

Augmenting Causal Diagrams with Effect Modification, Interaction and Other Parametric Information

Onyebuchi A. Arah^{1,2,3}

¹Department of Epidemiology, UCLA Fielding School of Public Health

²UCLA Center for Health Policy Research, Los Angeles, California, USA

³Academic Medical Center, University of Amsterdam, Netherlands

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Outline

- Background & Objective
- Notation & Definitions
- Effect Modification
- Joint Total Effects & Interaction
- Mediation & Interaction
- Conclusion

Background & Objective

- Directed acyclic graphs (DAGs) have become ubiquitous in epidemiology
- Despite this widespread use, students and researchers have not been able to use them to depict effect modification and interaction
- This study introduces and demonstrates how to augment DAGs with (parametric) information on product terms typically used in modeling effect modification and interaction

Notation & Definitions

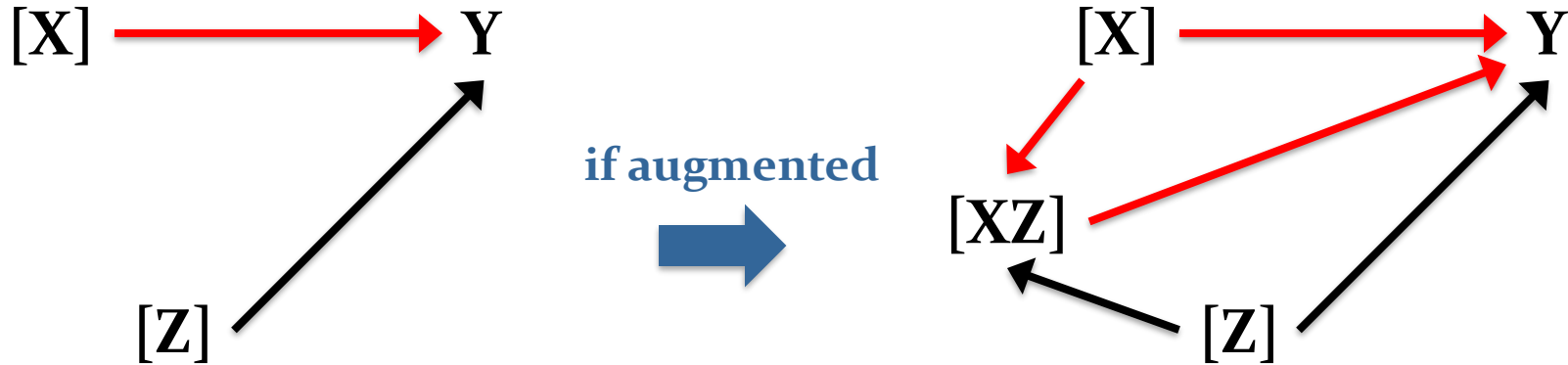
- ***X***: Primary exposure or intervention variable
- ***Z***: Effect-modifier
- ***A***: Secondary exposure or intervention variable
- ***M***: Mediator
- ***Y***: Outcome variable
- ***C***: Covariate, proxy or confounding variable; numbered sequentially
- ***U***: Unknown, unmeasured variable

- []: Square brackets indicate conditioning
- (): Round brackets or parentheses indicate unmeasured variable
- XZ : Product term node which is deterministic
- $X(Z)$: Product term node with unmeasured effect-modifier or secondary exposure variable

