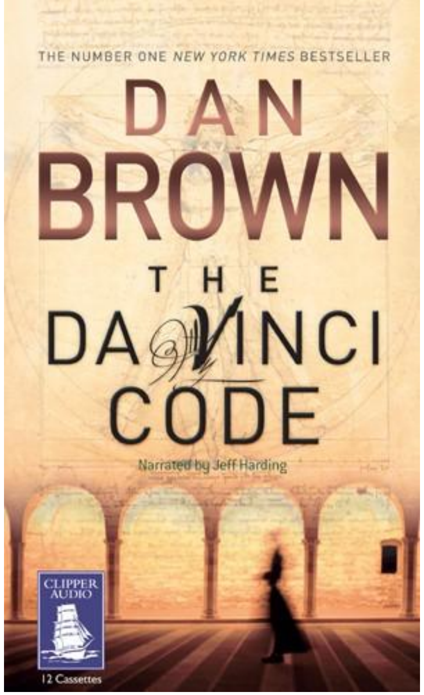
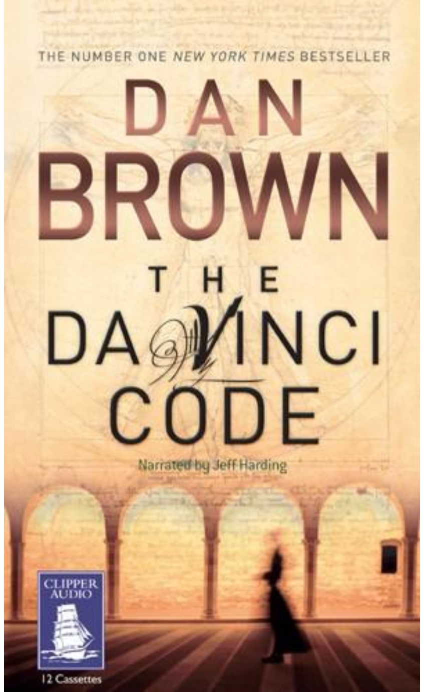
Cryptography and The Da Vinci Code



Prof. Keith Martin

Information Security Group
Royal Holloway
University of London

(OR… what Sophie Neveu did NOT seem to learn when she studied at Royal Holloway)



"**There's an easier way**," Sophie said, taking the pen from Teabing.

"**It works for all reflectional substitution ciphers, including the Atbash. A little trick I learned at the Royal Holloway**."

Sophie wrote the first half of the alphabet from left to right and then, beneath it, wrote the second half, right to left.

"**Cryptanalysts call it the fold-over. Half as complicated. Twice as clean**."

Teabing eyed her handiwork and chuckled.: "**Right you are. Glad to see those boys at the Holloway are doing their job**."

What is cryptography ?

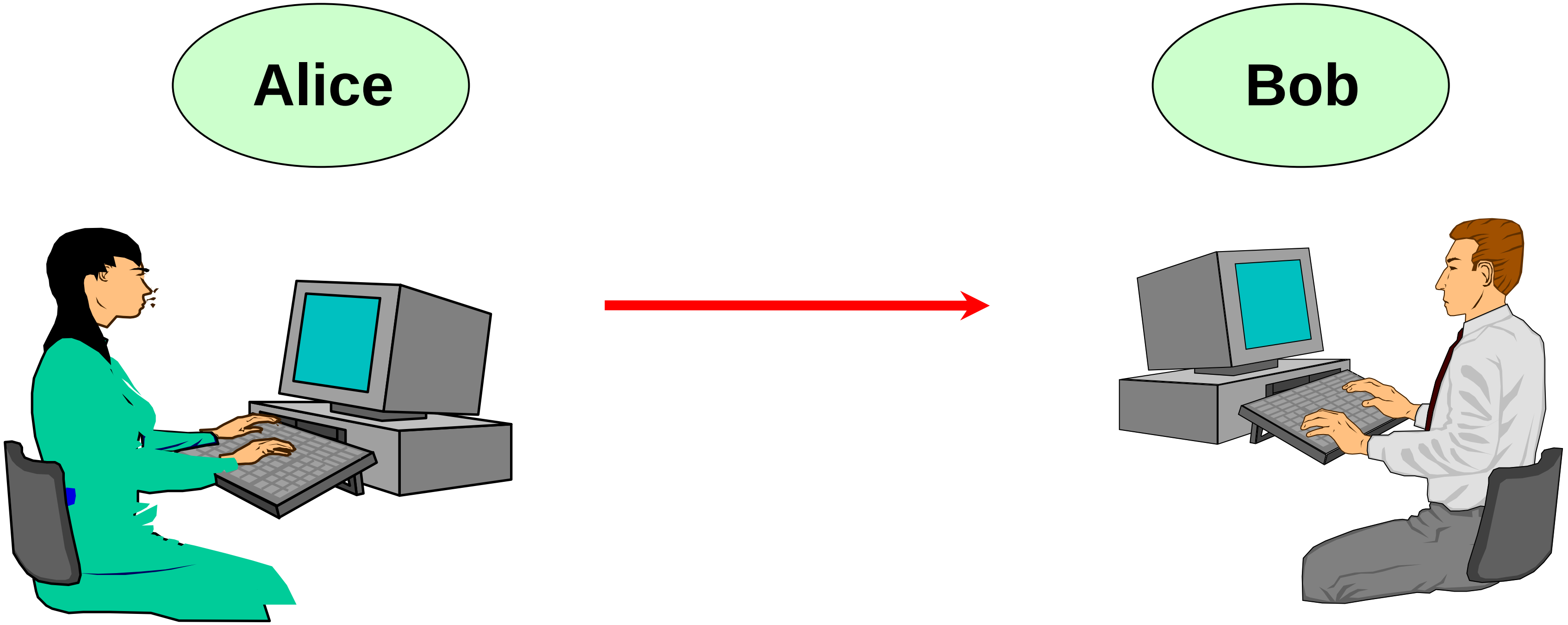
Have you used cryptography:

on a daily basis?

on a weekly basis?

occasionally?

