Cryptography

Lecture 0

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In the News

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- "... Unfortunately, endpoint security is so terrifically weak that [the adversary] can frequently find ways around it."

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- It's all about controlling access to information
  - A tool for enforcing policies on who can learn and/or influence information
  - Do we know what we are talking about?

What is information?

What is information?

- Or rather the lack of it?

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  - Uncertainty

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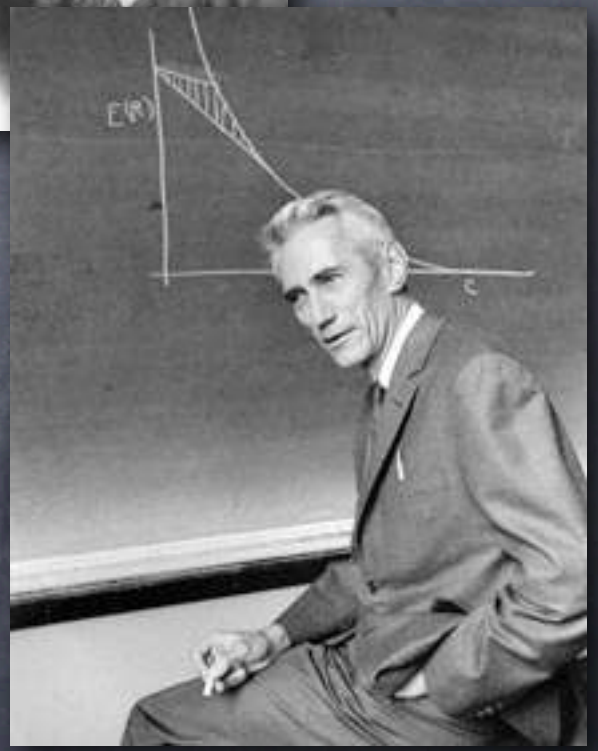

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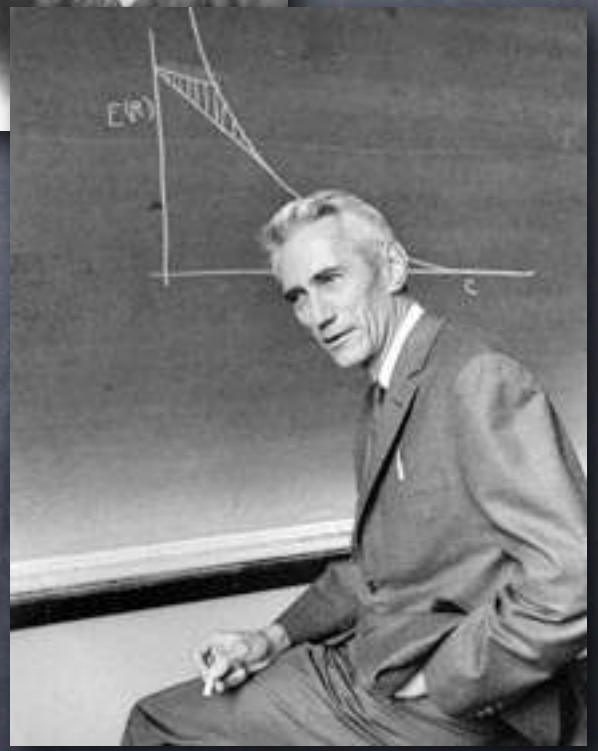

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  - Uncertainty
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    - Borrowed from thermodynamics
    - An inherently "probabilistic" notion

What is information?

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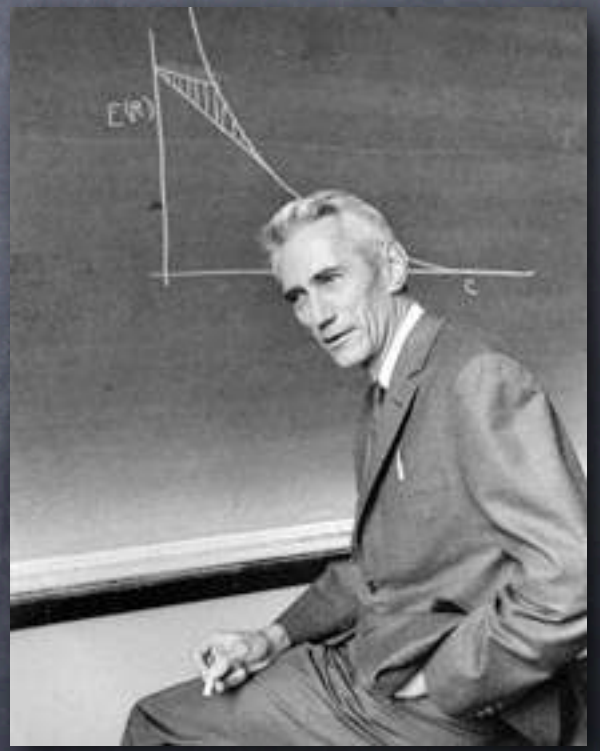

What is information?

- Information Theory: ways to quantify information

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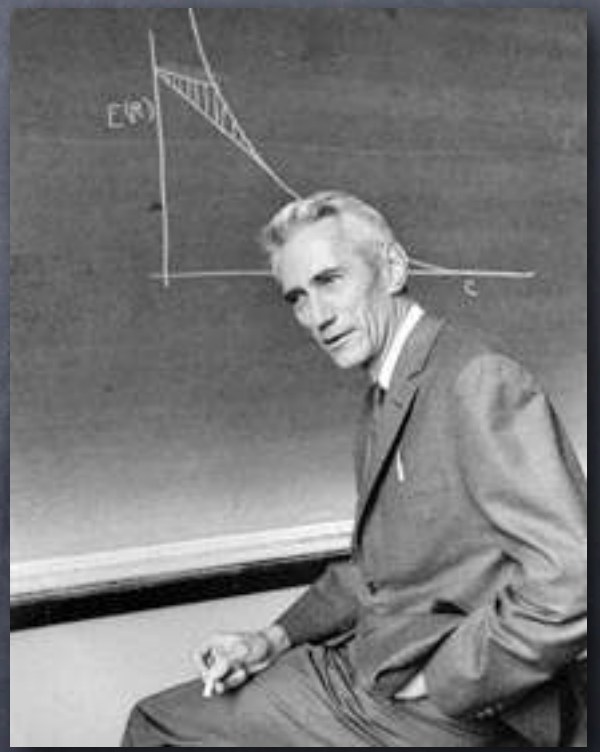

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  - Application 1: to study efficiency of communication (compression, error-correction)

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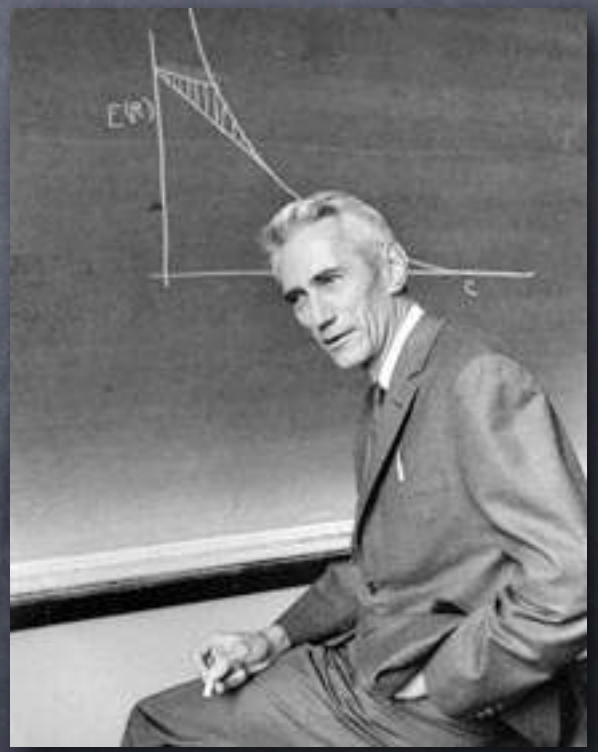

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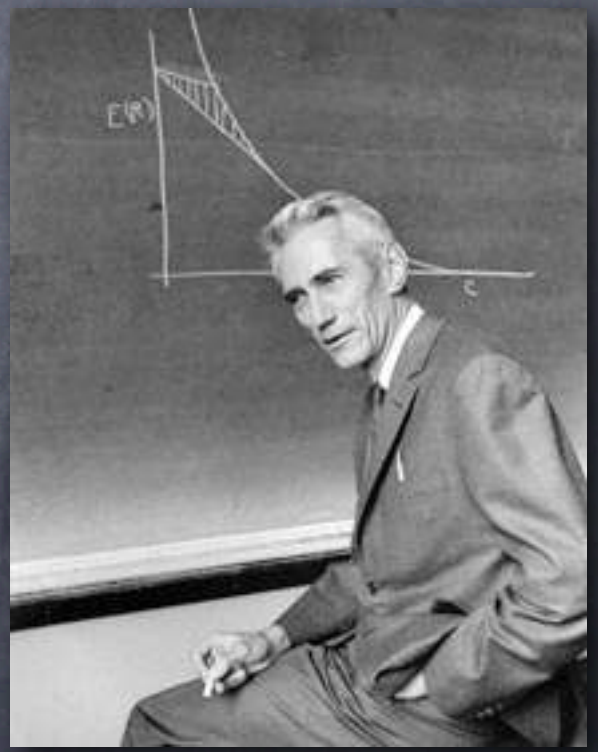

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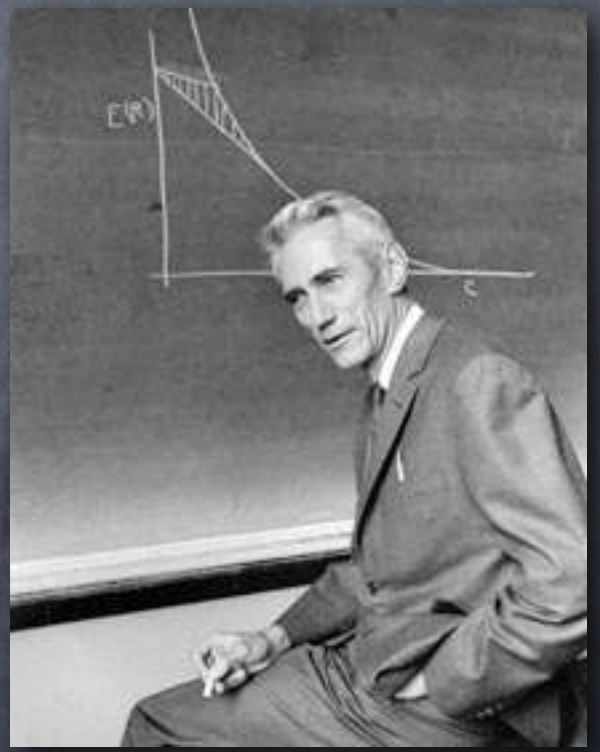
- Information Theory: ways to quantify information
  - Application 1: to study efficiency of communication (compression, error-correction)
  - Application 2: to study the possibility of secret communication
    - The latter turned out to be a relatively easy question! Secret communication possible only if (an equally long) secret key is shared ahead of time