Effect Modification

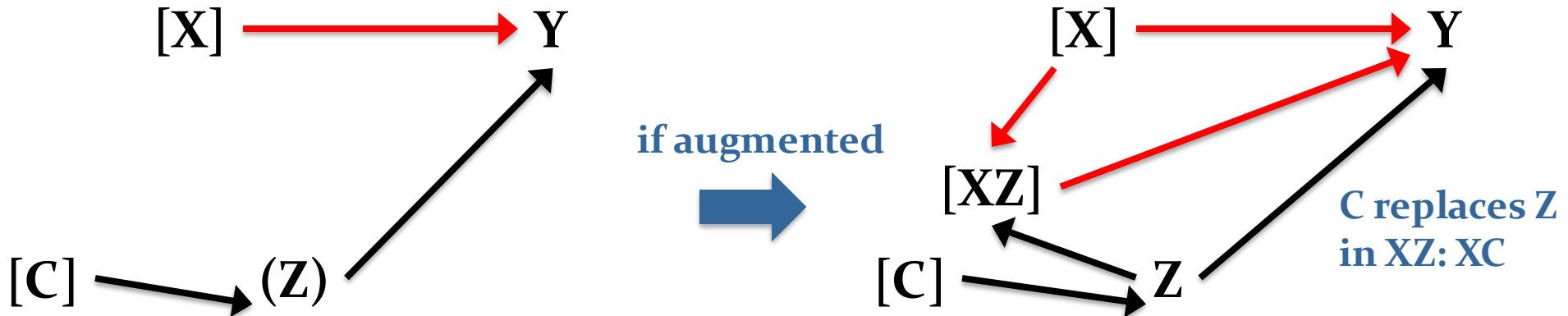
Four types of effect modification (EM)*

Type 1: Direct EM



Red path(s): total effect of X on Y

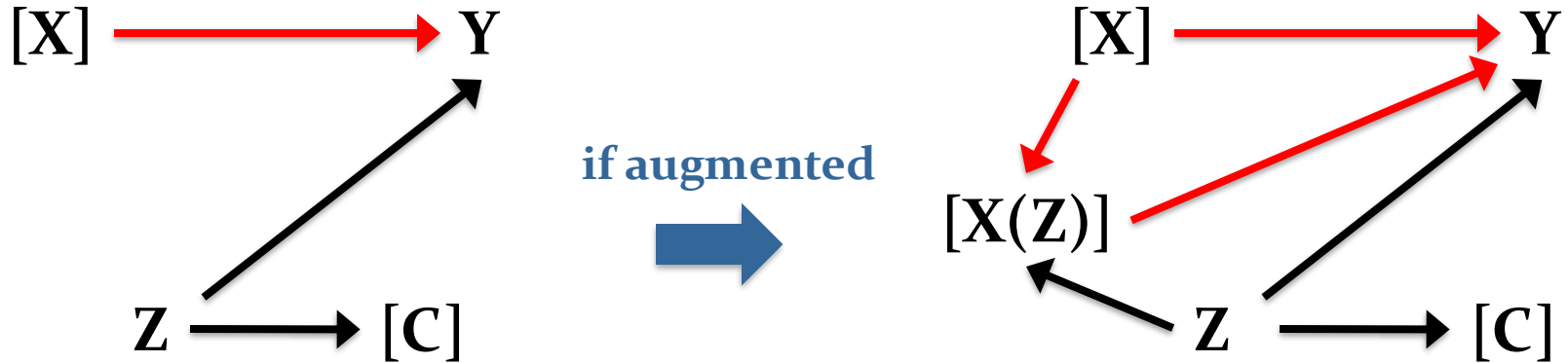
Type 2: Indirect EM



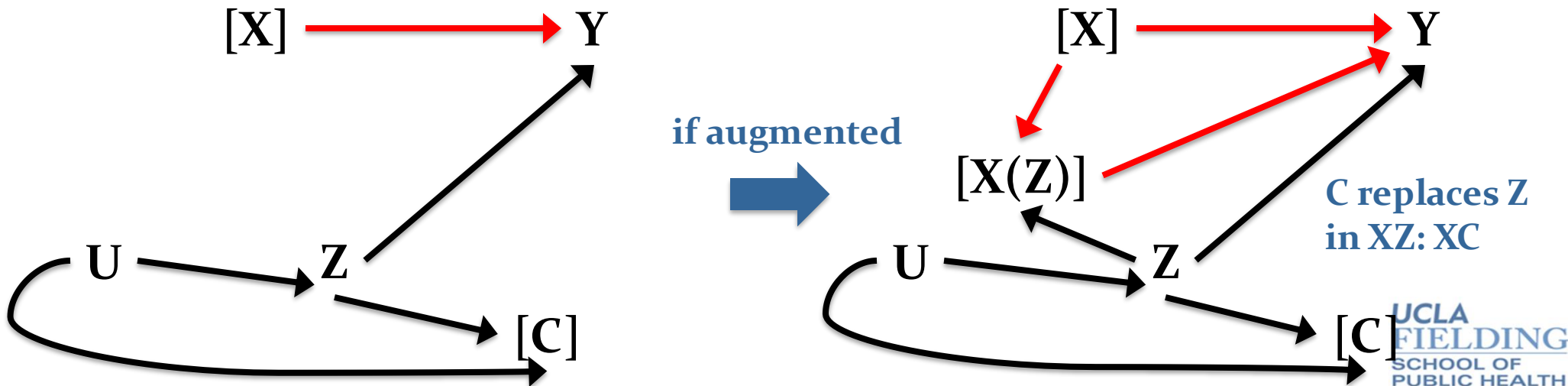
*VanderWeele TJ, Robins JM. *Epidemiology* 2007; 18(5): 561-568

Four types of effect modification (EM)

Type 3: EM by proxy

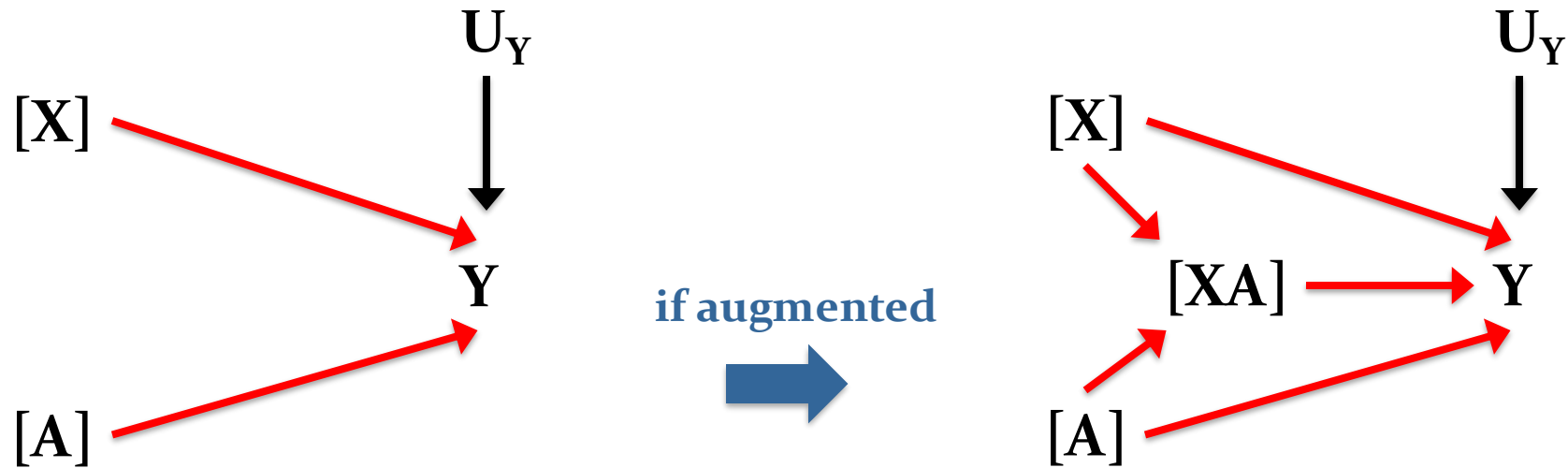


Type 4: EM by common cause



- With augmented DAGs, we can see that assessing effect modification requires
 - (i) the ‘direct’ arrow from X to Y and
 - (ii) the arrow from the product term XZ (or XC) to Y
 - (iii) quantifying these two paths without bias
- It also shows that assessing the signal carried by the direct arrow from Z to Y without bias is not necessary for effect modification

