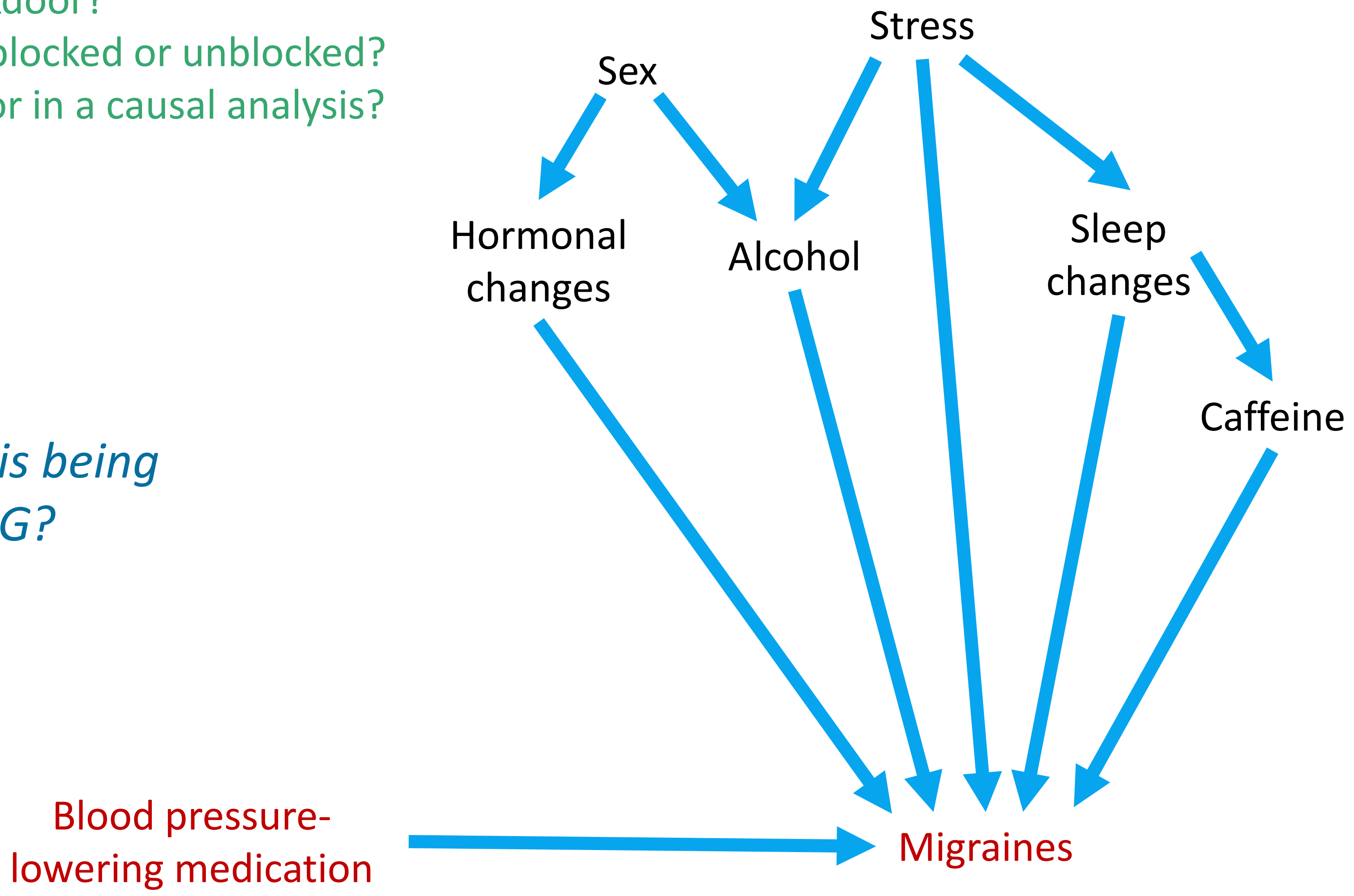


- Identify paths from Low Education to Diabetes
- Are these directed or backdoor?
    - If backdoor, are they blocked or unblocked?
- What would you control for in a causal analysis?



- Identify paths from Medication to Migraines
- Are these directed or backdoor?
    - If backdoor, are they blocked or unblocked?
- What would you control for in a causal analysis?

Q: What type of study is being represented by this DAG?



What to do…a cheat sheet

What is it?	What do to?	Why?
Confounder	Control/adjust for it	To reduce confounding in your estimation of the exposure-outcome relation.
Mediator/intermediate	Nothing	It is part of the causal pathway. If you do control for it, then you will block part of the true overall effect and will get an incorrect estimate of the overall exposure-outcome relation.
Collider	Nothing	It is not transmitting any association. If you do control/adjust for it, then you will induce an association and might bias your estimation of the exposure-outcome relation.

Final Remarks

Association v. causation

Utility of DAGs in epidemiologic analyses

- Help researchers think through their assumptions and evaluate potential confounding pathways
  - What are predictors of the exposure and of the outcome? Direction is important!
- Keep in mind that it is based on input information and assumptions when constructing the DAG; it does not give you the True “answer” about all potential confounding

- More questions? Email me: garc991@usc.edu