Claude Shannon



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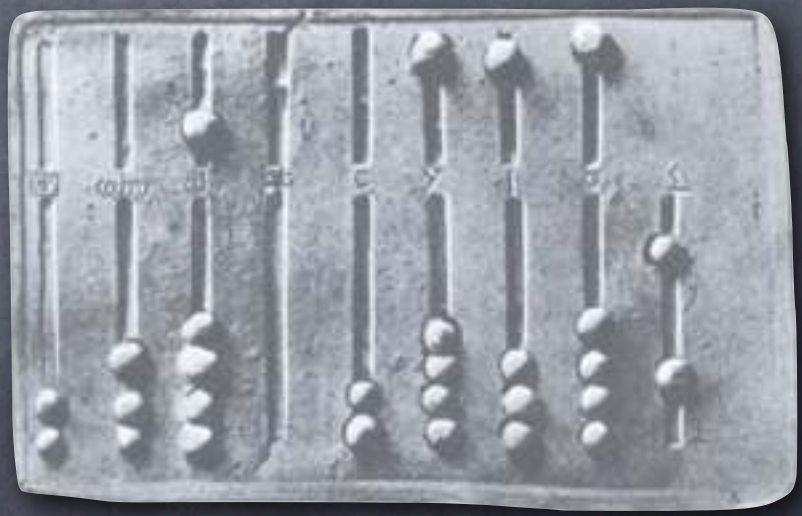
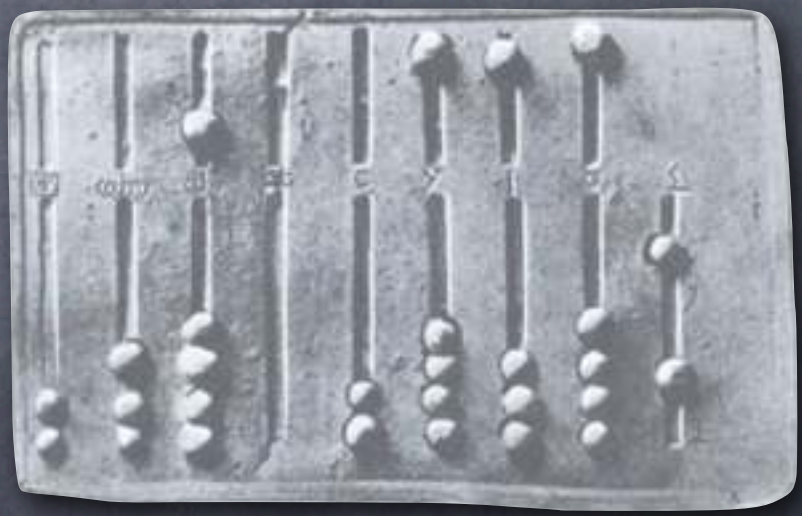


Access to Information

- A second look
- Information at hand may still not be "accessible" if it is hard to work with it
  - Computation!
- Shannon's information may reduce uncertainty only for computationally all-powerful parties



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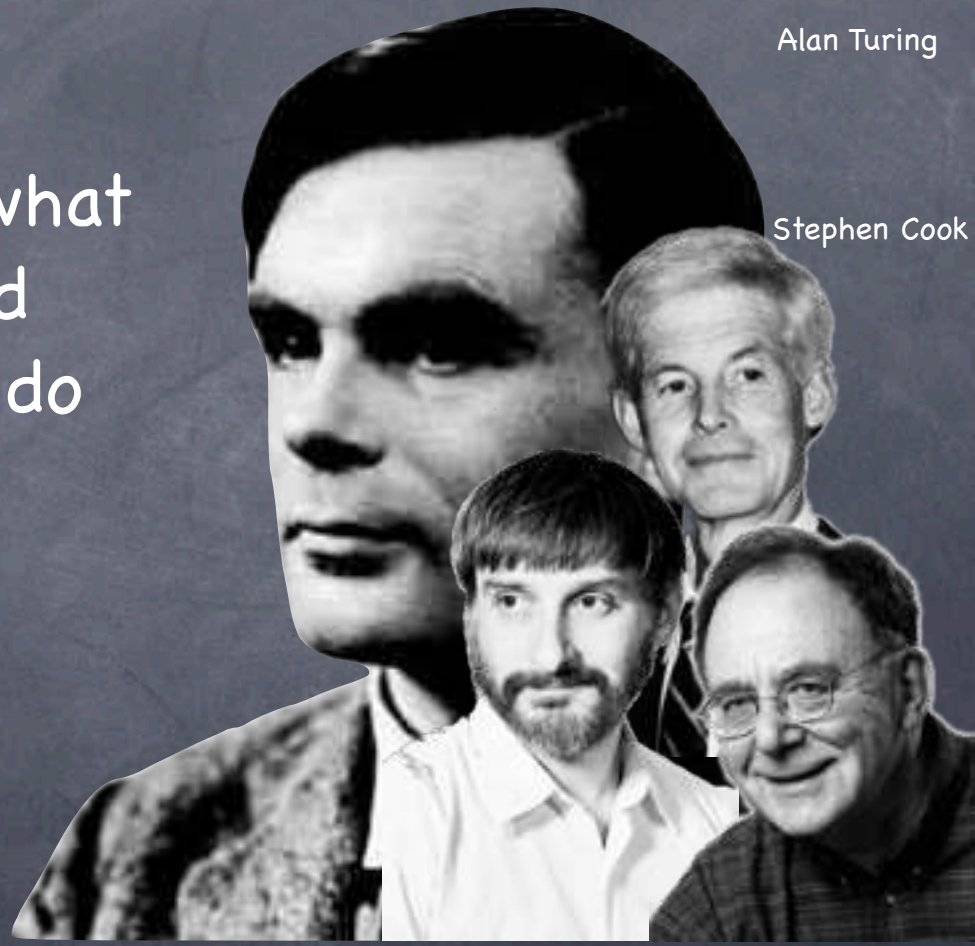

Computational Complexity

- A systematic study of what computationally bounded parties can and cannot do
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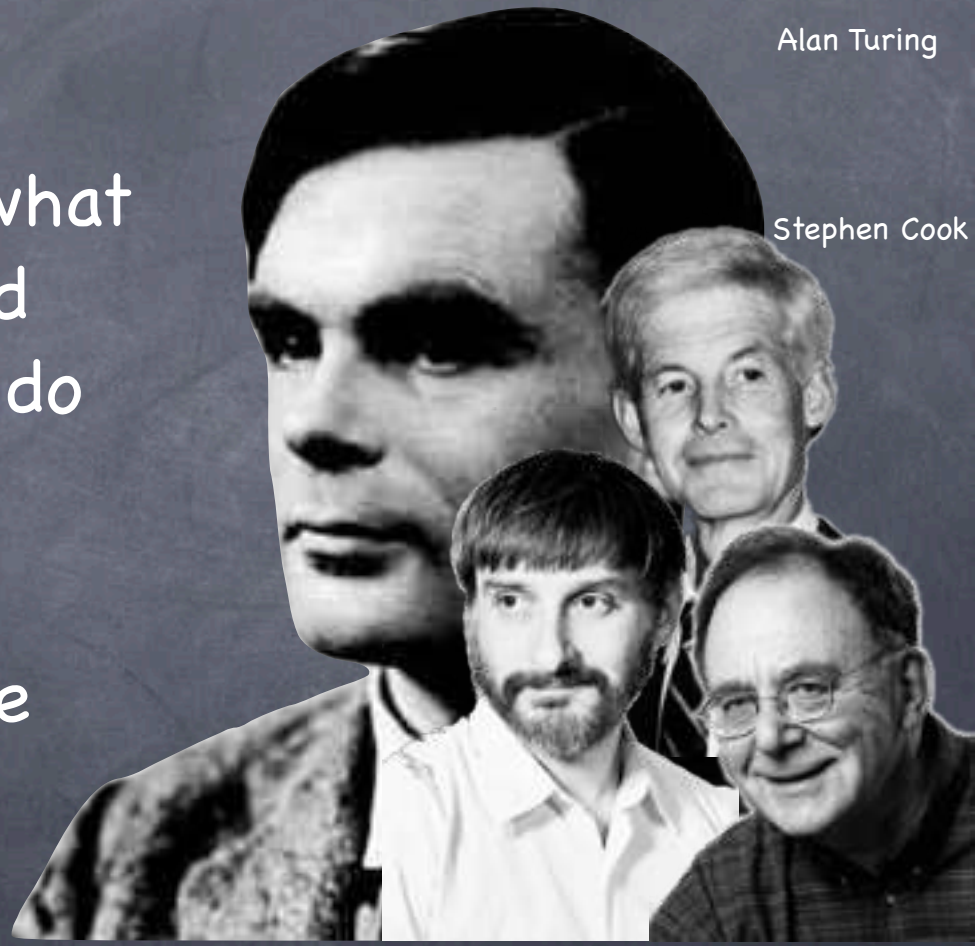
- Much known, much more unknown



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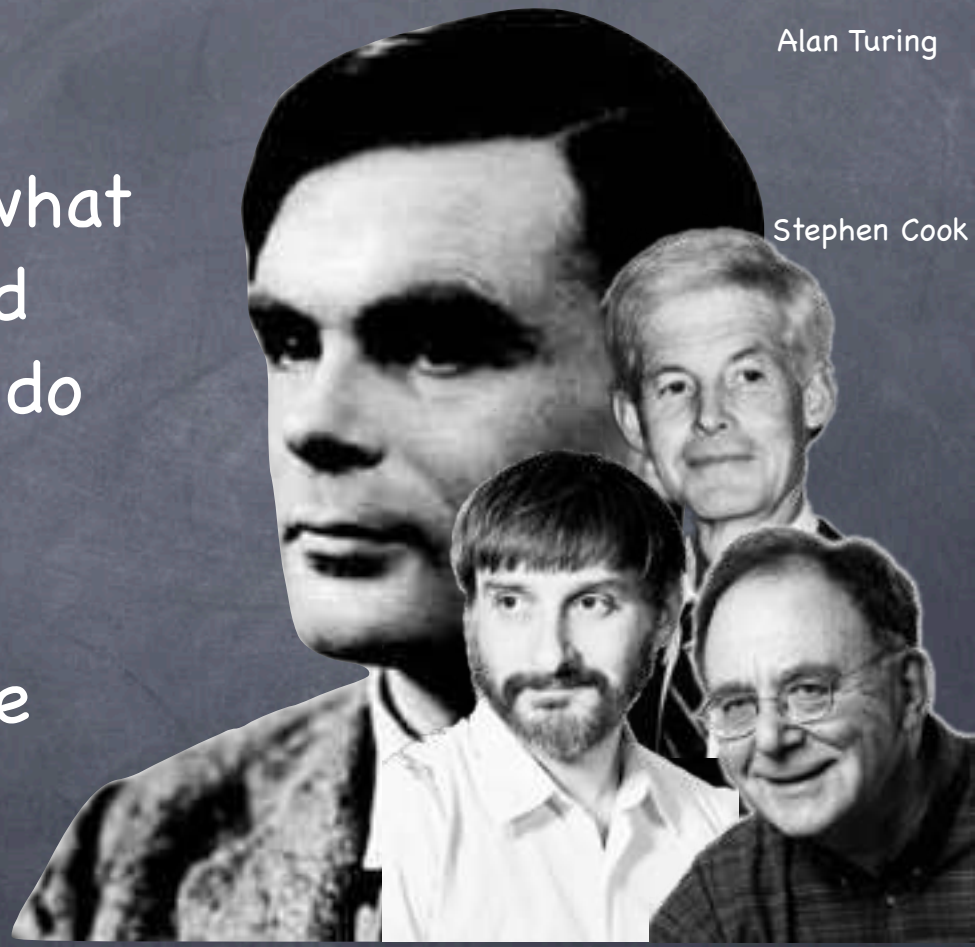