Joint Total Effects & Interaction



Red path(s): total joint effects of X and A on Y

With augmentation, we see that

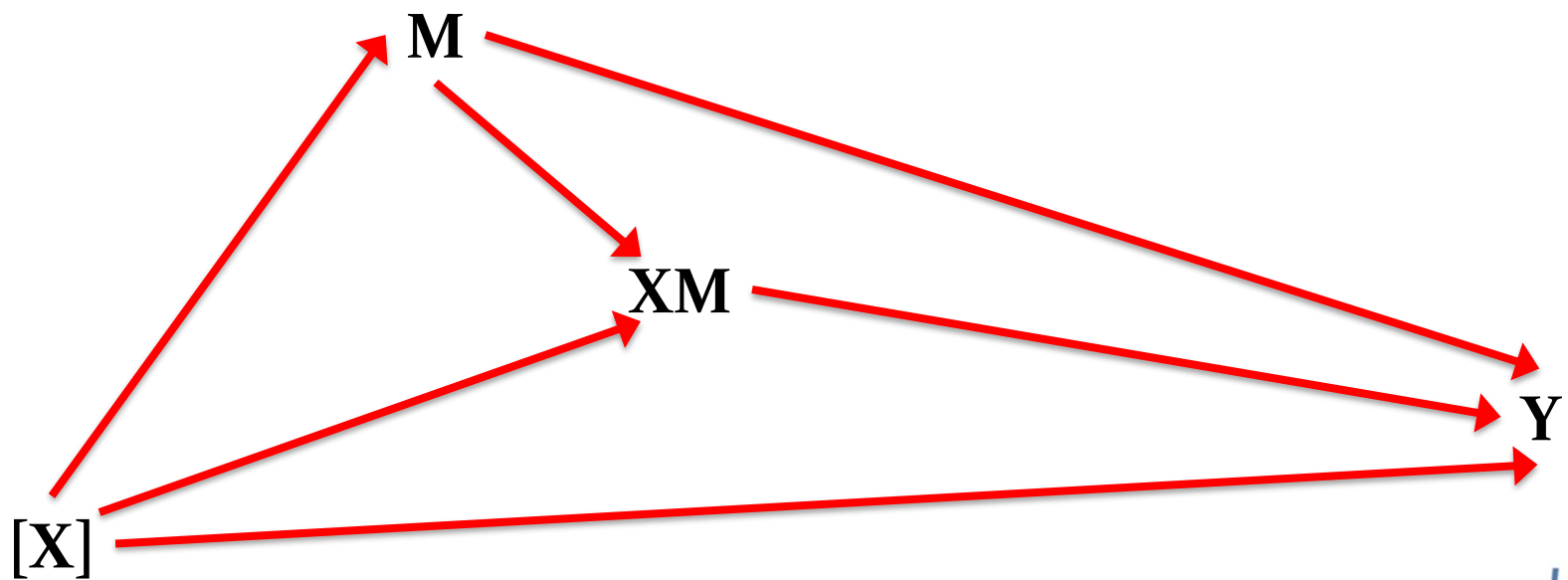
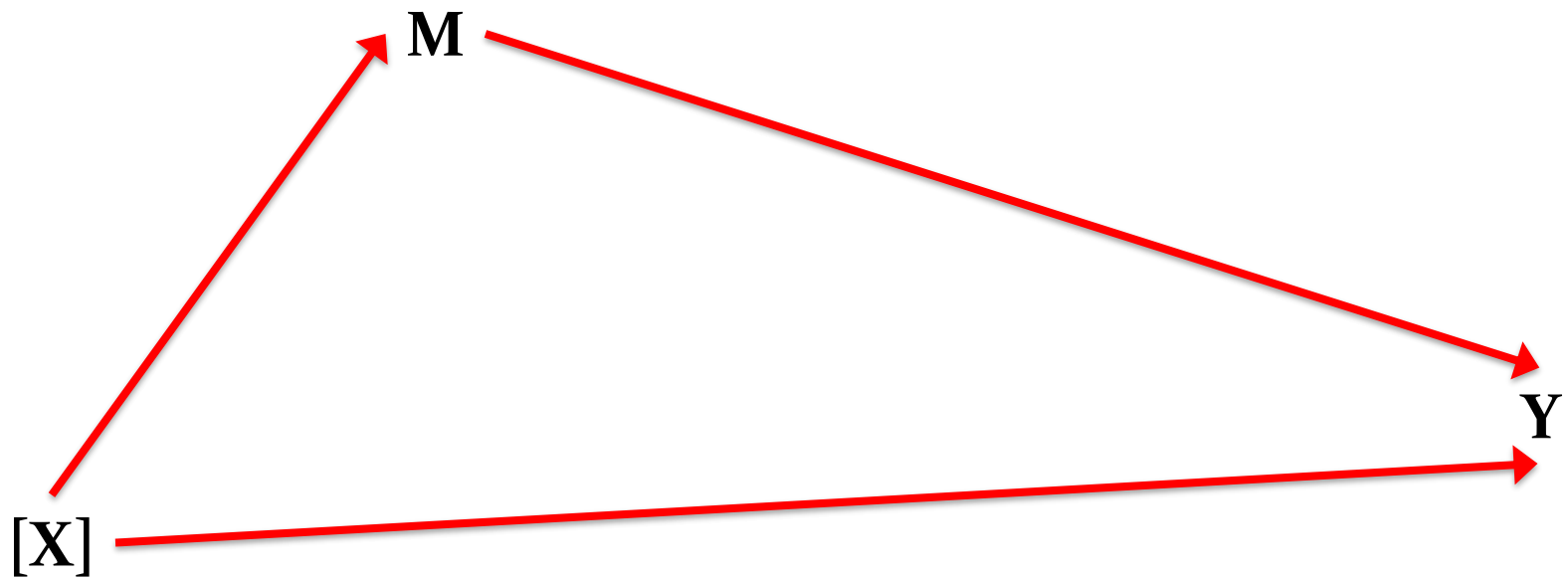
1. Joint effects of A and X have 3 components represented by the three arrows from X, A, and AX into Y
2. Decomposition of Y (outcome) yields 4 components under the joint effects DAG: the 3 components of joint effects + the background risk captured in U_Y
3. Joint total effects of X and A require joint uncontrolled confounding of $X \rightarrow Y$ and $A \rightarrow Y$

Mediation & Interaction

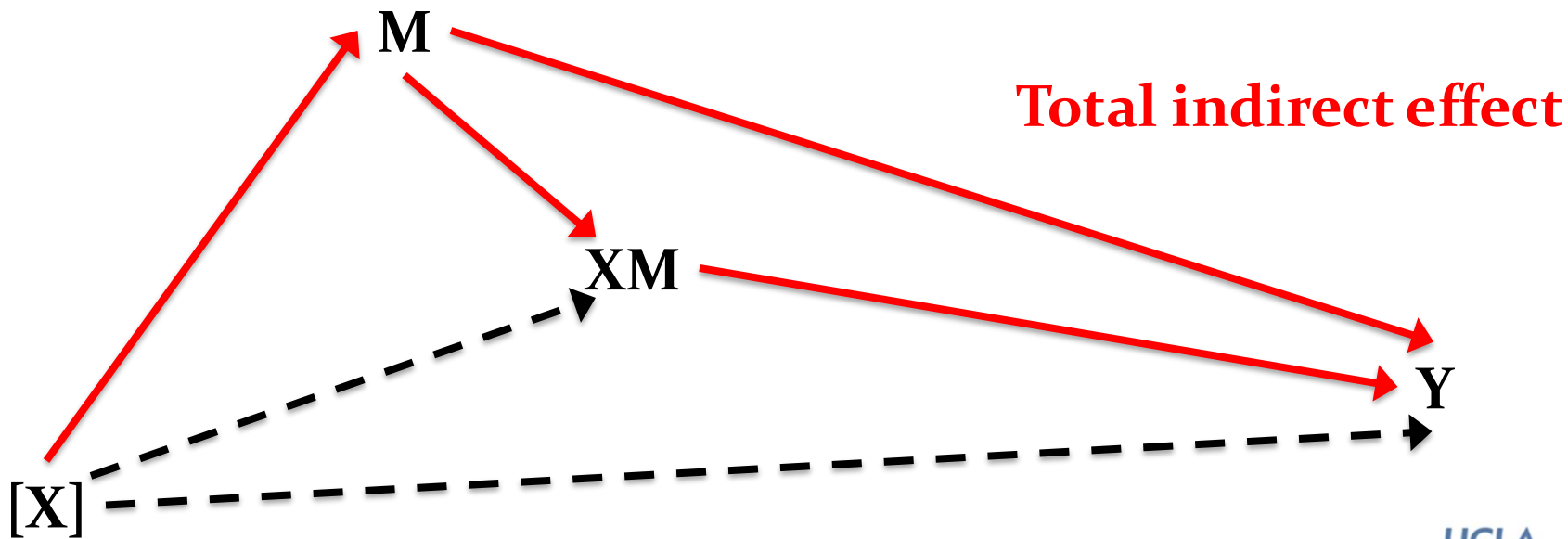
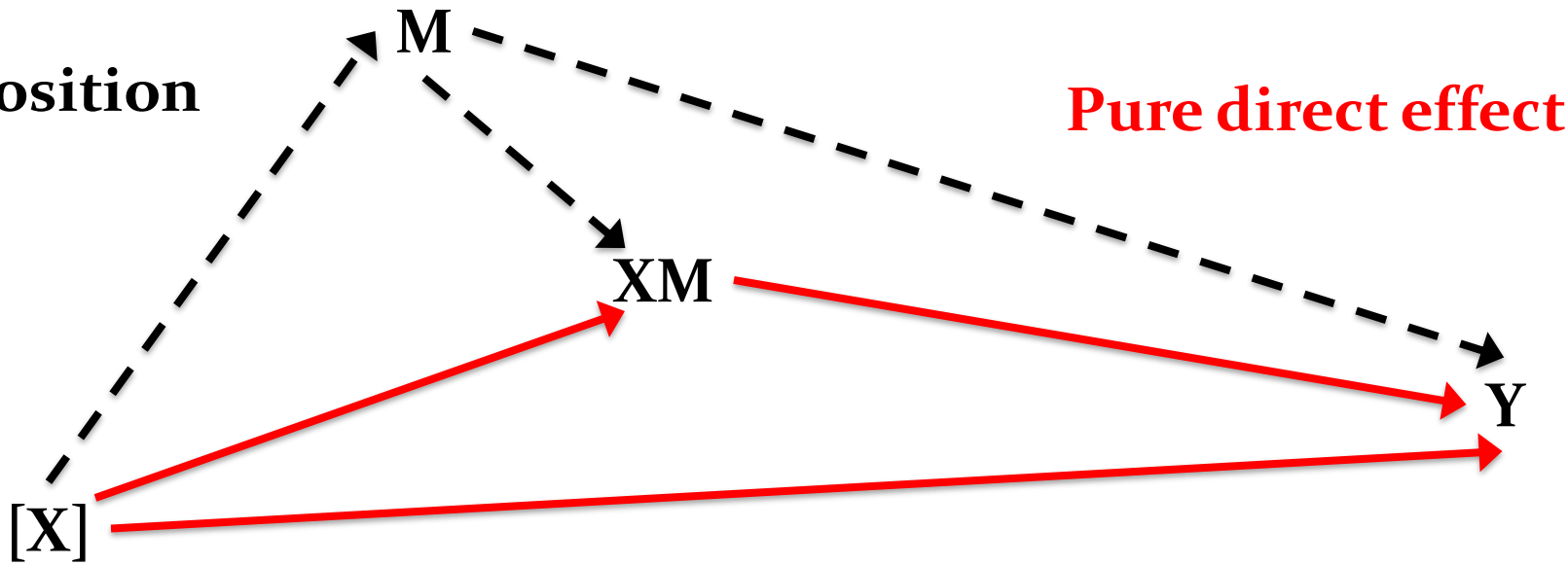
- **There are now several ways of decomposing effects under mediation analysis (VanderWeele 2015):**
 - **2 way: $PDE + TIE$, $TDE + PIE$, $CDE + PE$**
 - **3 way: $PDE + PIE + INT_{med}$**
 - **4 way: $CDE + INT_{ref} + INT_{med} + PIE$**

