Phenotypic Data and Individual Privacy

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What is a linking attack? Case of Netflix Prize

Movie ratings database

Anonymized Netflix Prize Training Dataset made available to contestants

100 million ratings
500,000 users

200 movie ratings/user
5,000 users/movie rating

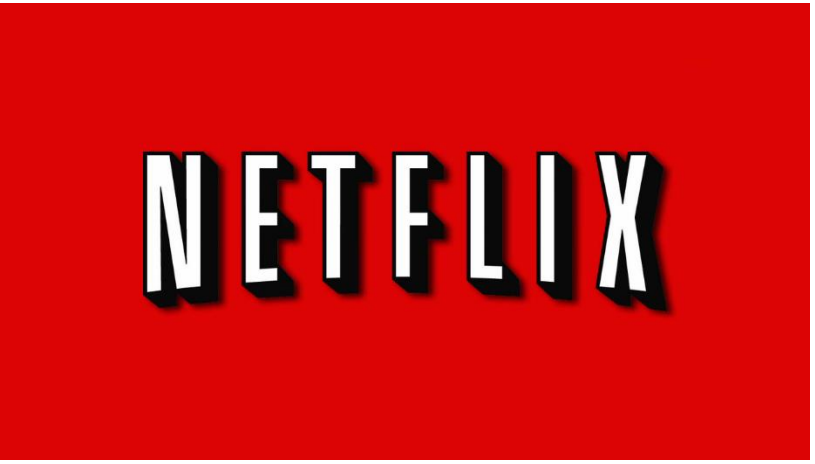
User (ID)	Movie (ID)	Date of Rating	Rating [1,2,3,4,5]
NTFLX-0	NTFLX-19	10/12/2008	1
NTFLX-1	NTFLX-116	4/23/2009	3
NTFLX-2	NTFLX-92	5/27/2010	2
NTFLX-1	NTFLX-666	6/6/2016	5
…	…	…	…
…	…	…	…

What is a linking attack? Case of Netflix Prize

Robust De-anonymization of Large Datasets
(How to Break Anonymity of the Netflix Prize Dataset)