A simple scenario



Risks to information

- Passive attacks
  - unauthorised access to information
- Active attacks
  - Unauthorised alteration
  - Unauthorised deletion
  - Unauthorised transmission
  - Falsification of origin of information
  - Unauthorised prevention of access to information

Cryptography: the toolkit

Cryptography provides a mathematical toolkit of techniques that can be called upon in order to implement the security services required for any application.

Cryptographic **primitives**

Identification schemes

Block ciphers

Digital signatures

Stream ciphers

Message authentication codes

Bit commitment

Hash functions

One-way functions

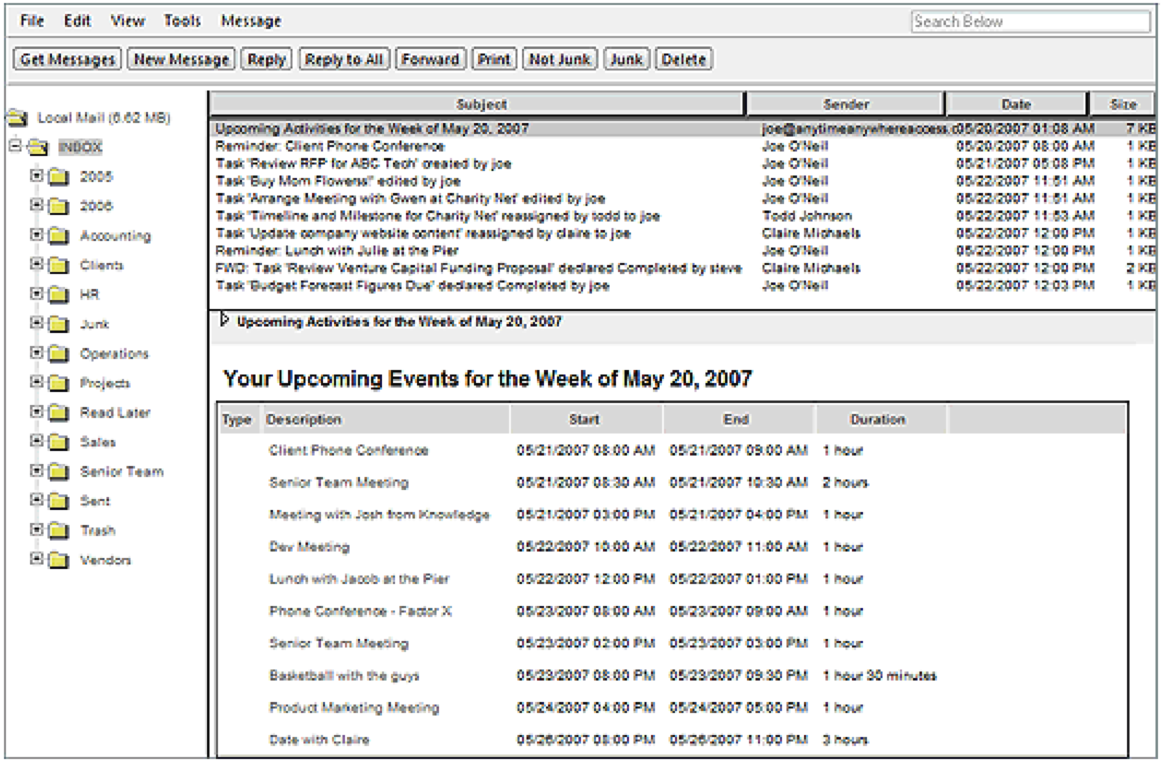
Secret sharing schemes

Zero-knowledge protocols

The need for confidentiality

Sending a letter to a friend

Sending an email to a friend



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▷ **Upcoming Activities for the Week of May 20, 2007**