where

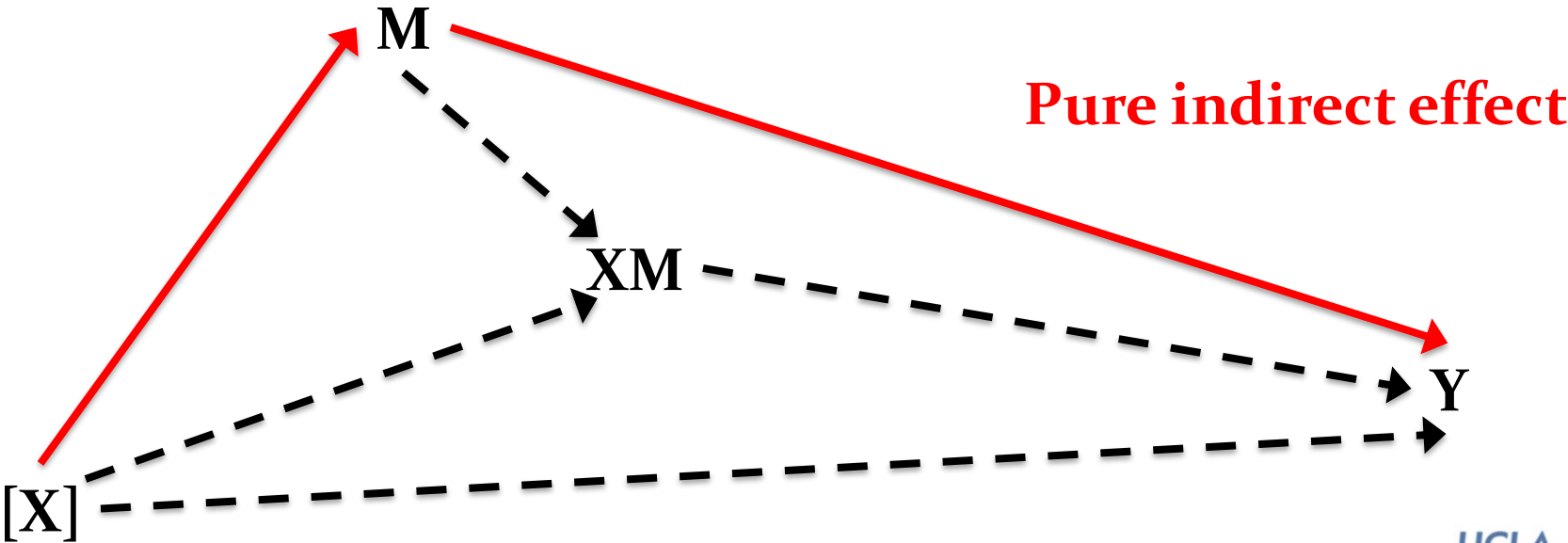
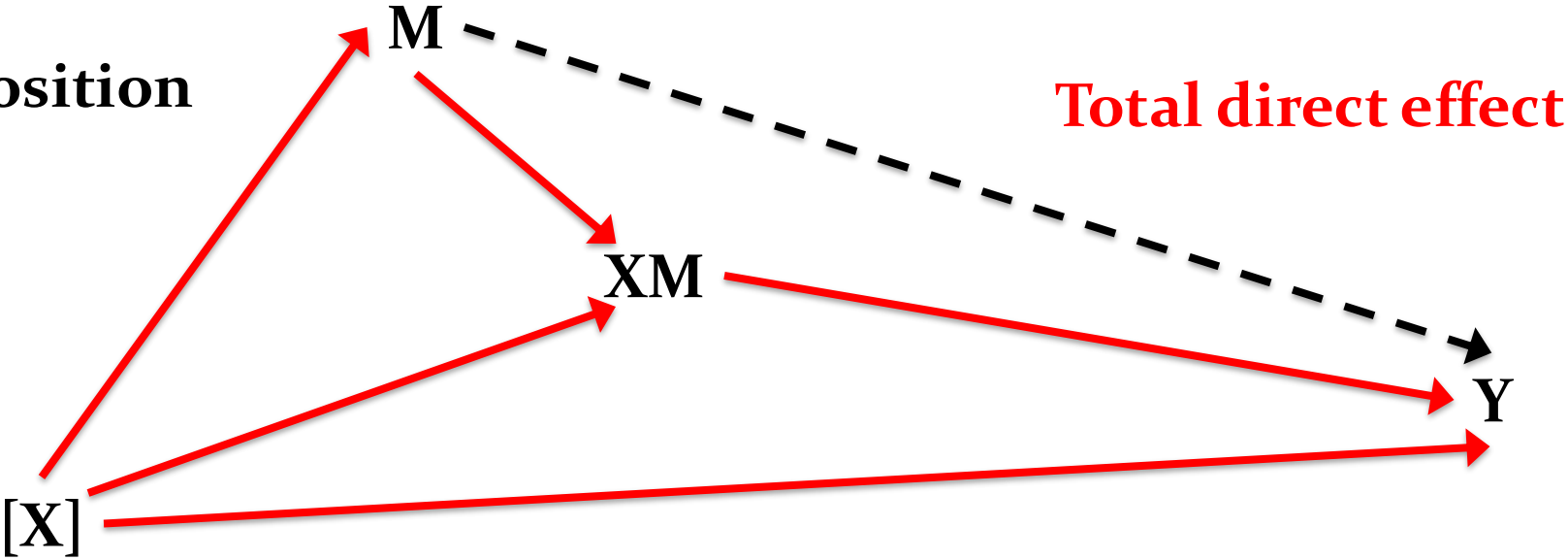
PDE:	pure (natural) direct effect
TIE:	total (natural) indirect effect
TDE:	total (natural) direct effect
PIE:	pure (natural) indirect effect
CDE:	controlled direct effect
PE:	portion eliminated
INT_{med}:	mediated interaction
INT_{ref}:	reference interaction