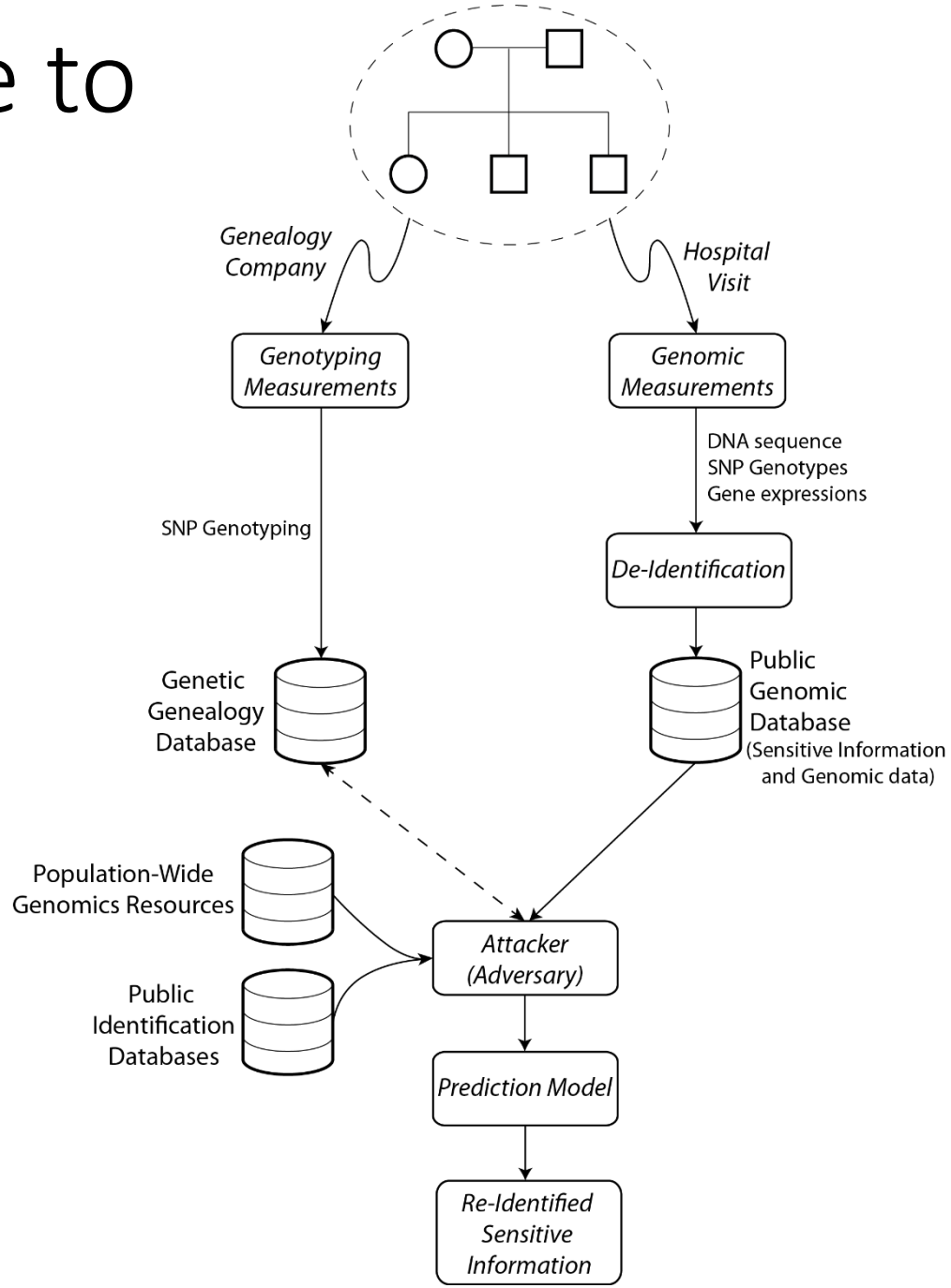
Arvind Narayanan and Vitaly Shmatikov

The University of Texas at Austin



1. Very large datasets
2. A lot of users have a Netflix and an IMDb account
3. A user rates similar scores to a movie in Netflix and IMDb
4. A user rates a particular movie around the same date in Netflix and IMDb

How does this relate to genomic privacy?