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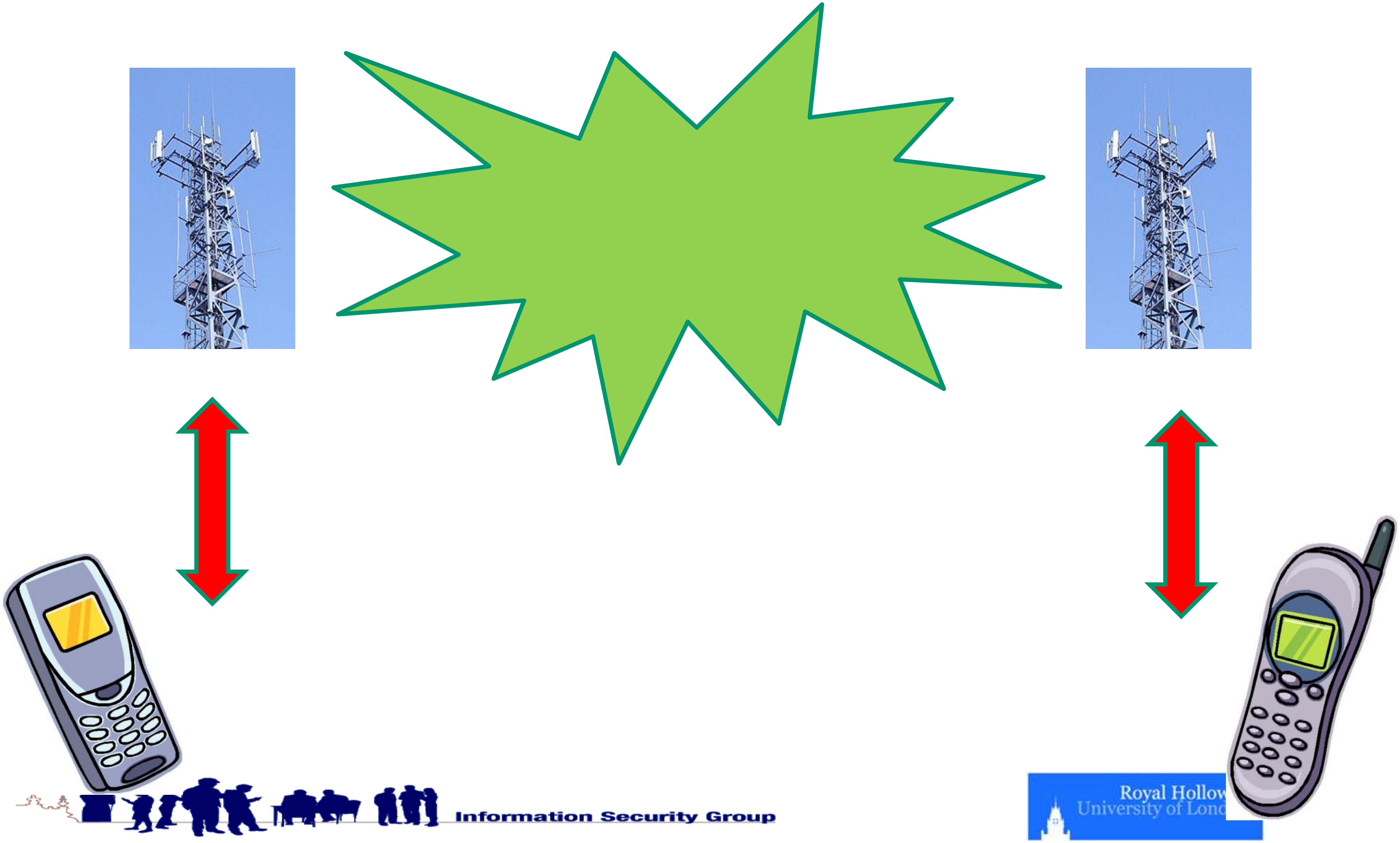
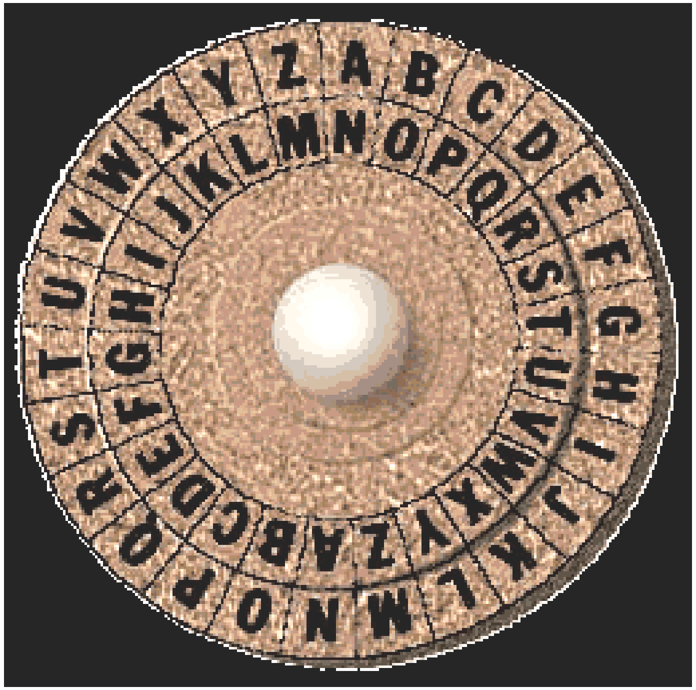
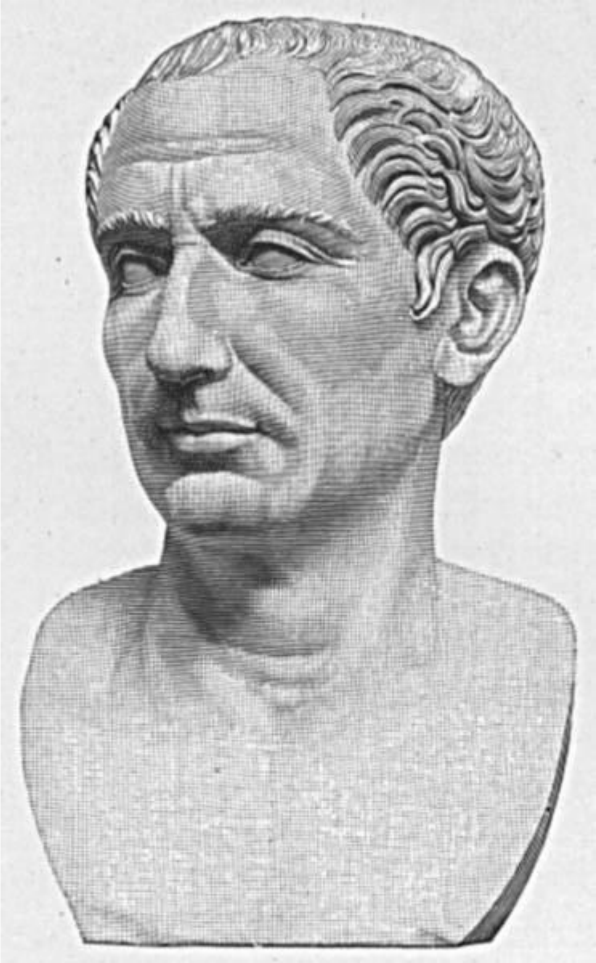
	Date with Claire	05/26/2007 08:00 PM	05/26/2007 11:00 PM	3 hours