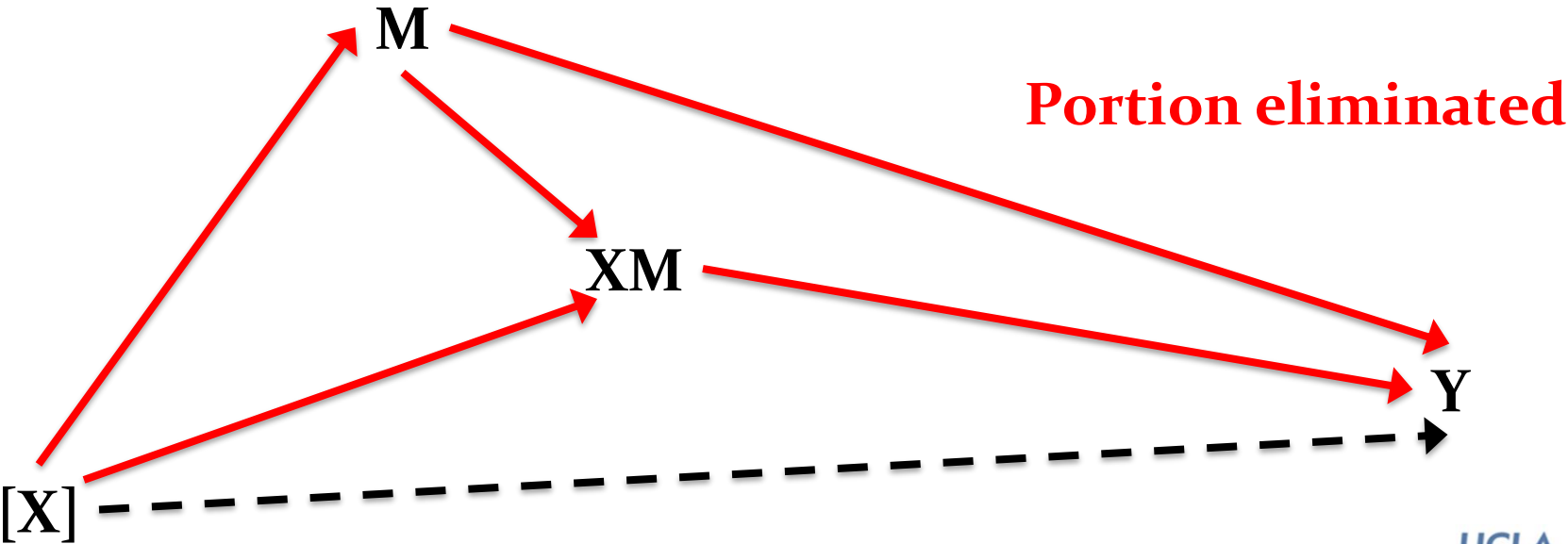
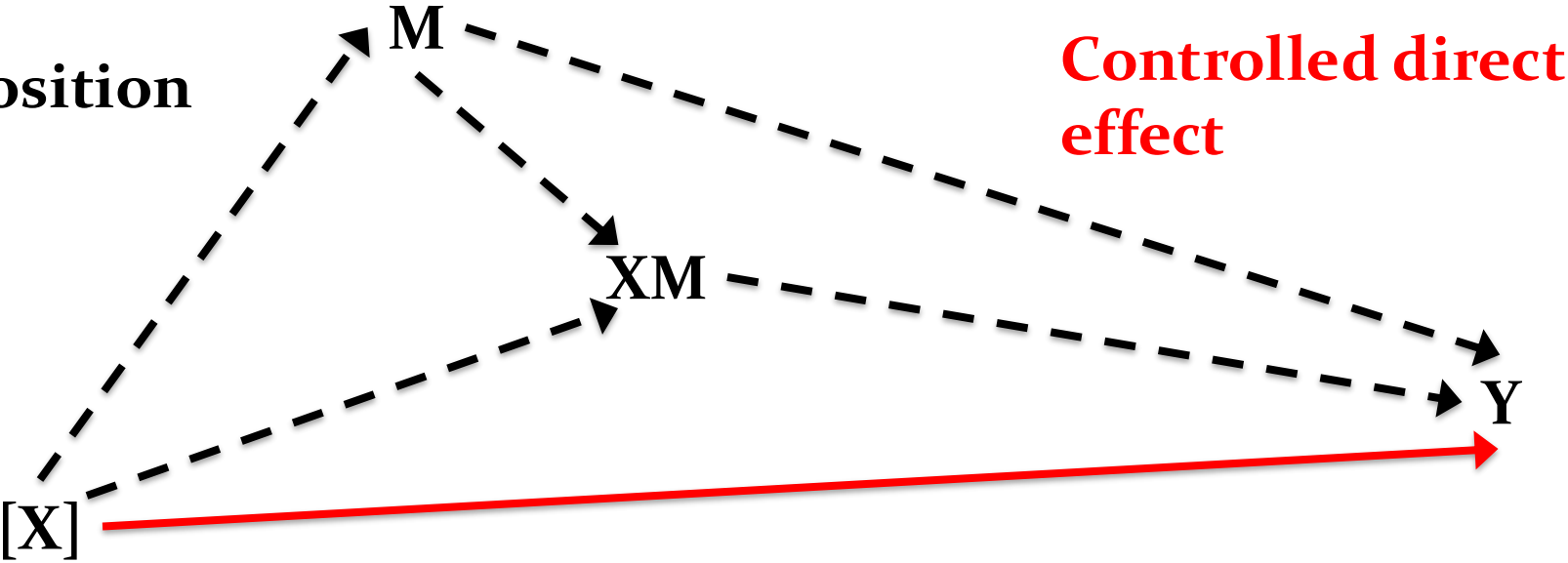
2-Way
Decomposition
(I)