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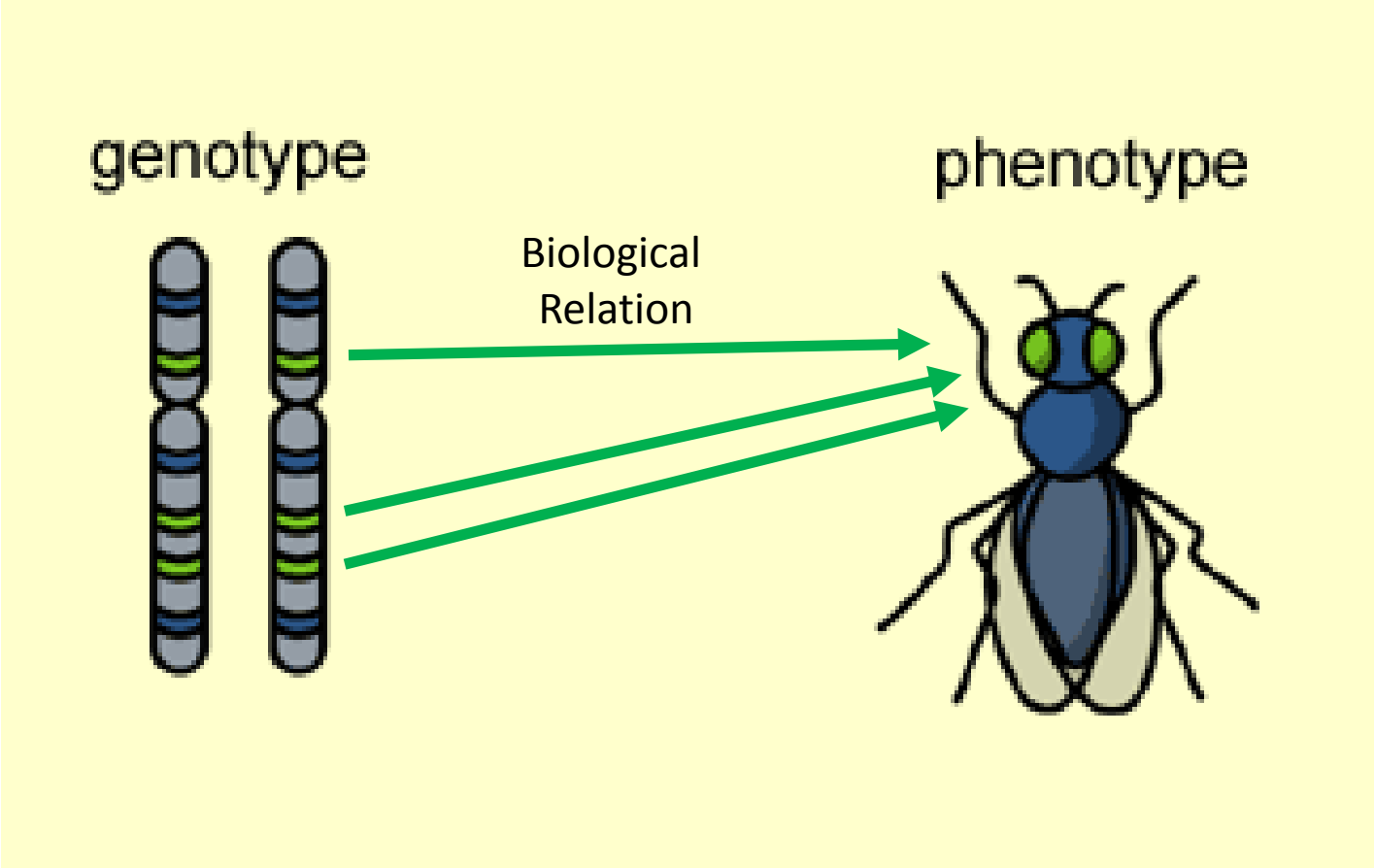
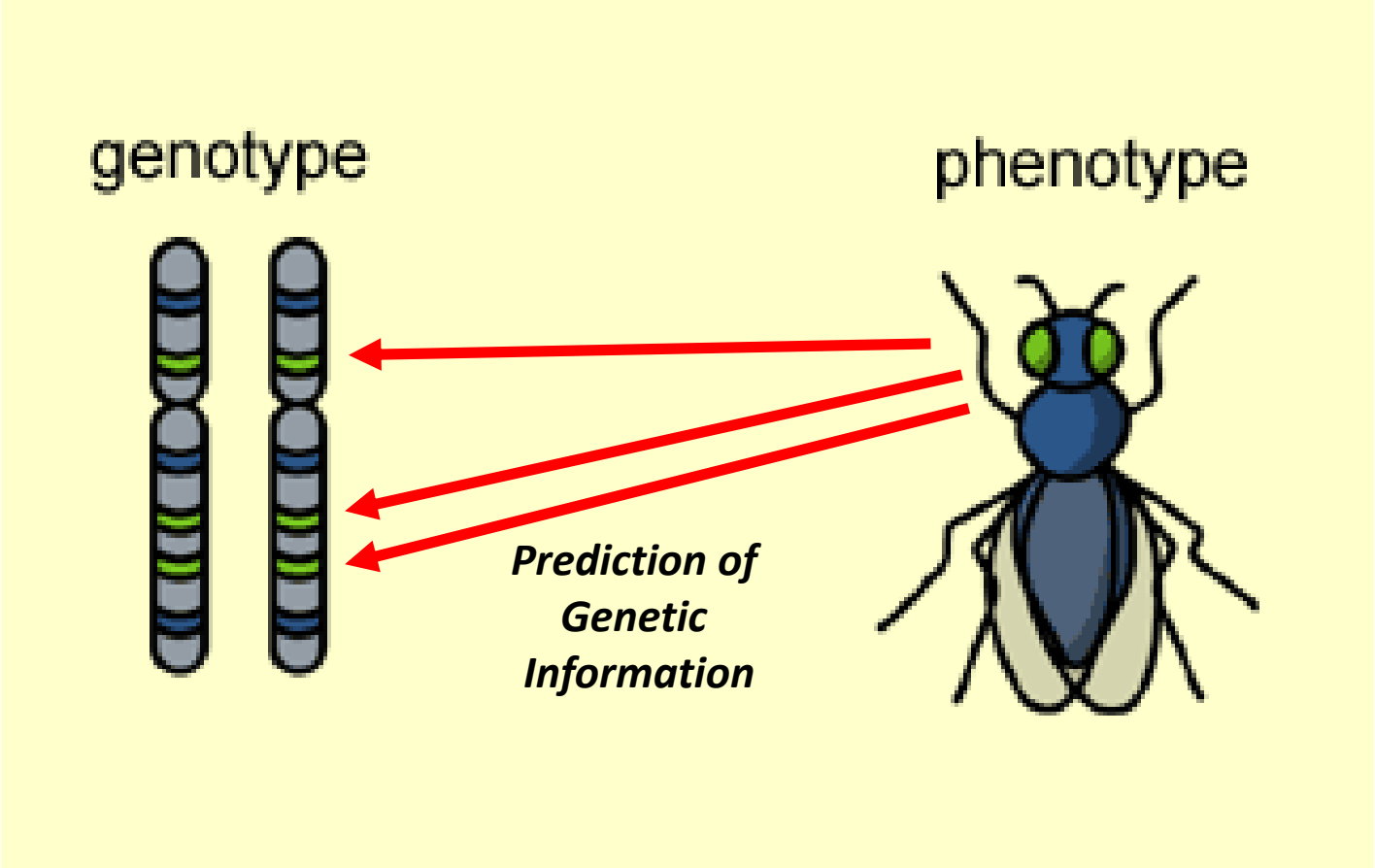