Calling a friend on a mobile



The Caesar Cipher


A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
N O P Q R S T U V W X Y Z A B C D E F G H I J K L M



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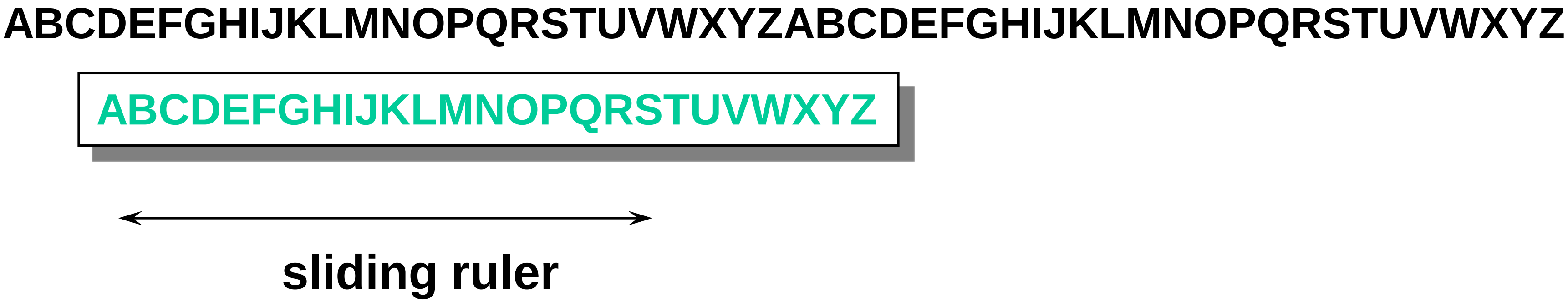

ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

sliding ruler

Caesar Cipher Example

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C													

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E

A	X	E

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E
C		

A	X	E

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E
C	E	

A	X	E

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E
C	E	G

A	X	E

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E
C	E	G

A	X	E
C		

Caesar Cipher Example

Key shift C

A	B	C	D	E	F	G	H	I	J	…	X	Y	Z
C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E
C	E	G

A	X	E
C	Z	

Caesar Cipher Example

Key shift C

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C	D	E	F	G	H	I	J	K	L	…	Z	A	B

A	C	E
C	E	G

A	X	E
C	Z	G

Caesar Cipher Challenges

What creature hops about and explodes near a naked flame?

MX MW E KEWLSTTIV (key shift E)

Which creature says "baa" and fights at sea?

ZNOY OY G HGZZRKYNKKV (key shift G)

Which animal runs very fast and keeps you warm?

AL AK S OAFVUZWWLSZ (key shift S)

Simple Substitution Cipher

a	b	c	d	e	f	g	h	i	j	k	l	m
D	I	Q	M	T	B	Z	S	Y	K	V	O	F
n	o	p	q	r	s	t	u	v	w	x	y	z
E	R	J	A	U	W	P	X	H	L	C	N	G

Keyspace of the Substitution Cipher

The key space of the Simple Substitution Cipher is approximately 4 x 10^{26}, that is:

400 000 000 000 000 000 000 000 000

Just how big is that?

There are an estimated 10 sextillion (that's 10^{22}) stars in our universe. That means that the Simple Substitution Cipher has about 40 000 **times** the number of keys than there are stars in our universe.

The key space of DES is somewhere between 10^{16} and 10^{17}. That's a much smaller number – it's only about 100 000 times the number of stars in our galaxy!