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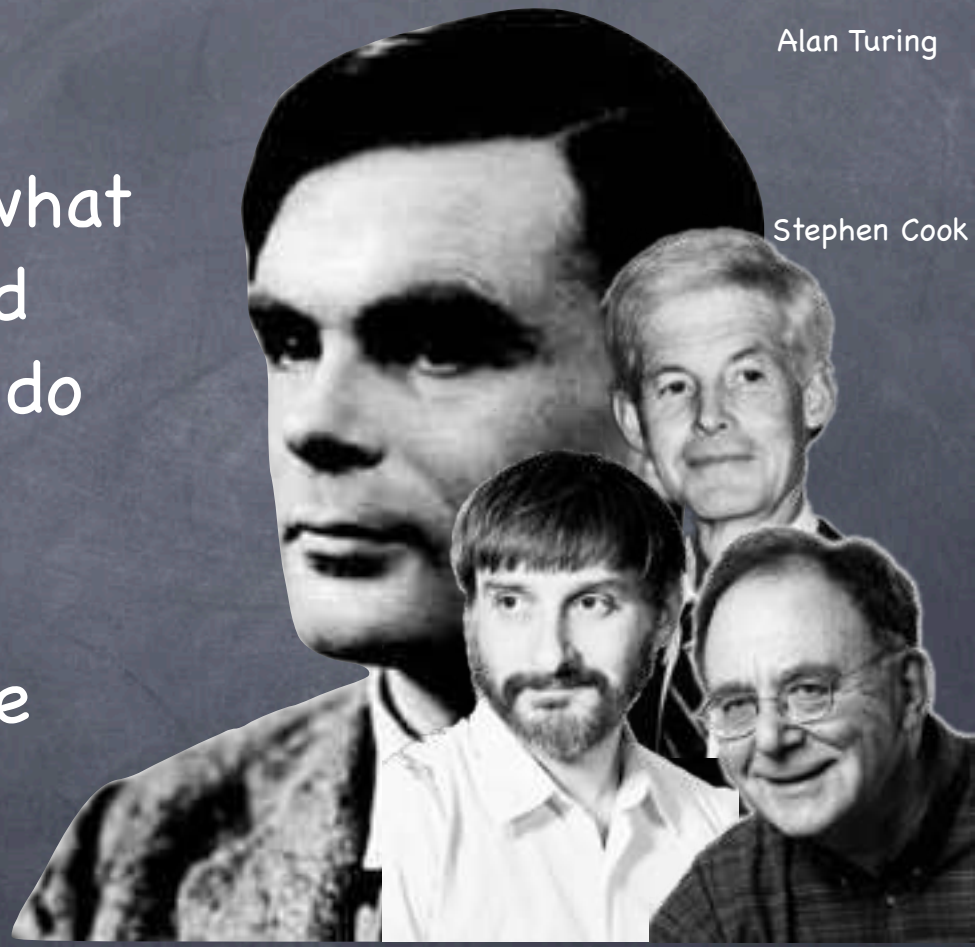
- Much known, much more unknown
  - Much "believed"
- Basis of the Modern Theory of Cryptography



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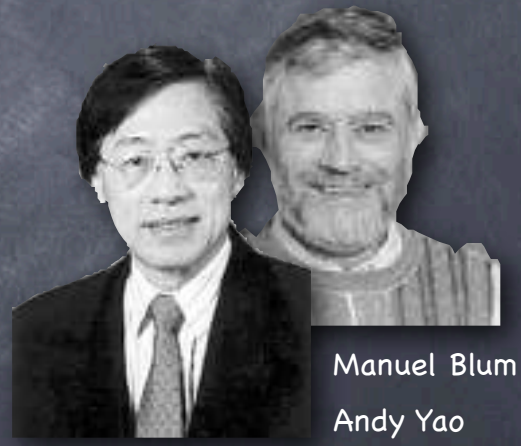
  - But possible against computationally bounded players: use pseudo-random strings!
- Pseudo-random number generator
  - a.k.a Stream Cipher
  - Generate a long string of random-looking bits from a short random seed



Manuel Blum

Andy Yao

The Public-Key Revolution

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- "Non-Secret Encryption"

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  - Instead, a public key. Anyone can create encryptions, only the creator of the key can decrypt!
- Publicly verifiable digital signatures
- Forms the backbone of today's secure communication


Merkle, Hellman, Diffie


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- Public-Key cryptography and beyond!

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- And other fancy things... with sophisticated control over more complex "access" to information

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- Public-Key cryptography and beyond!
- Secret computation: collaboration among mutually distrusting parties
  - Compute on distributed data, without revealing their private information to each other
  - Compute on encrypted data
- And other fancy things... with sophisticated control over more complex "access" to information
- Do it all faster, better, more conveniently and more securely (or find out if one cannot). And also make sure we know what we are trying to do.