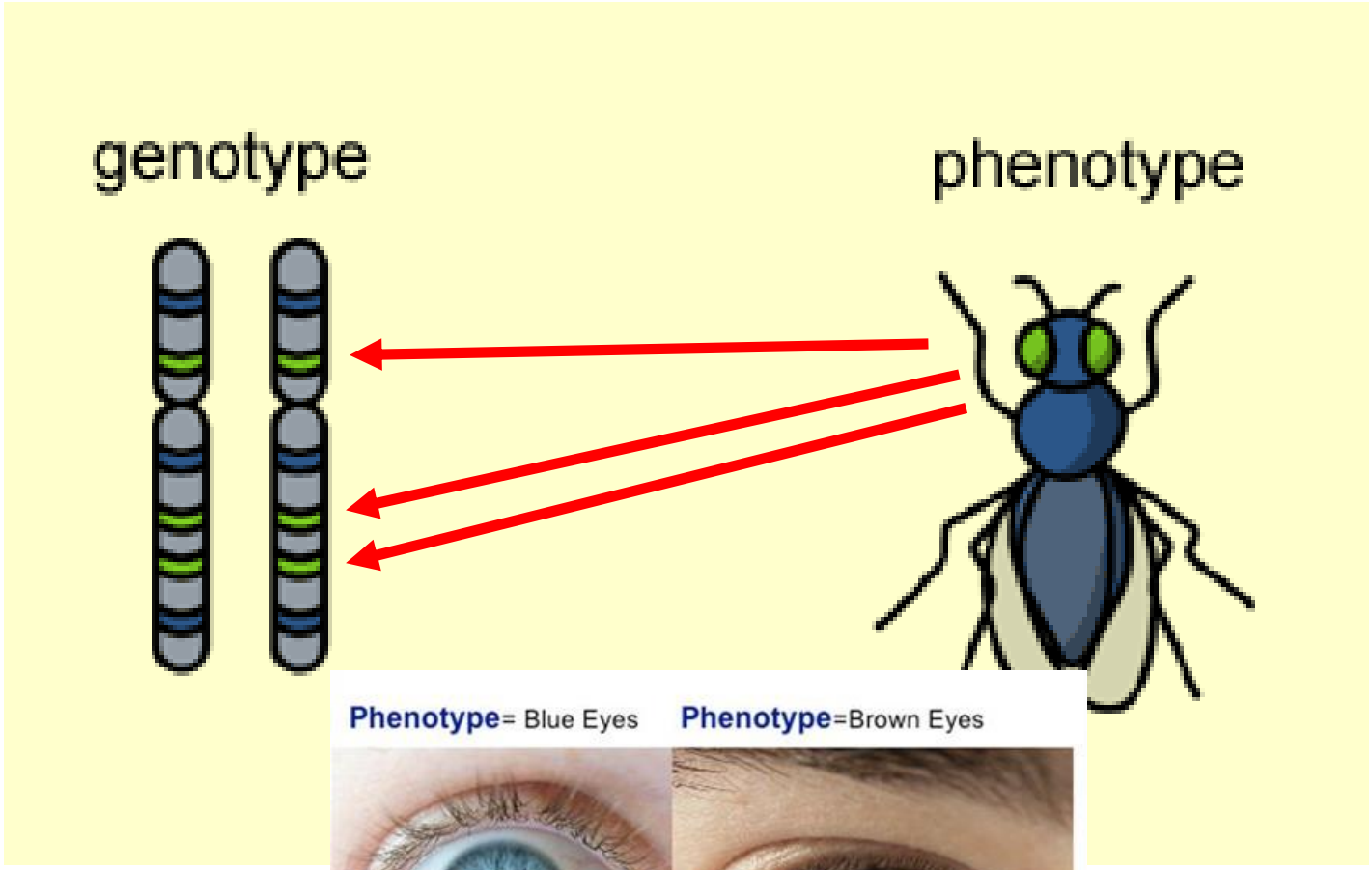