Substitution Cipher Examples

Decrypt the following ciphertexts

1 **B TO T OTA**

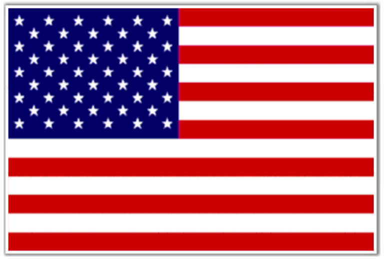
2 **XAV**

3 **VBDDQD**

4 **VBDDQD** **(given that the plaintext is the name of a country)**

5 **ABXAZ O OAZ TCYE TE F CEOE UCZXT**

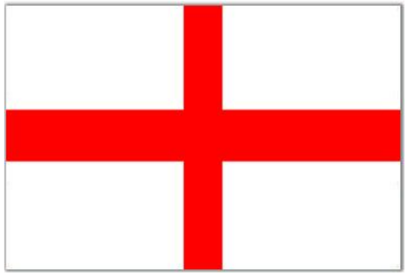
World Cup 2010 Special Examples



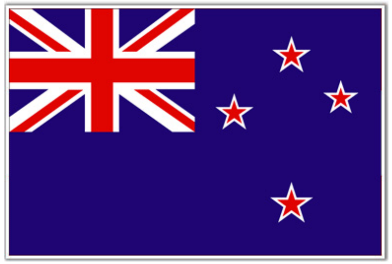
TBZ

GYZICEBCG

HPSNRPV

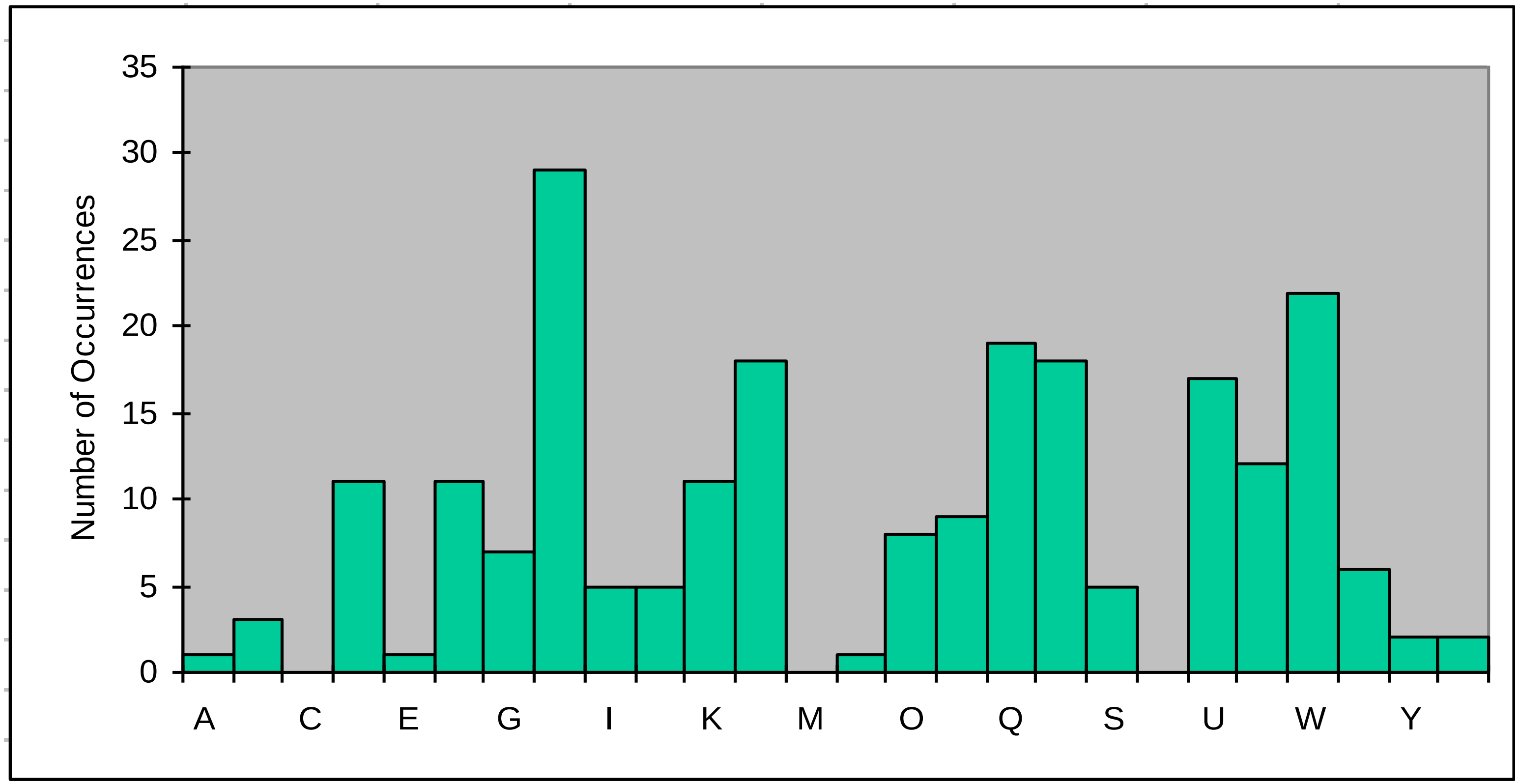


OQC UQFKFOX



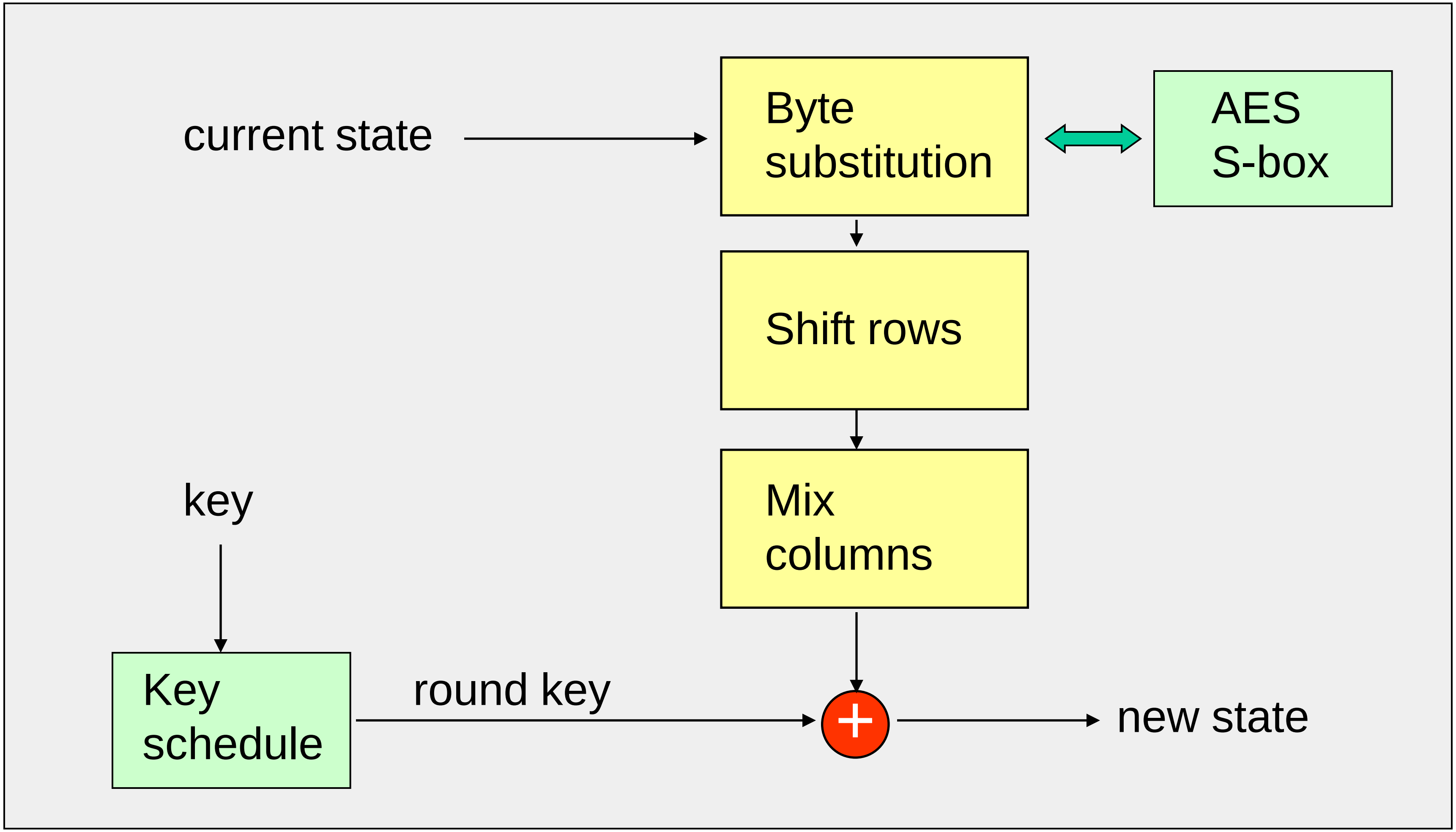
YEVENLEM

Substitution Cipher Histogram

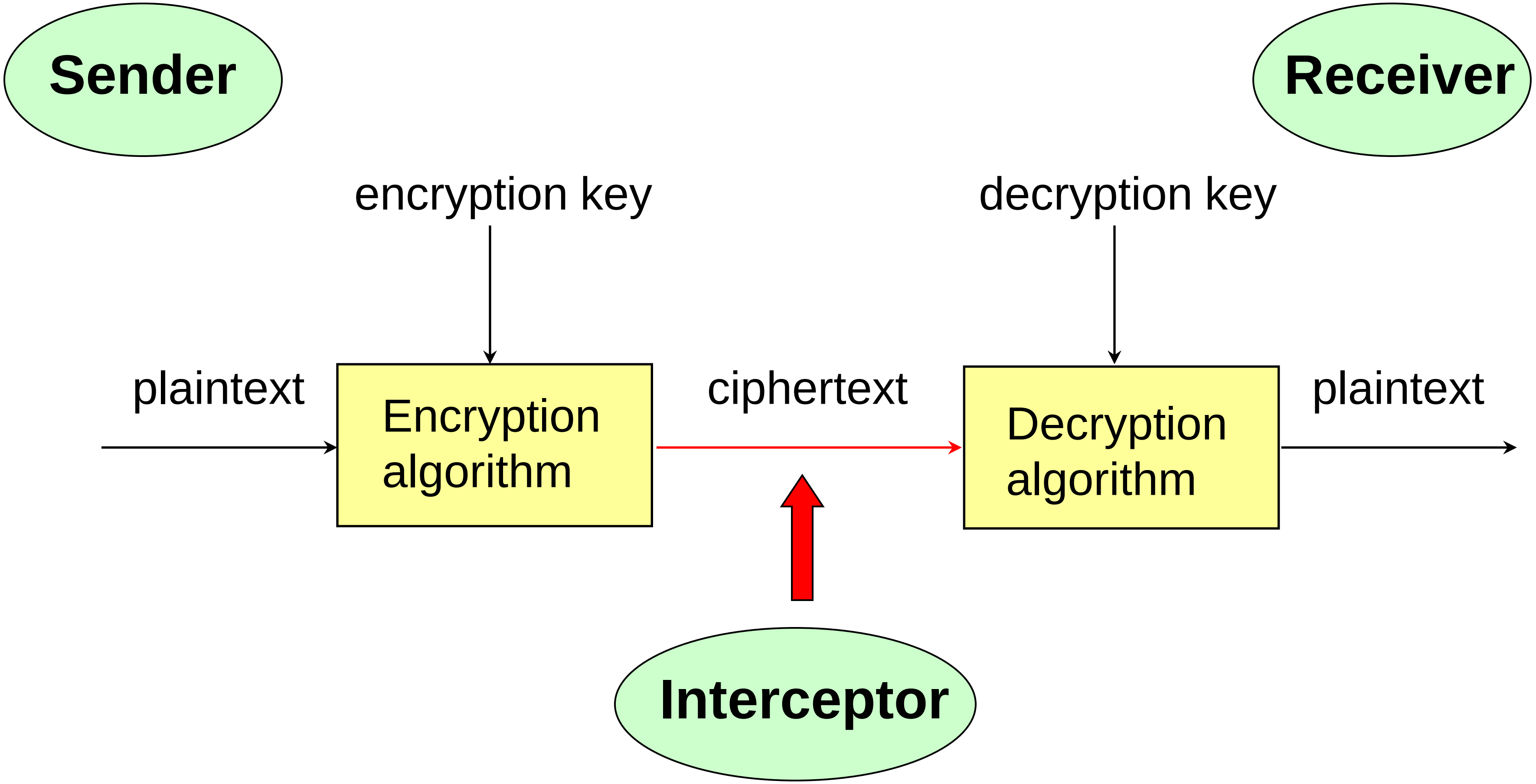