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- Public-Key
- S
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  -
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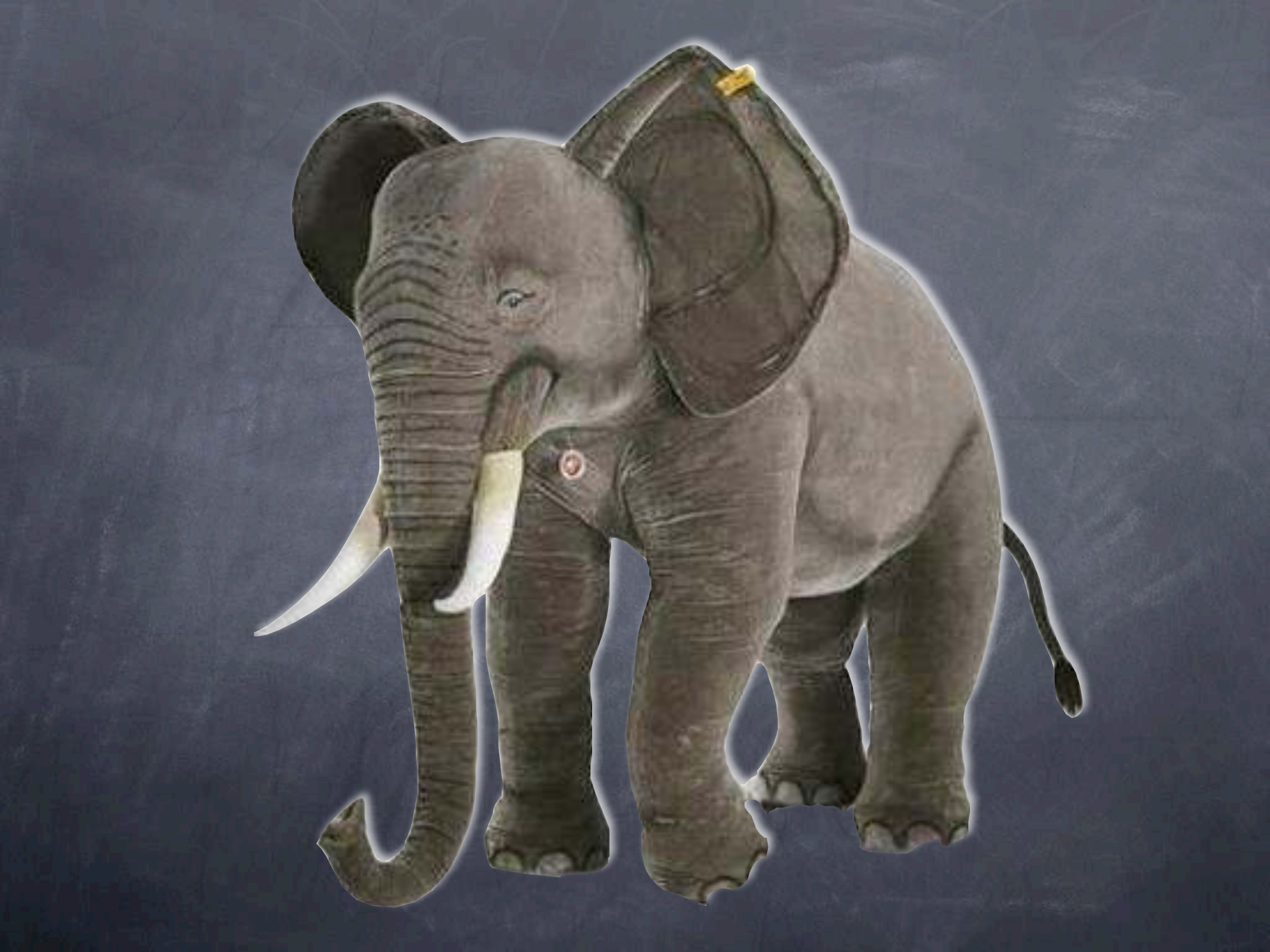
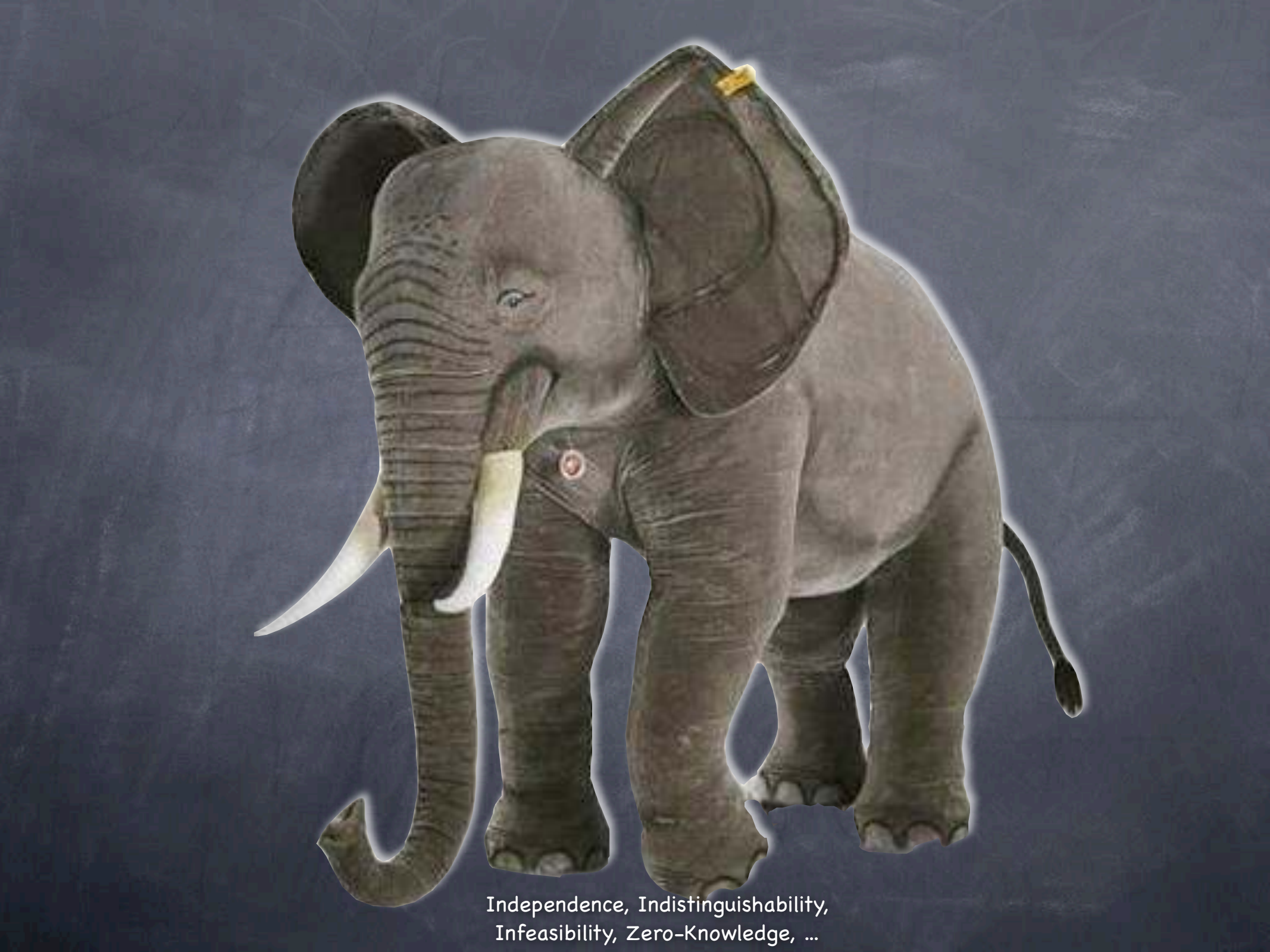
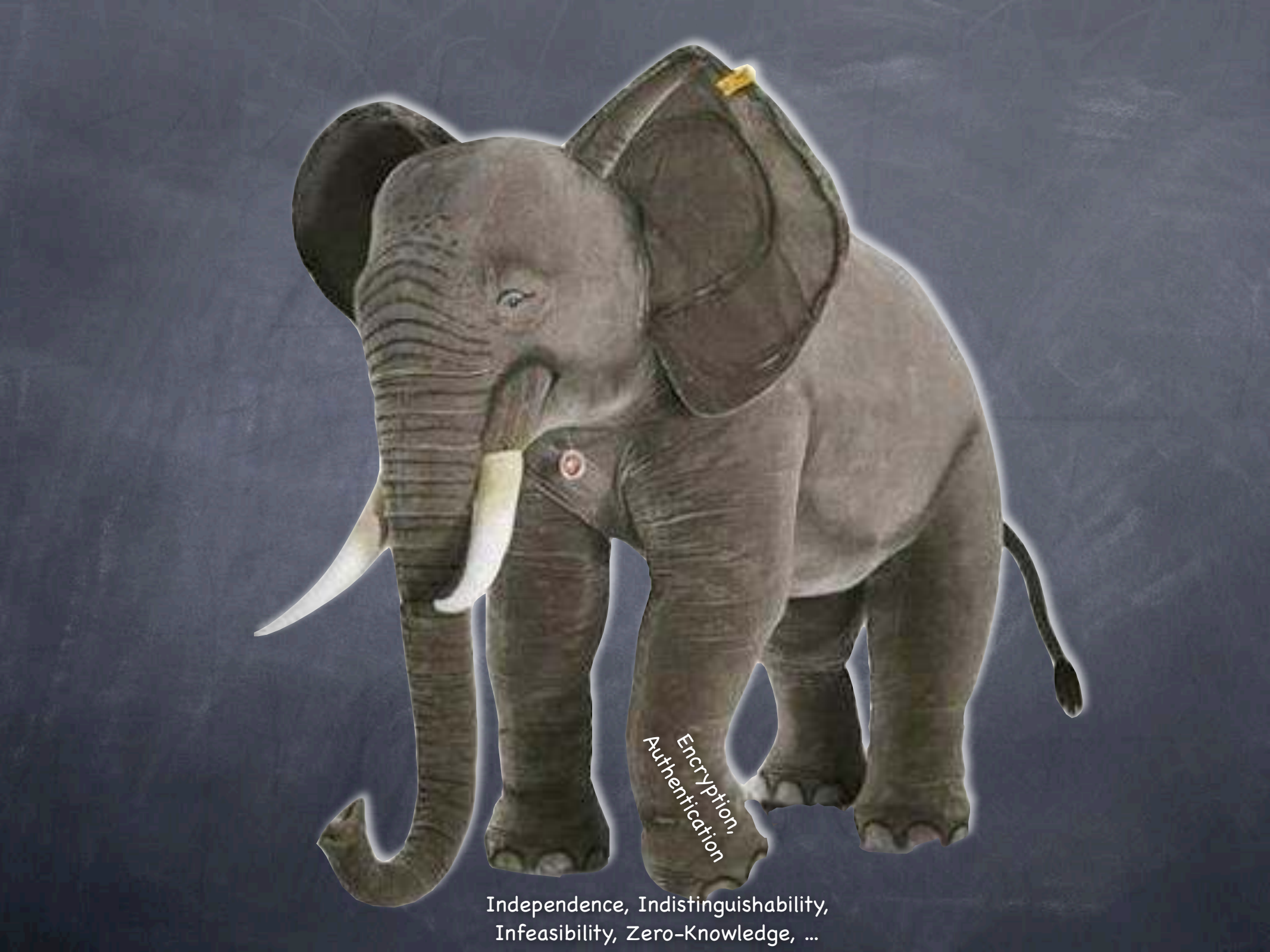



Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...


Encryption,
Authentication
Independence, Indistinguishability,
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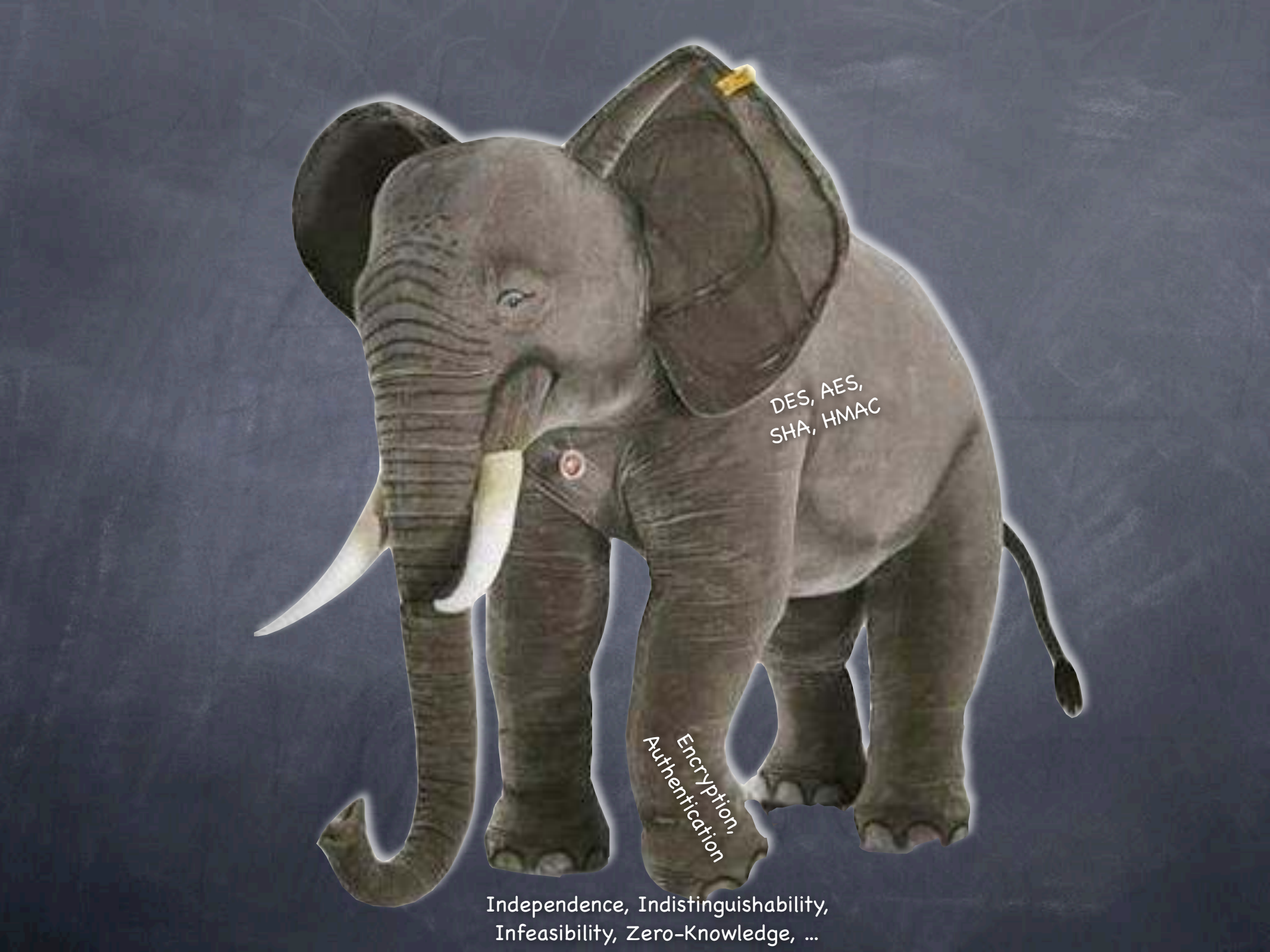
DES, AES,
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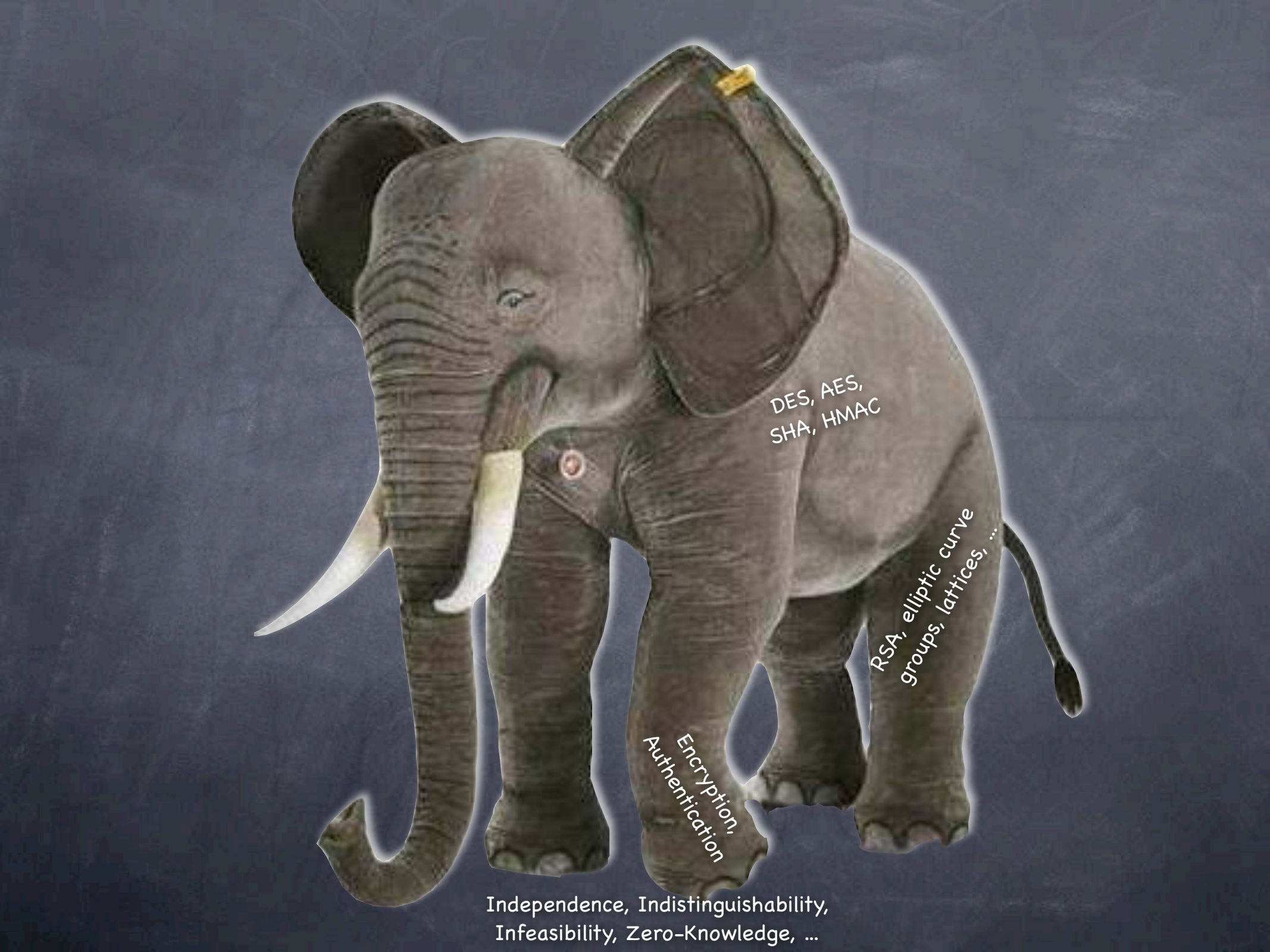
DES, AES,
SHA, HMAC
RSA, elliptic curve
groups, lattices, ...
Encryption,
Authentication
Independence, Indistinguishability,
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Stream ciphers,
Block ciphers