How does this relate to genomic privacy?



How does this relate to genomic privacy?



Linking Attacks: Phenotypic Data

Phenotype Dataset (Public)

Phenotype ID	HIV Status	Phenotype 1	Phenotype 2	⋯	Phenotype q
PID-*1*	HIV+	0.1	-2.7	⋯	90.3
PID-*2*	HIV-	0.5	8.6	⋯	63.5
⋮	⋮	⋮	⋮	⋮	⋮
PID-n	HIV-	-0.2	5.4	⋯	50.3

Phenotype-Genotype Correlation Dataset

Phenotype 1 ⟷ Genotype 1
Phenotype 2 ⟷ Genotype 2
⋯
Phenotype q ⟷ Genotype q

Genotype Dataset (Stolen/Hacked/Queried)

Genotype ID	Genotype 1	Genotype 2	⋯	Genotype q
GID-*1*	0	1	⋯	1
GID-*2*	2	1	⋯	0
⋮	⋮	⋮	⋮	⋮
GID-m	1	2	⋯	1

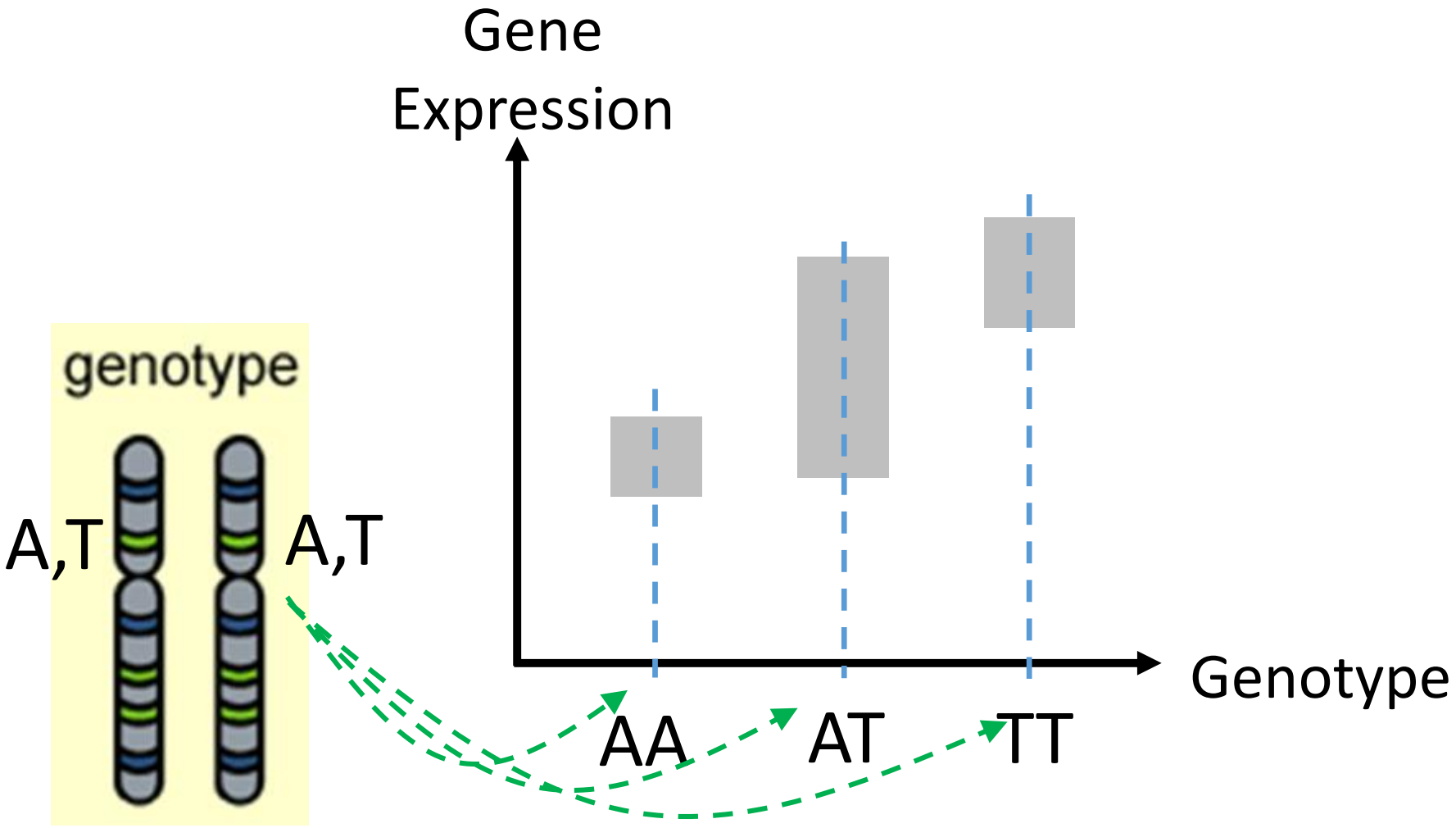
Genotype Prediction

Phenotype ID	HIV Status	Predicted Genotypes: Genotype 1	Genotype 2	⋯	Genotype q
PID-*1*	HIV+	1	0	⋯	2
PID-*2*	HIV-	2	2	⋯	1
⋮	⋮	⋮	⋮	⋮	⋮
PID-n	HIV-	0	1	⋯	1

