Introduction to Modern Cryptography

Master of Logic 2012

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- me
- pure mathematics at ETH Zurich
- PhD from Aarhus, Denmark
- research: quantum cryptography
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- plays ultimate frisbee

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- switched sides of the table

Outline of the Course

- Historical cryptography & principles of modern cryptography
- perfectly-secret encryption

Outline of the Course II

	secret key	public key
confidentiality	private-key encryption	public-key encryption
authentication	message authentication codes (MAC)	digital signatures

Outline of the Course II

- reduction proofs
- pseudorandomness
- block ciphers: DES, AES

	secret key	public key
confidentiality	private-key encryption	public-key encryption
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Outline of the Course II

- algorithmic number theory
- key distribution, Diffie-Hellmann
- RSA

- reduction proofs
- pseudorandomness
- block ciphers: DES, AES

	secret key	public key
confidentiality	private-key encryption	public-key encryption
authentication	message authentication codes (MAC)	digital signatures

Fun Stuff

- zero-knowledge proofs
- multi-party computation (secret sharing, bit commitment, oblivious transfer)
- electronic voting and auctions
- quantum cryptography
- position-based cryptography
- ...

Questions ?

Introduction

- for centuries, cryptography has been an "art of writing codes and solving codes"
- goal: secret communication
- mainly used by military and intelligence
- "modern cryptography"

Claude Elwood Shannon

1916 - 2001

- Father of Information Theory
- Graduate of MIT
- Bell Labs

- juggling, unicycling, chess
- ultimate machine

Silvio Micali

- MIT
- Foundations of Modern Cryptography

Shafi Goldwasser

Oded Goldreich

- Weizmann Institute

Modern Cryptography

- "scientific study of techniques for securing digital information, transactions and distributed computations"
- crypto is everywhere!

Auguste Kerckhoffs

1835 - 1903

- Dutch linguist and cryptographer
- Kerckhoffs' principle:

"A cryptosystem should be secure even if everything about the system, except the key, is public knowledge"

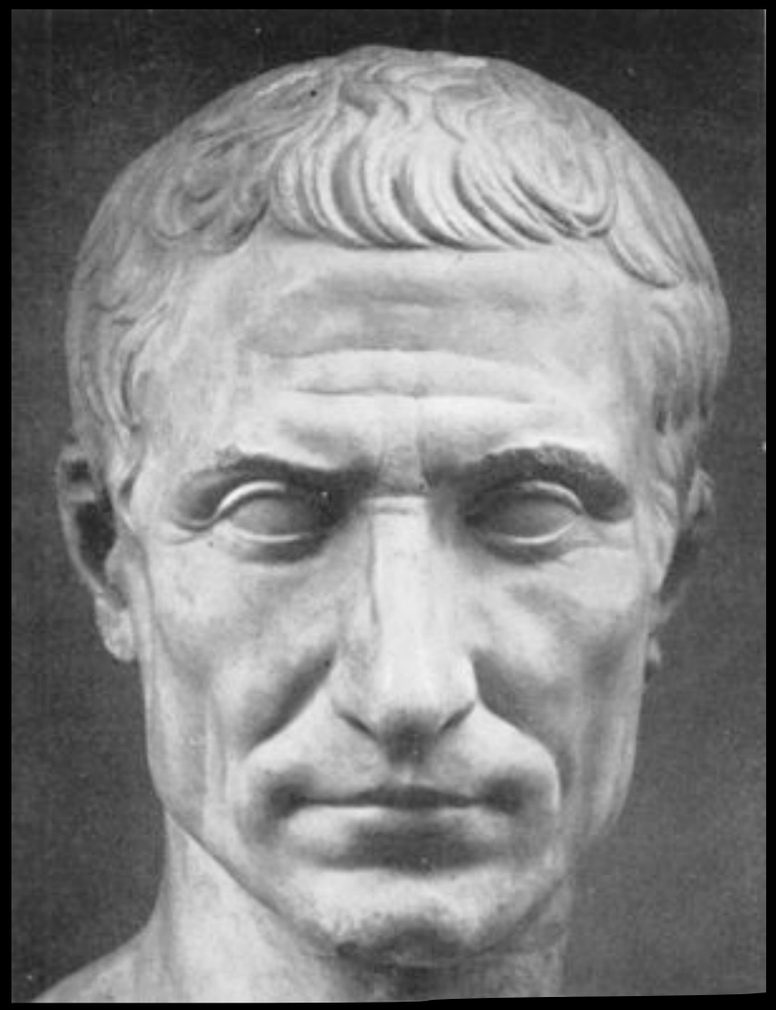
- leader of Volapük movement

AES and SHA competitions

- AES: advanced encryption standard
- SHA: secure hash algorithm
- both determined by a public procedure led by the National Institute for Standards and Technology (NIST)
- SHA-3 zoo