Secure Multi-Party
Computation

Secret sharing,
Verifiable Secret
sharing

Universal composition

ZK proofs

Blind signatures,
Mix-nets, DC-nets,...

Concrete cryptanalysis
(Birthday attacks,
differential cryptanalysis, ...)

Identity-Based
Encryption

Obfuscation, Leakage
resilient crypto,
Imperfect randomness, ...

DES, AES,
SHA, HMAC

PK Encryption,
Signatures

Random Oracle Model,
Generic group model

SSL, TSL

Hybrid encryption

Pseudorandomness
generators, PRF, ...

Semantic security, non-
malleability, existential
unforgeability...

Signcryption

Malware, DDoS,
Side-channels

RSA, elliptic curve
groups, lattices, ...

e-cash, e-Voting,
Fair Exchange, Privacy
Preserving Datamining, ...

one-way functions,
collision-resistant hash
functions, ...

Encryption,
Authentication

Algorithms,
Reductions

Formal
methods

Independence, Indistinguishability,
Infeasibility, Zero-Knowledge, ...

In This Course

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(how to tame the elephant...)

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- A few assignments

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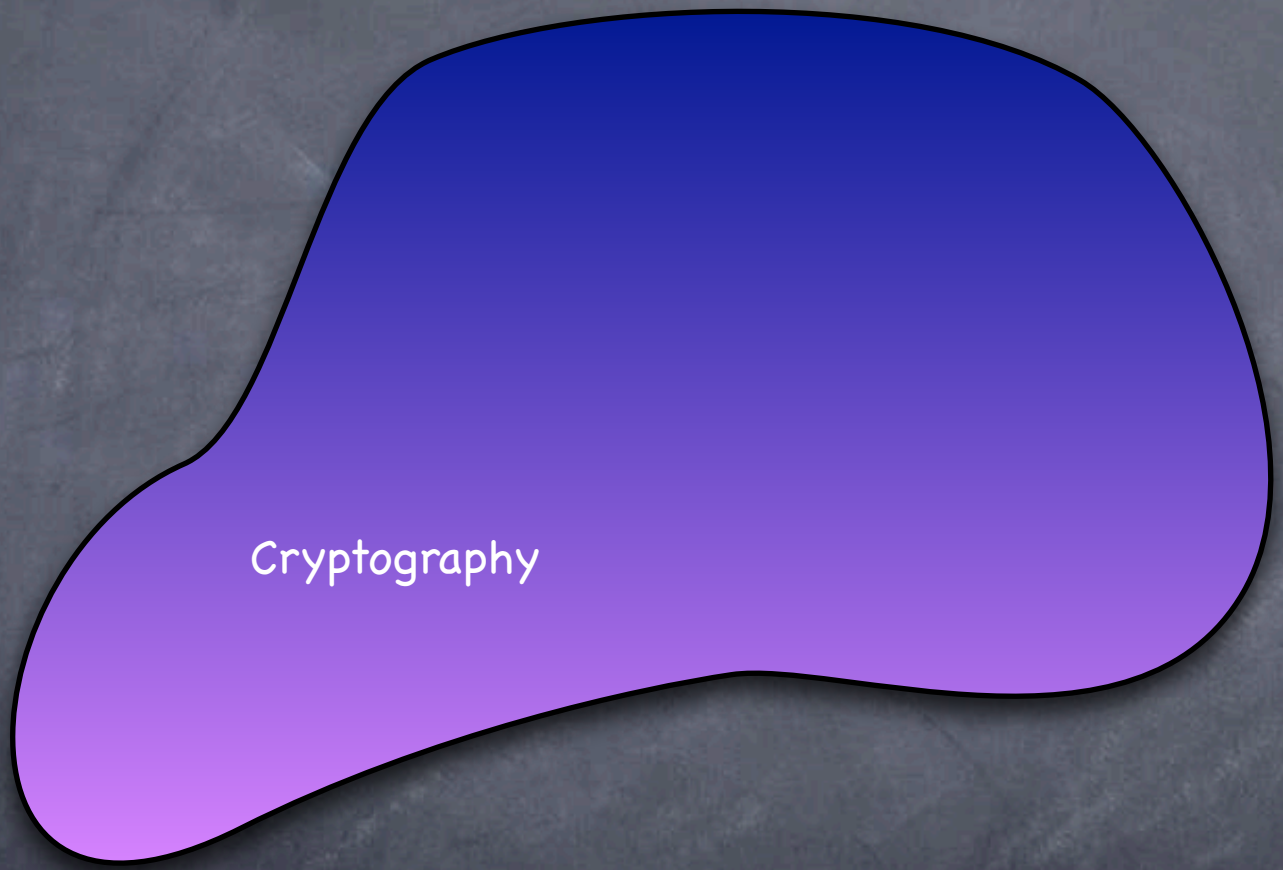

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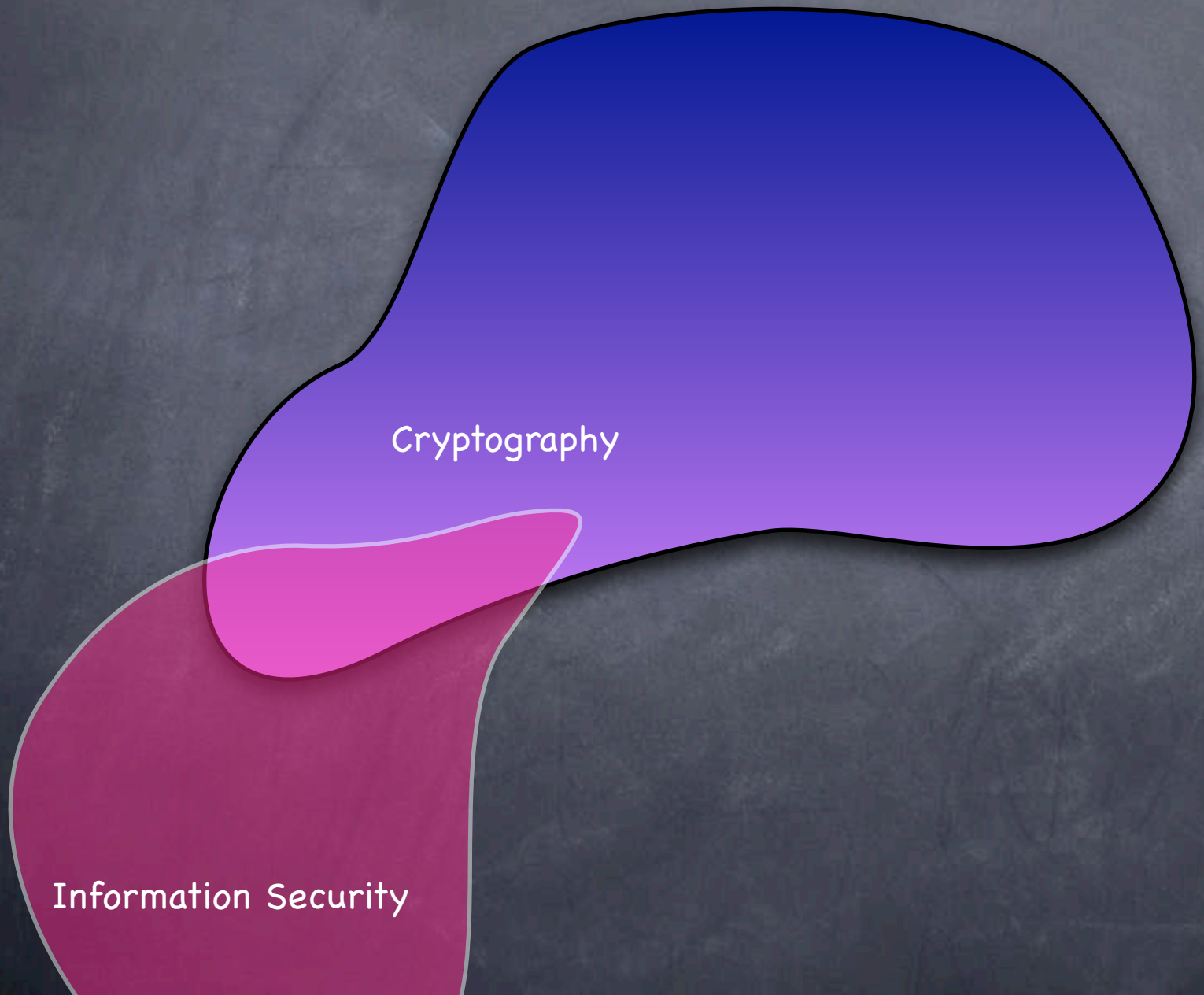