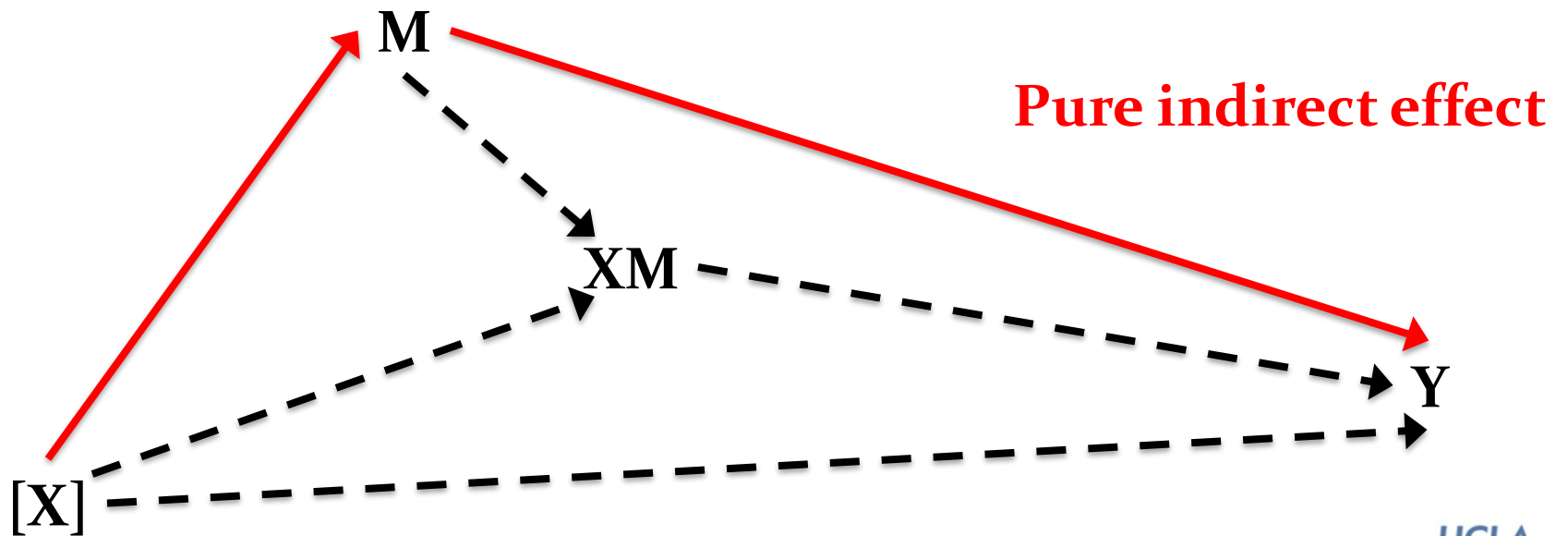
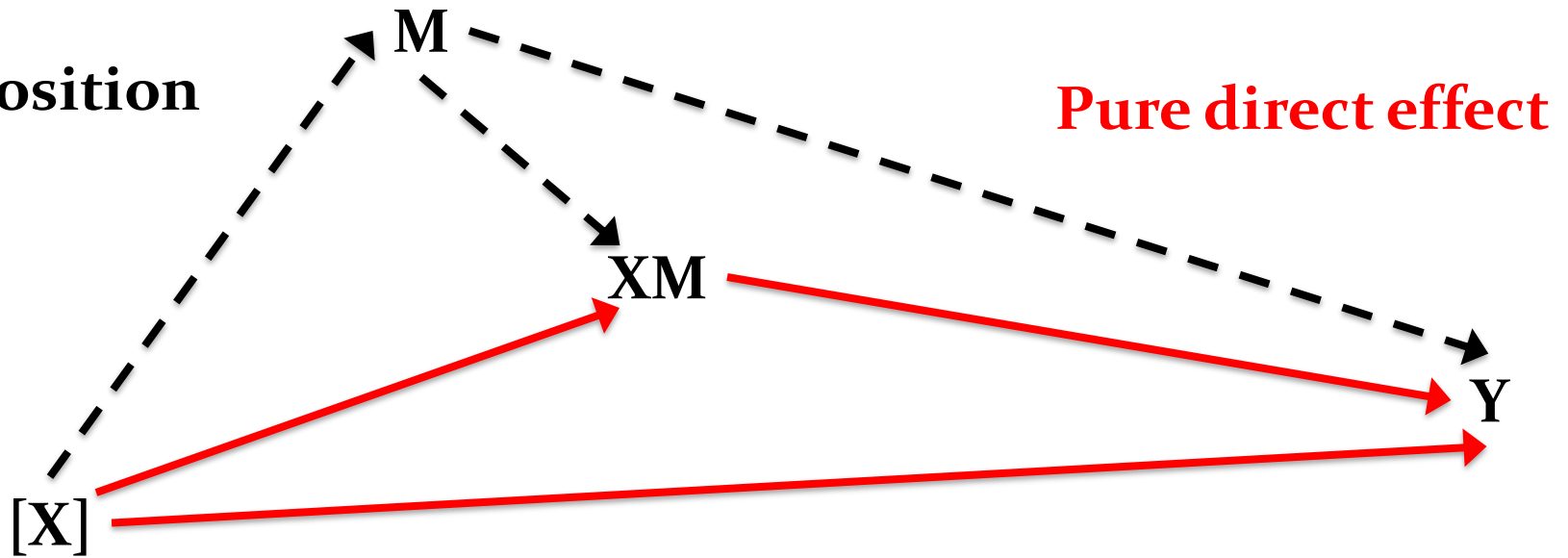
2-Way
Decomposition
(II)