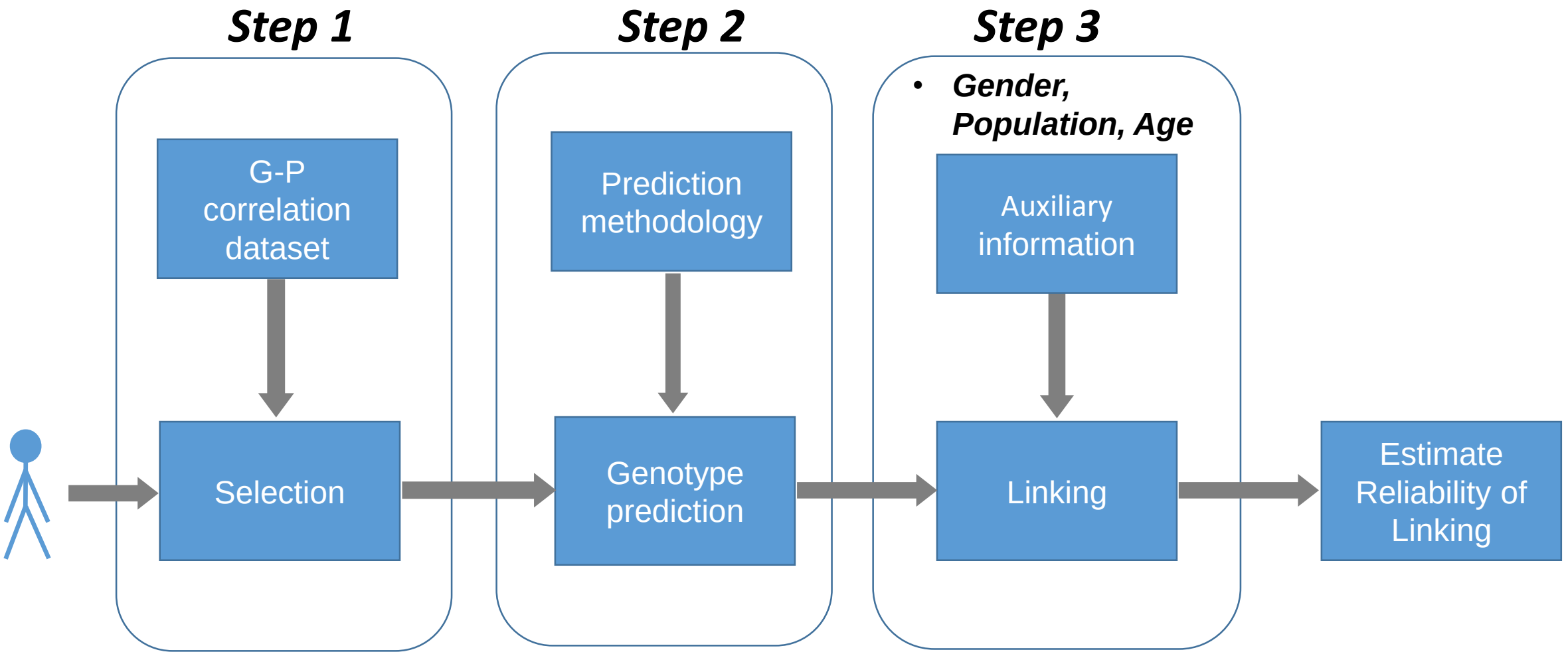
Genotype Comparison and Matching

Genotype ID	Phenotype ID	HIV Status	Predicted/Matched Genotypes: Genotype 1	Genotype 2	⋯	Genotype q
GID-*1*	PID-*8*	HIV+	0/0	1/1	⋯	1/1
GID-*2*	PID-*3*	HIV-	2/2	1/1	⋯	0/0
GID-*3*			1/0	1/0	⋯	0/2
GID-*4*	PID-*1*	HIV+	1/1	0/0	⋯	2/2
GID-*5*			0/1	1/1	⋯	2/1
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Gene expression-genotype linking: expression Quantitative Trait Loci



3-Steps of a Linking Attack



Take Home Messages

- Your genetic information (4 letters) can be guessed somewhat accurately from your physical characteristics!
  - Height, eye color, hair color, weight…
- There are 3 steps in a linking attack!
- Phenotype and genotype datasets can be reliably linked to reveal sensitive information!
- Auxiliary information is very important!
  - Your gender and where you are from can be used against you in a linking attack
- Relatives are also at risk of privacy breach!