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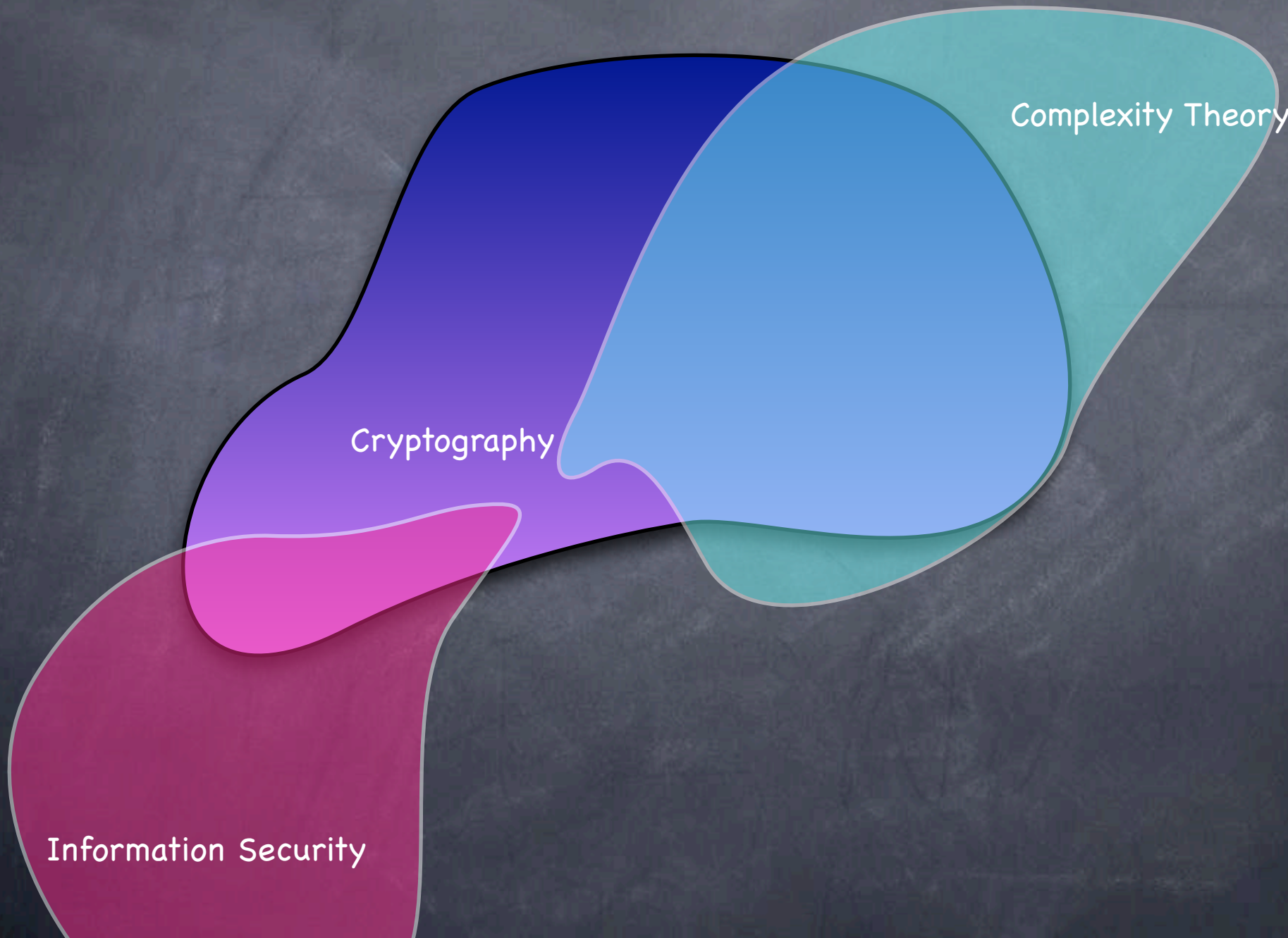

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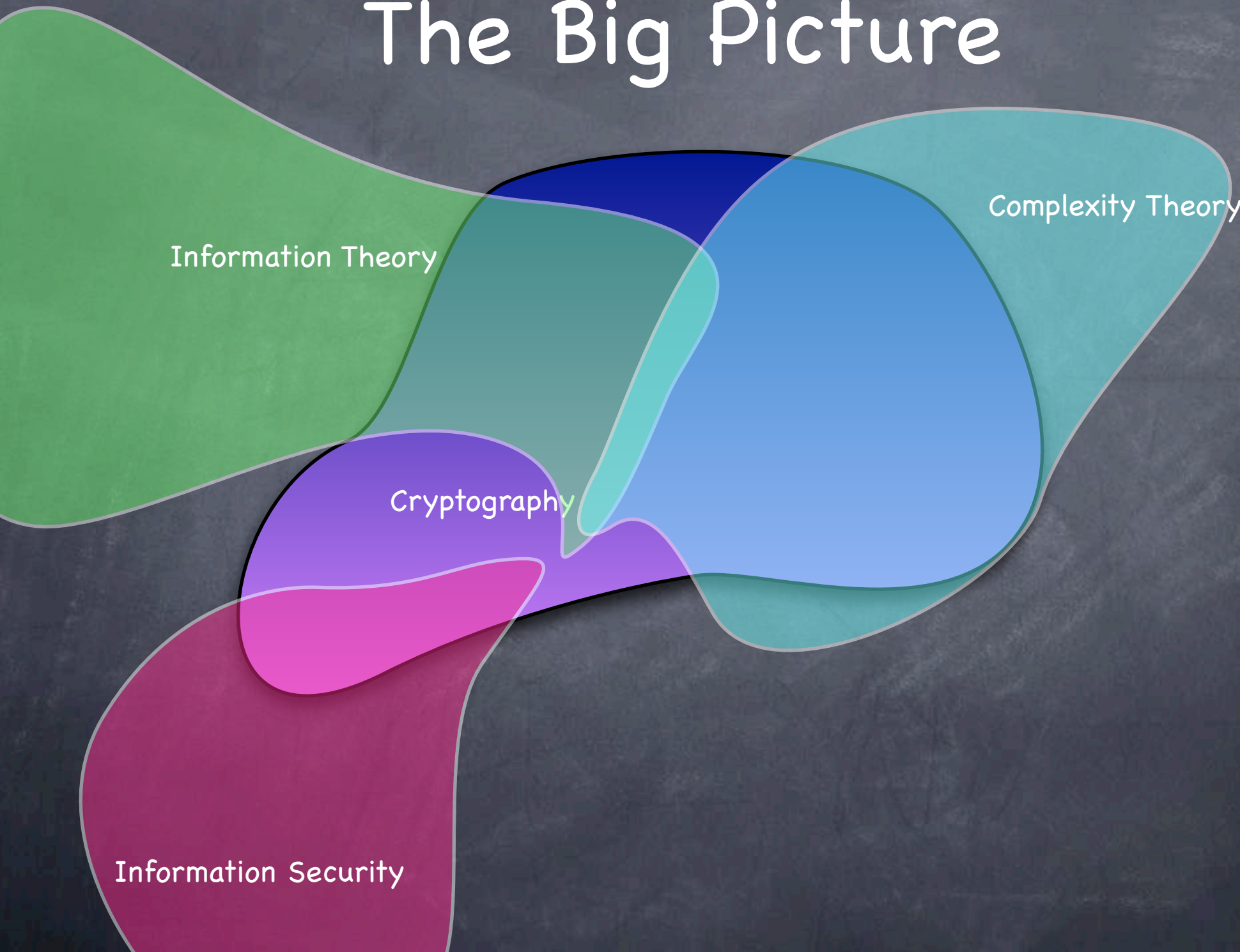