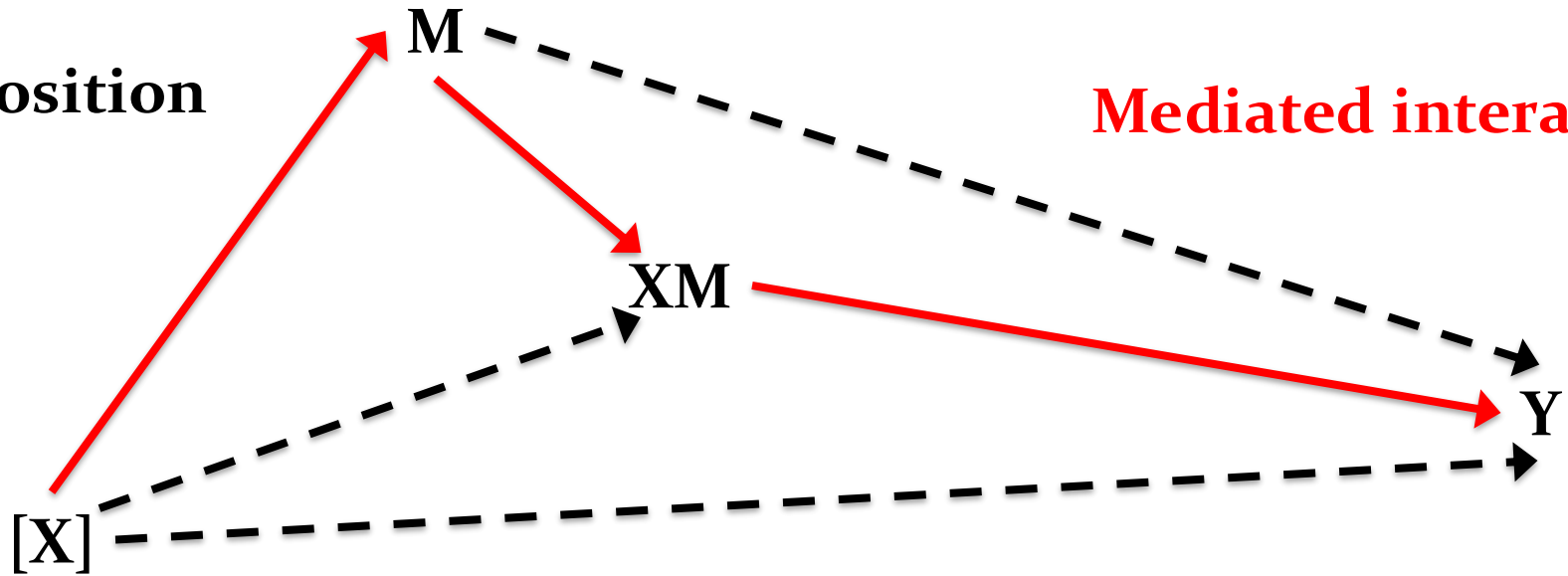
2-Way
Decomposition
(III)



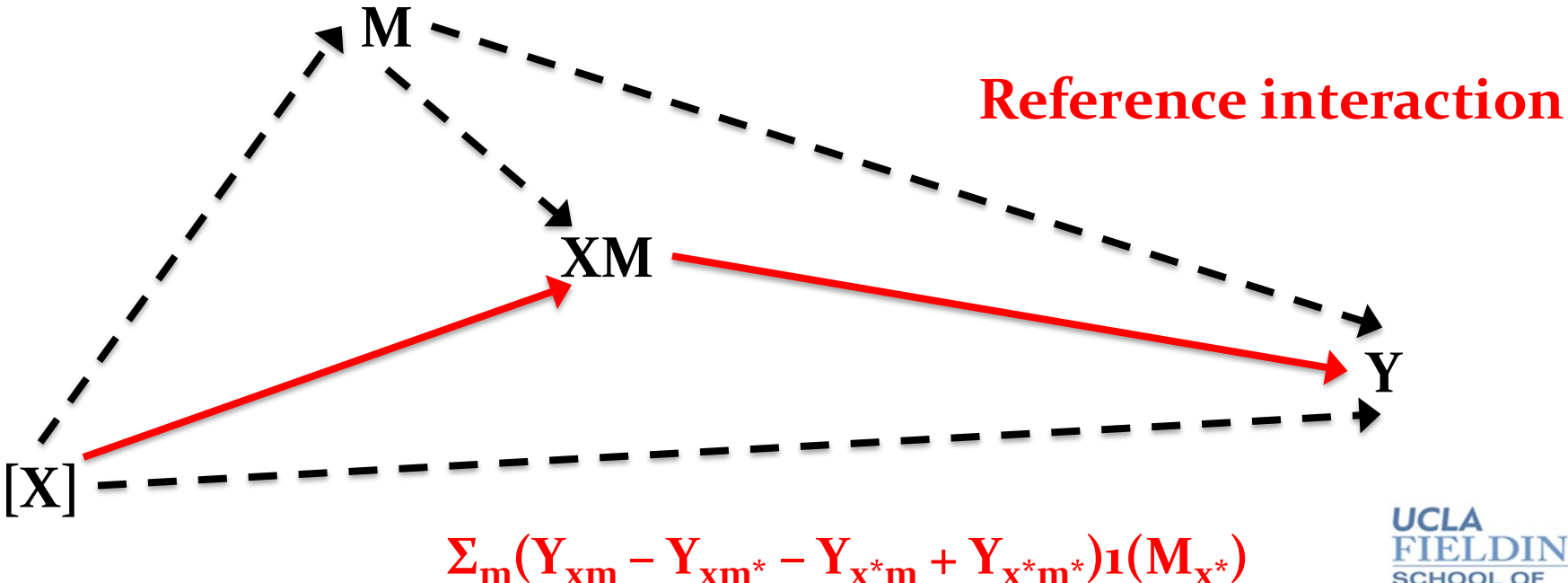
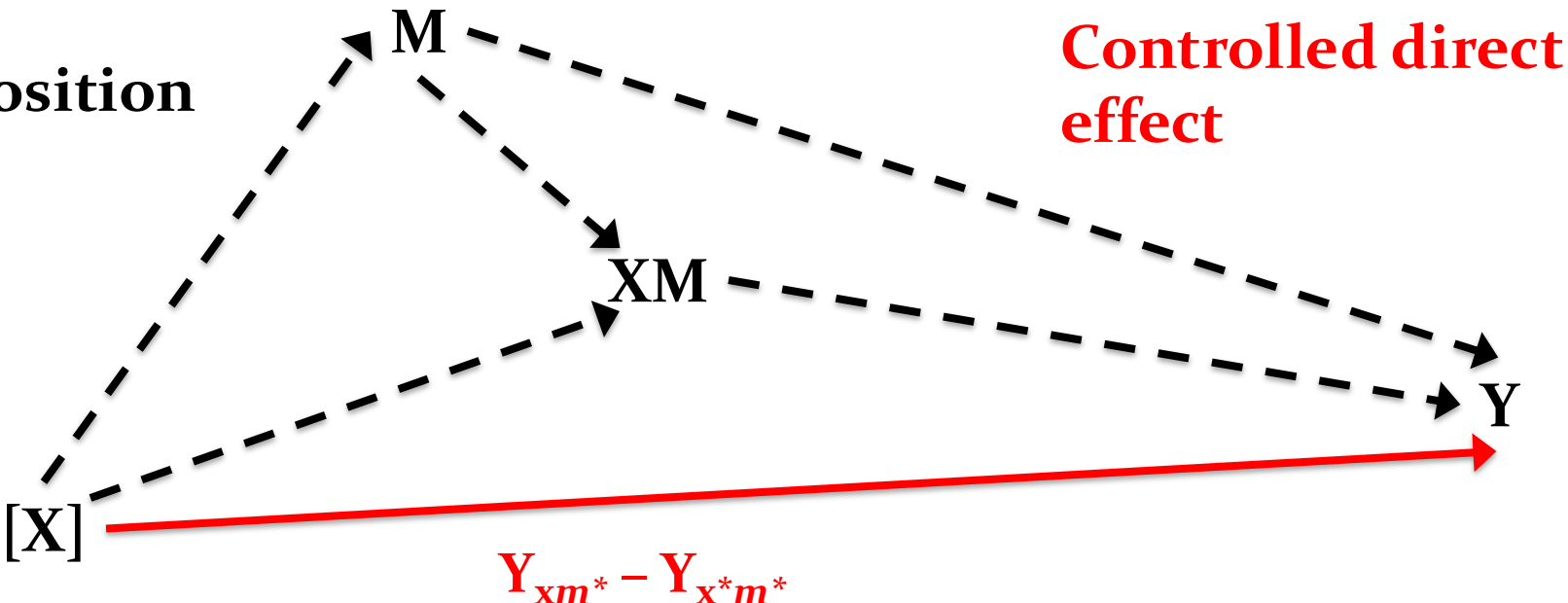
3-Way Decomposition