Gaius Julius Caesar

100 BC – 44 BC



- not best known for his cryptographic skills
- Roman general

- suffered from epilepsy, or migraine headache

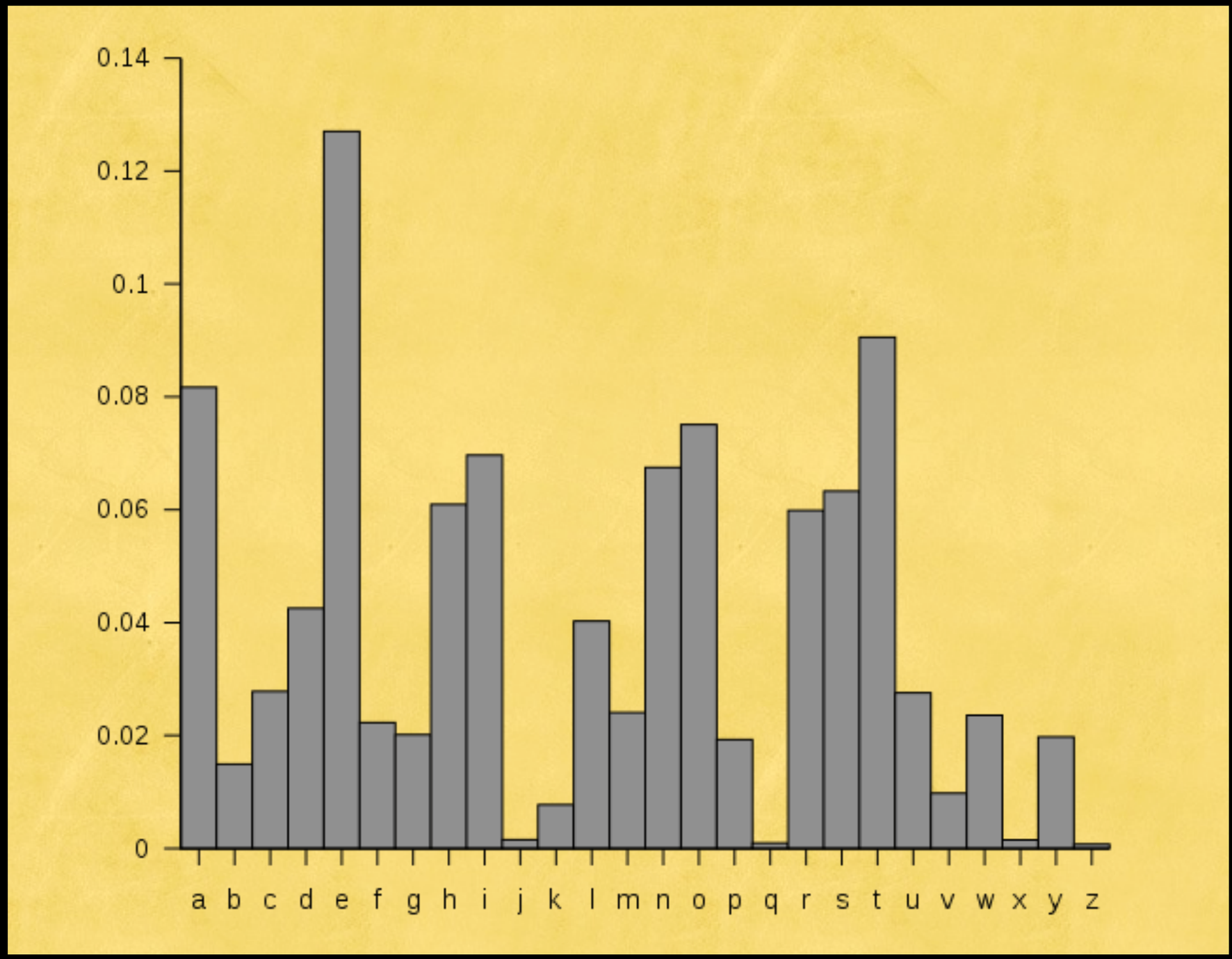
Modular Arithmetic

- Given integers a and $N>1$ we write

$$[a \bmod N] \in \{0,1,2,\ldots,N\text{-}1\}$$

as the remainder of a upon division by N

Frequency analysis



Wikipedia source

Blaise de Vigenère

1523–1596

- diplomat and cryptographer
- Vigenère's cipher

- interested in alchemy

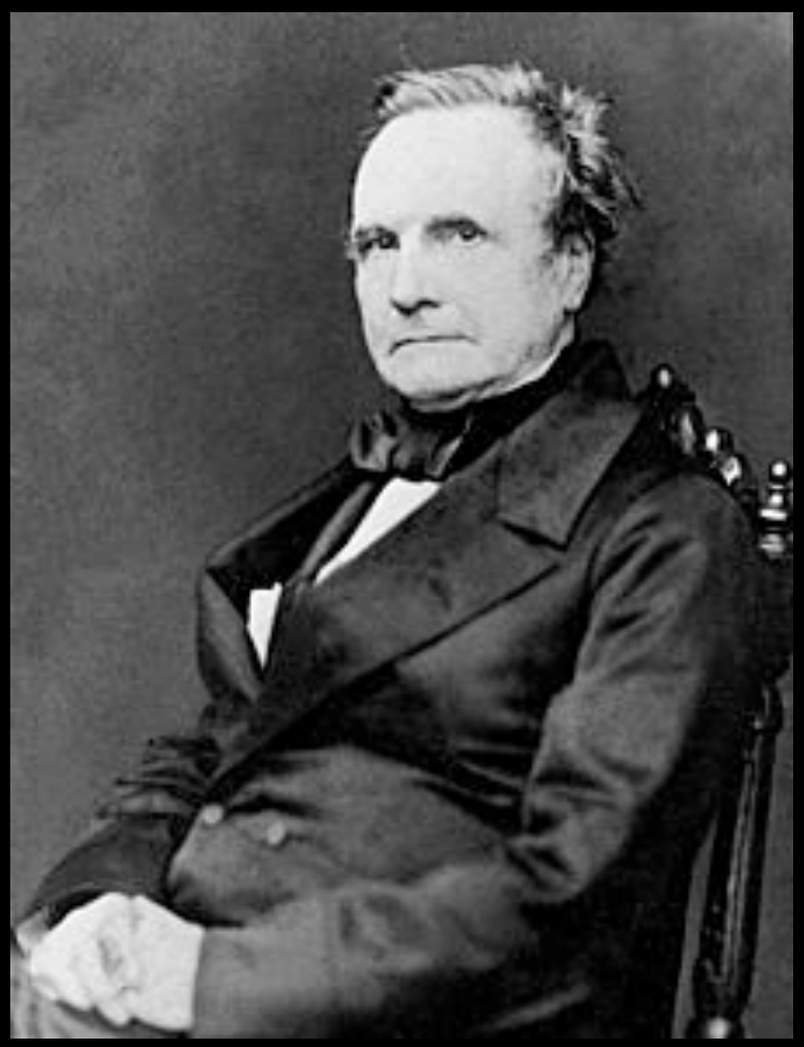
Friedrich Kasiski

1805 – 1881

- Preussian infantry officer
- cryptographer and archeologist

Charles Babbage

1791 – 1871



- mathematician, philosopher, inventor and mechanical engineer
- father of the computer
- designed the "difference machine" and "Analytical Engine"

- counted broken window panes
- hated organ grinders

Jonathan Katz

Yehuda Lindell

- 3 Basic Principles of Modern Cryptography

1. Formulation of Exact Definitions

- "a cryptographic scheme is secure if no adversary of a specified power can achieve a specified break"
  example: encryption
- mathematical definitions vs the real world
  example: power-usage attacks
- cryptographers face a similar problem as Turing: "Am I modeling the right thing?"

2. Reliance on Precise Assumptions

- unconditional security is often impractical
  (unfortunate state of computational complexity)
- validation of assumptions (independent of cryptography)
  example: factoring
- allows to compare crypto schemes

3. Rigorous Proofs of Security

- Intuition is not good enough. History knows countless examples of broken schemes
- bugs vs security holes
  software users vs adversaries
- reduction proofs: Given that Assumption X is true, Construction Y is secure.
  Any adversary breaking Construction Y can be used as subroutine to violate Assumption X.