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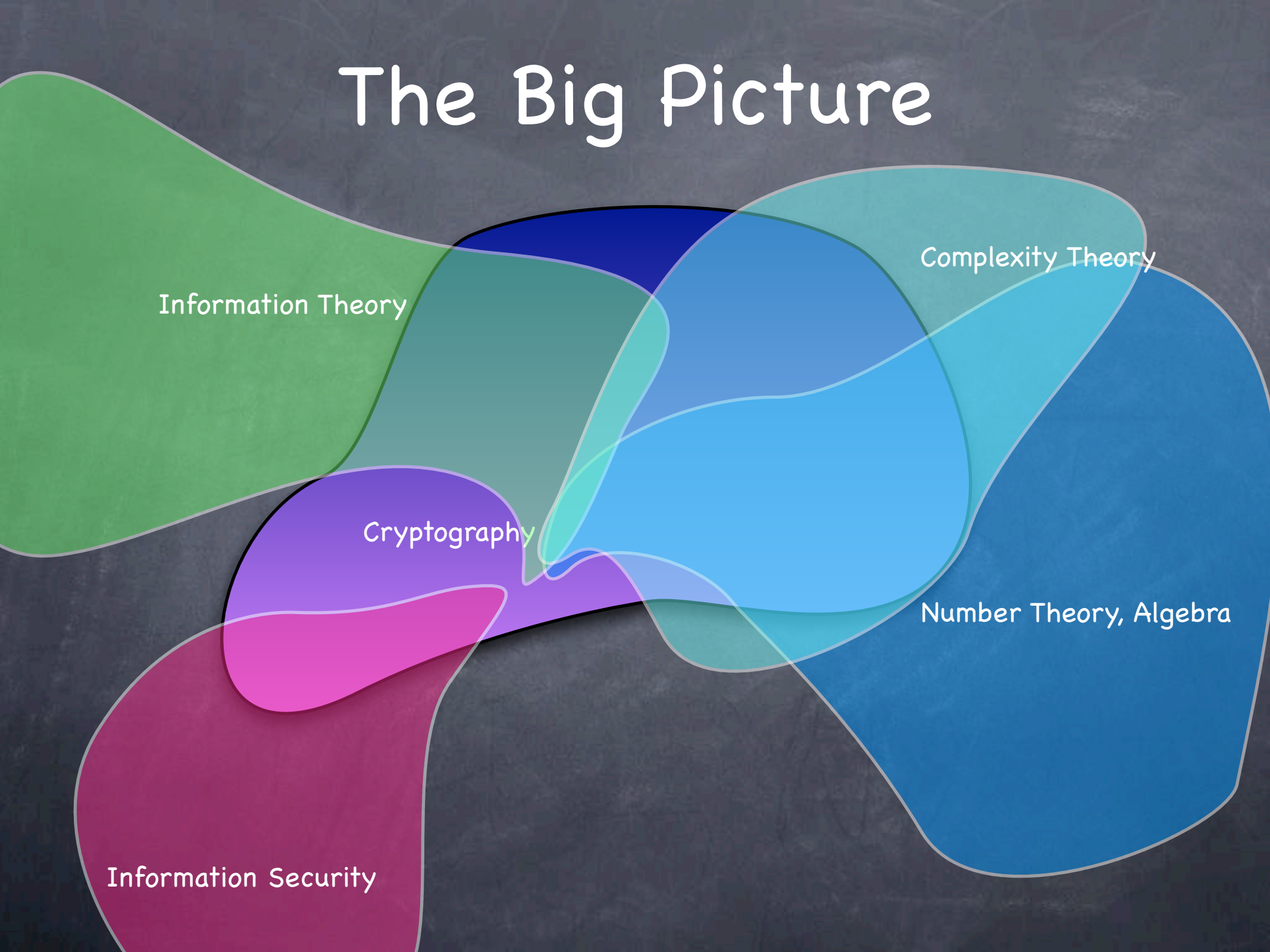

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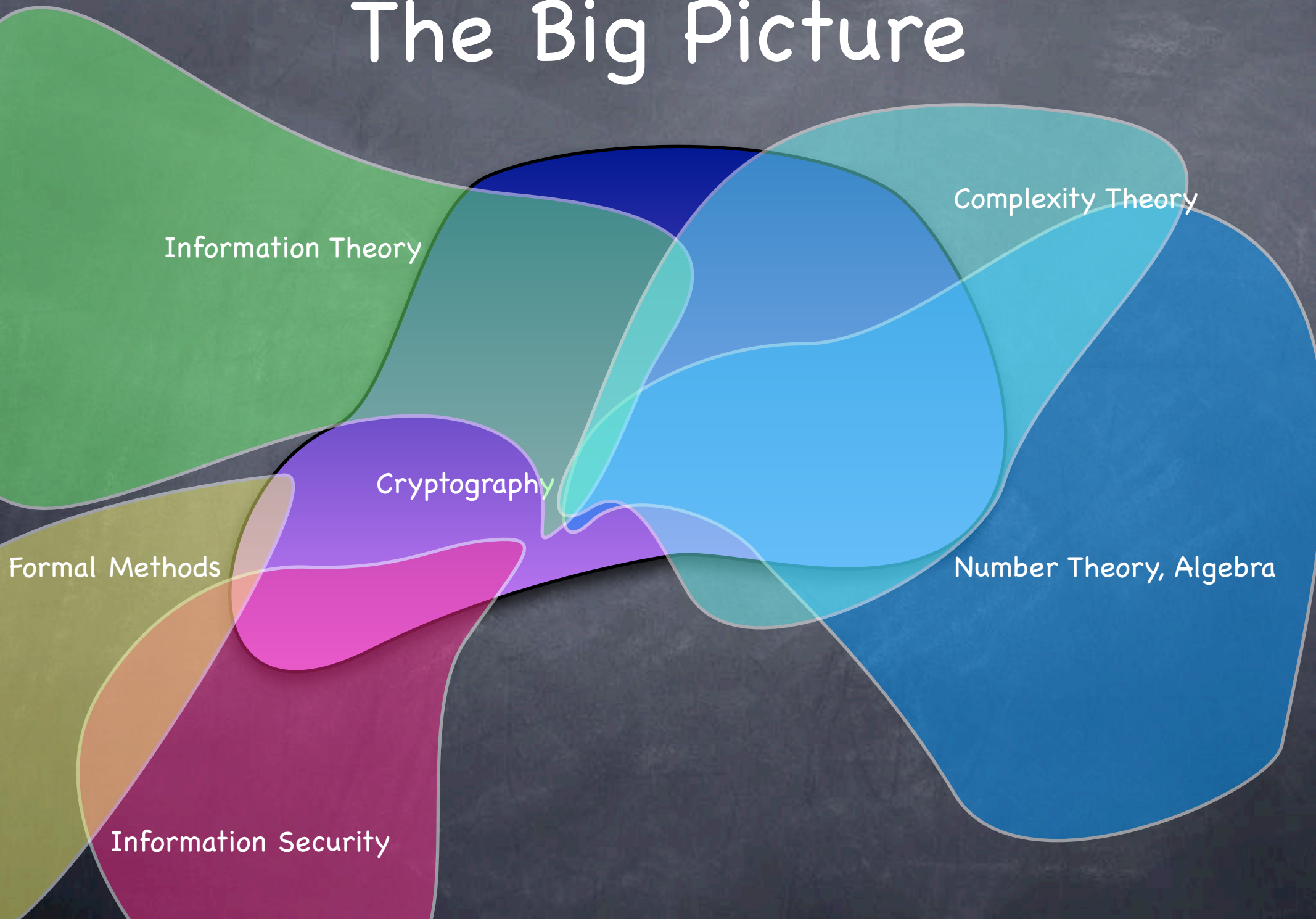

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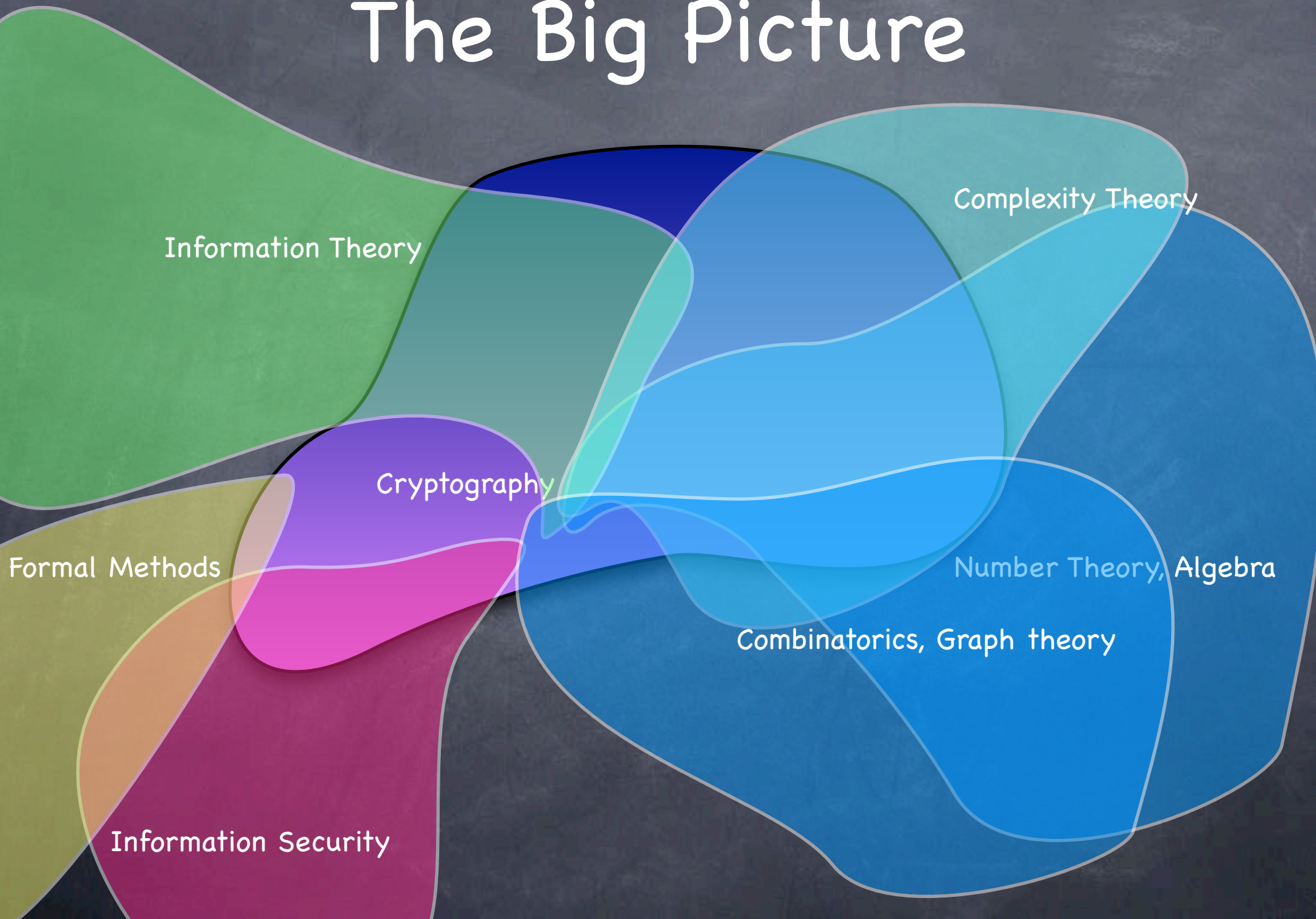