A histogram showing the relative frequencies of the letters in a cryptogram that was obtained by using a simple substitution cipher.

Advanced Encryption Standard



A cryptosystem



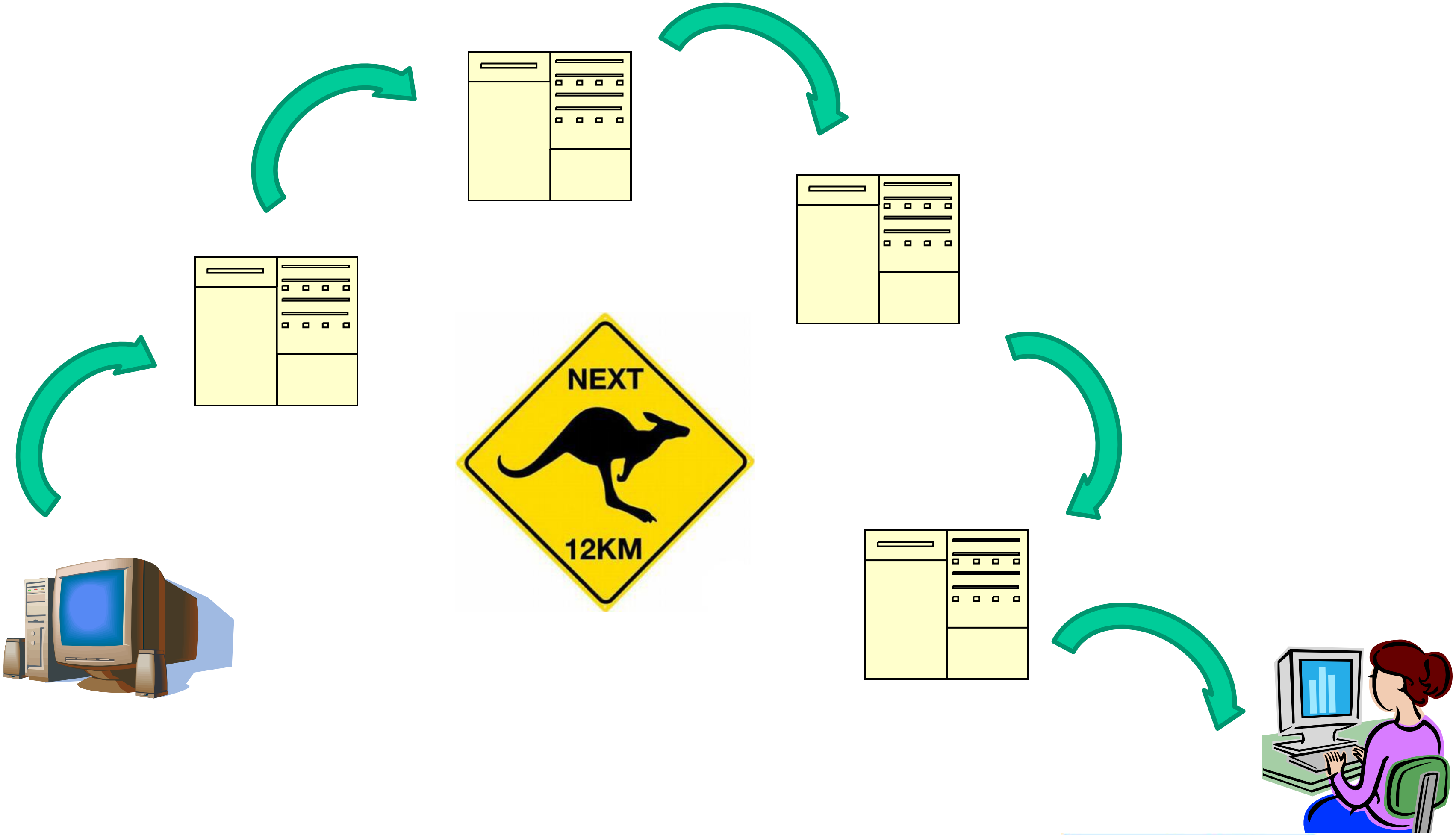
The need for data integrity

Two things that can go wrong...