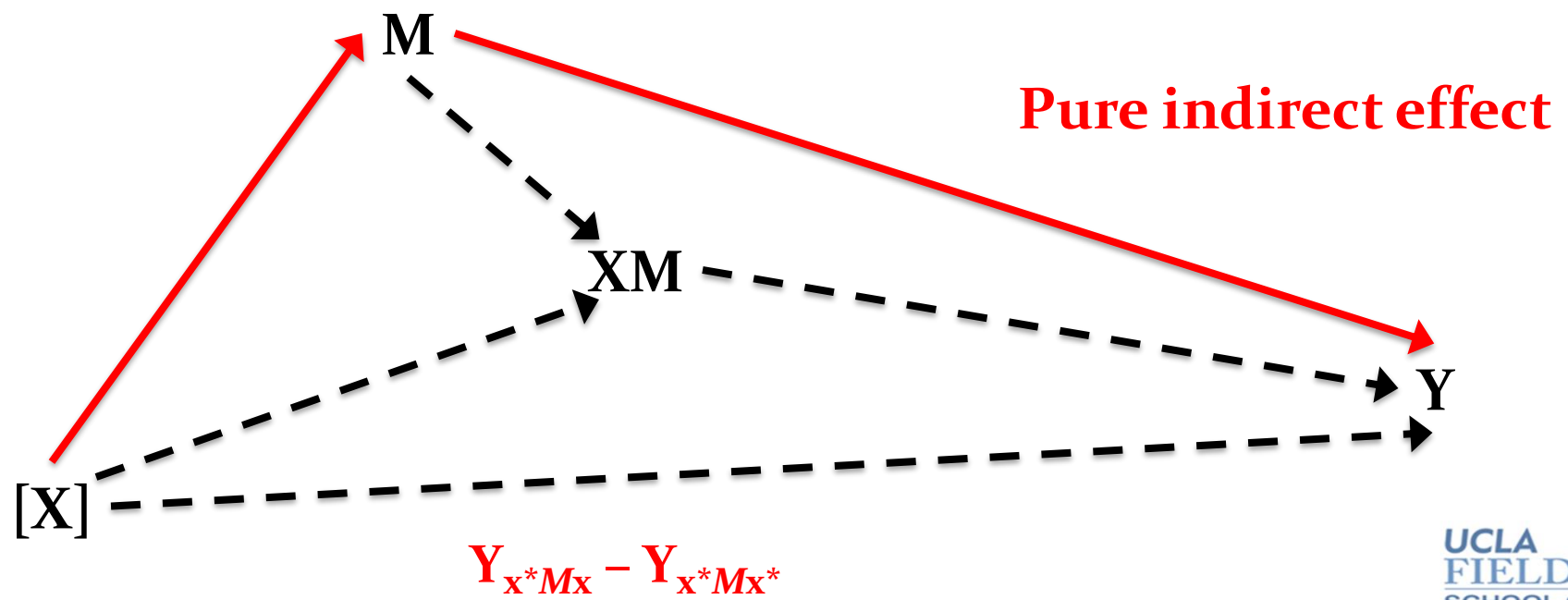
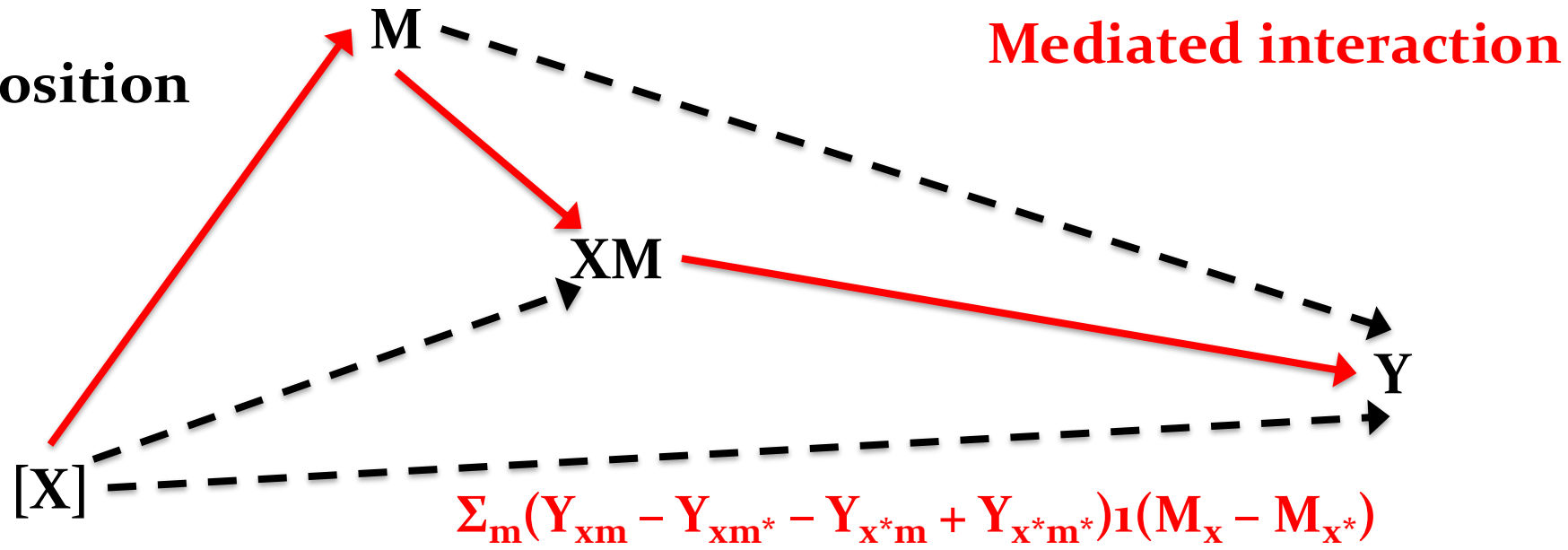
3-Way Decomposition



4-Way Decomposition



4-Way
Decomposition



Conclusion

- Existing graphical rules continue to be applicable to augmented DAGs
- Several important implications can be read from the augmented DAGs
- The augmentation also allows for an intuitive visual depiction of the structural classification of effect decomposition and related concepts
- Augmentation should make DAGs more widely useful in applications

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Contact

Onyebuchi A. Arah, MD, MSc, DSc, MPH, PhD

Department of Epidemiology

UCLA Fielding School of Public Health

Email: ARAH@UCLA.EDU