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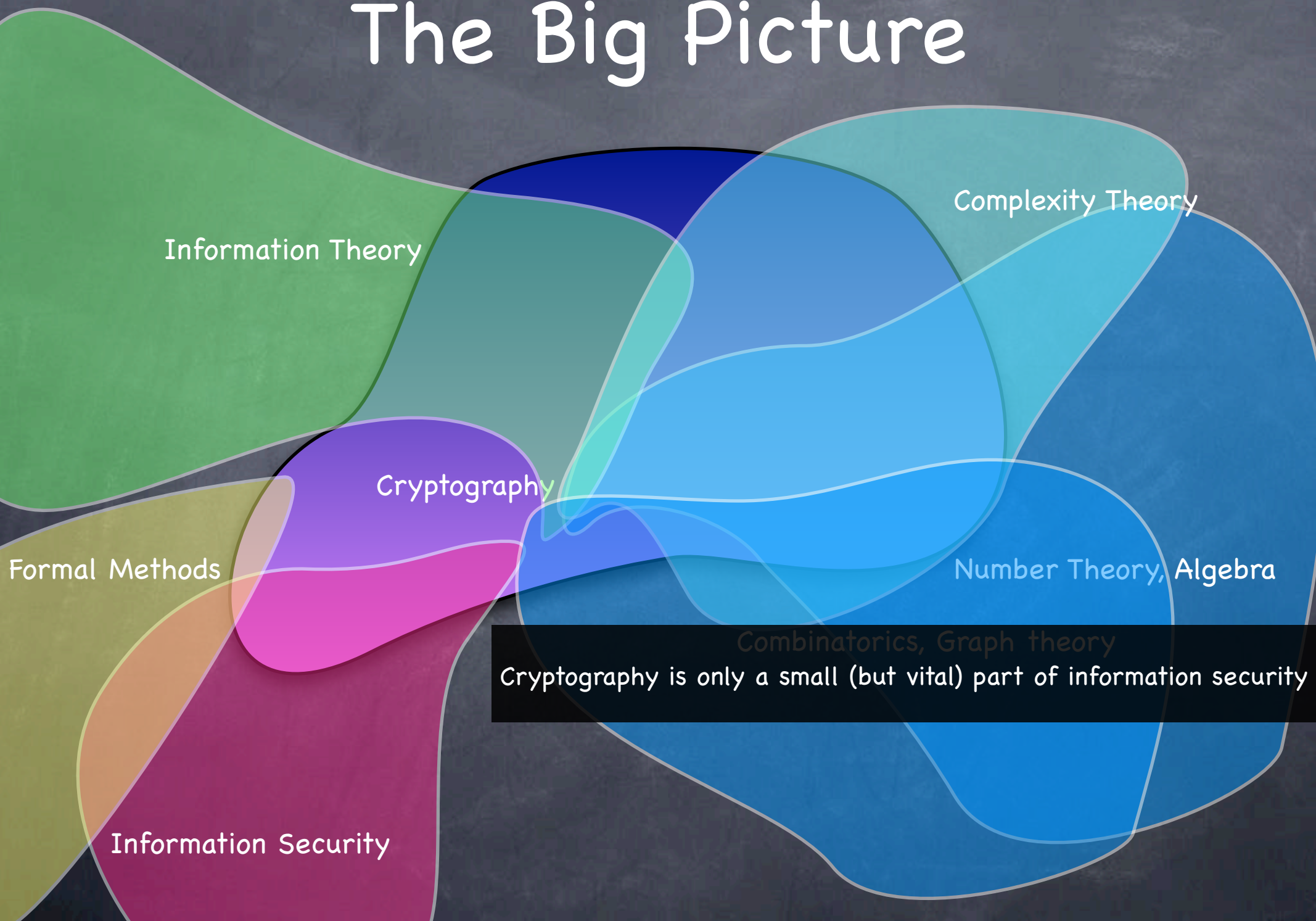

Cryptography is only a small (but vital) part of information security

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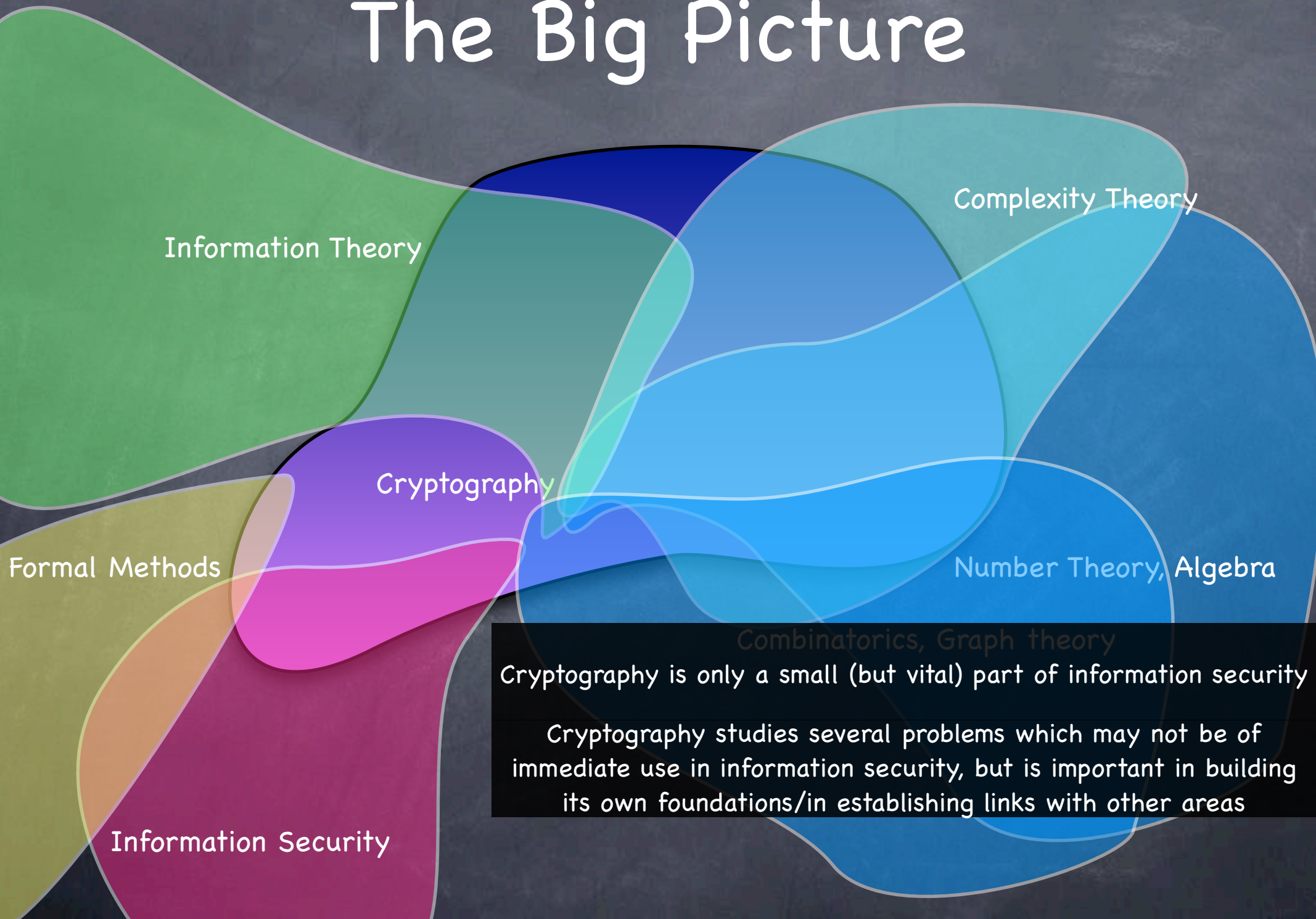

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Cryptography studies several problems which may not be of immediate use in information security, but is important in building its own foundations/in establishing links with other areas

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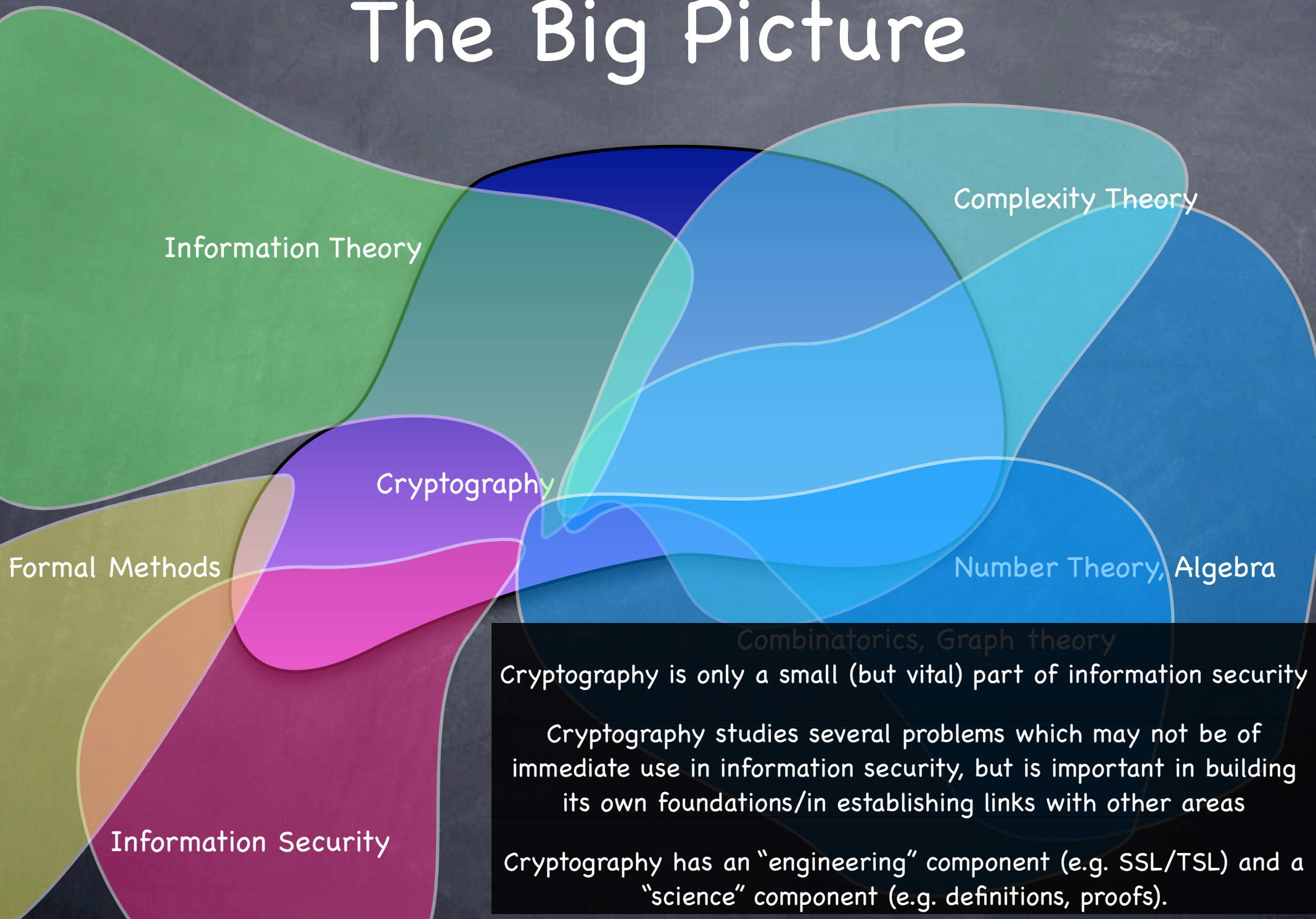

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Cryptography has an "engineering" component (e.g. SSL/TSL) and a "science" component (e.g. definitions, proofs).

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- Can they do it, just by talking to each other (using private channels between every pair of parties)?

Puzzle #2

- Alice and Bob hold secret bits x and y
- Carol wants to learn $x \wedge y$. Alice and Bob are OK with that.
- But they don't want Carol/each other to learn anything else!
  - i.e., Alice should learn nothing about y, nor Bob about x. Carol shouldn't learn anything else about x,y "other than" $x \wedge y$
- Can they do it, just by talking to each other (using private channels between every pair of parties)?