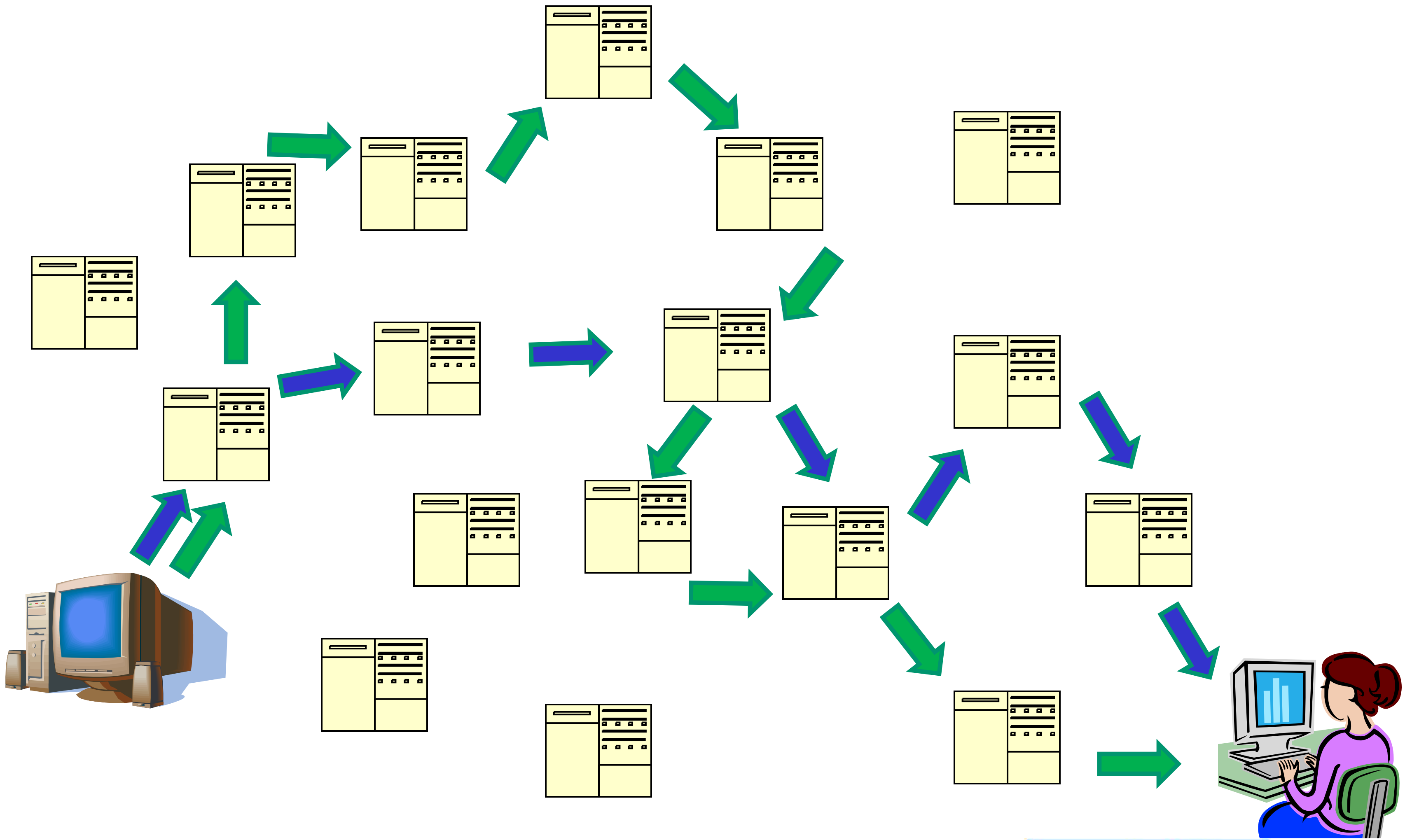
Accidental errors

Deliberate errors

How the Internet works (part 1)



How the Internet works (part 2)



International Morse Code

- 1 dash = 3 dots.
- The space between parts of the same letter = 1 dot.
- The space between letters = 3 dots.
- The space between words = 7 dots.

A	● ▬
B	▬ ● ● ●
C	▬ ● ▬ ●
D	▬ ● ●
E	●
F	● ● ▬ ●
G	▬ ▬ ●
H	● ● ● ●
I	● ●
J	● ▬ ▬ ▬
K	▬ ● ▬
L	● ▬ ● ●
M	▬ ▬
N	▬ ●
O	▬ ▬ ▬
P	● ▬ ▬ ●
Q	▬ ▬ ● ▬
R	● ▬ ●
S	● ● ●
T	▬
U	● ● ▬
V	● ● ● ▬
W	● ▬ ▬
X	▬ ● ● ▬
Y	▬ ● ▬ ▬
Z	▬ ▬ ● ●
.	● ▬ ● ▬ ● ▬
,	▬ ▬ ● ● ▬ ▬
?	● ● ▬ ▬ ● ●
/	▬ ● ● ▬ ●
@	● ▬ ▬ ● ▬ ●
1	● ▬ ▬ ▬ ▬
2	● ● ▬ ▬ ▬
3	● ● ● ▬ ▬
4	● ● ● ● ▬
5	● ● ● ● ●
6	▬ ● ● ● ●
7	▬ ▬ ● ● ●
8	▬ ▬ ▬ ● ●
9	▬ ▬ ▬ ▬ ●
0	▬ ▬ ▬ ▬ ▬

Morse Code Example

0010	01	1000	00	111

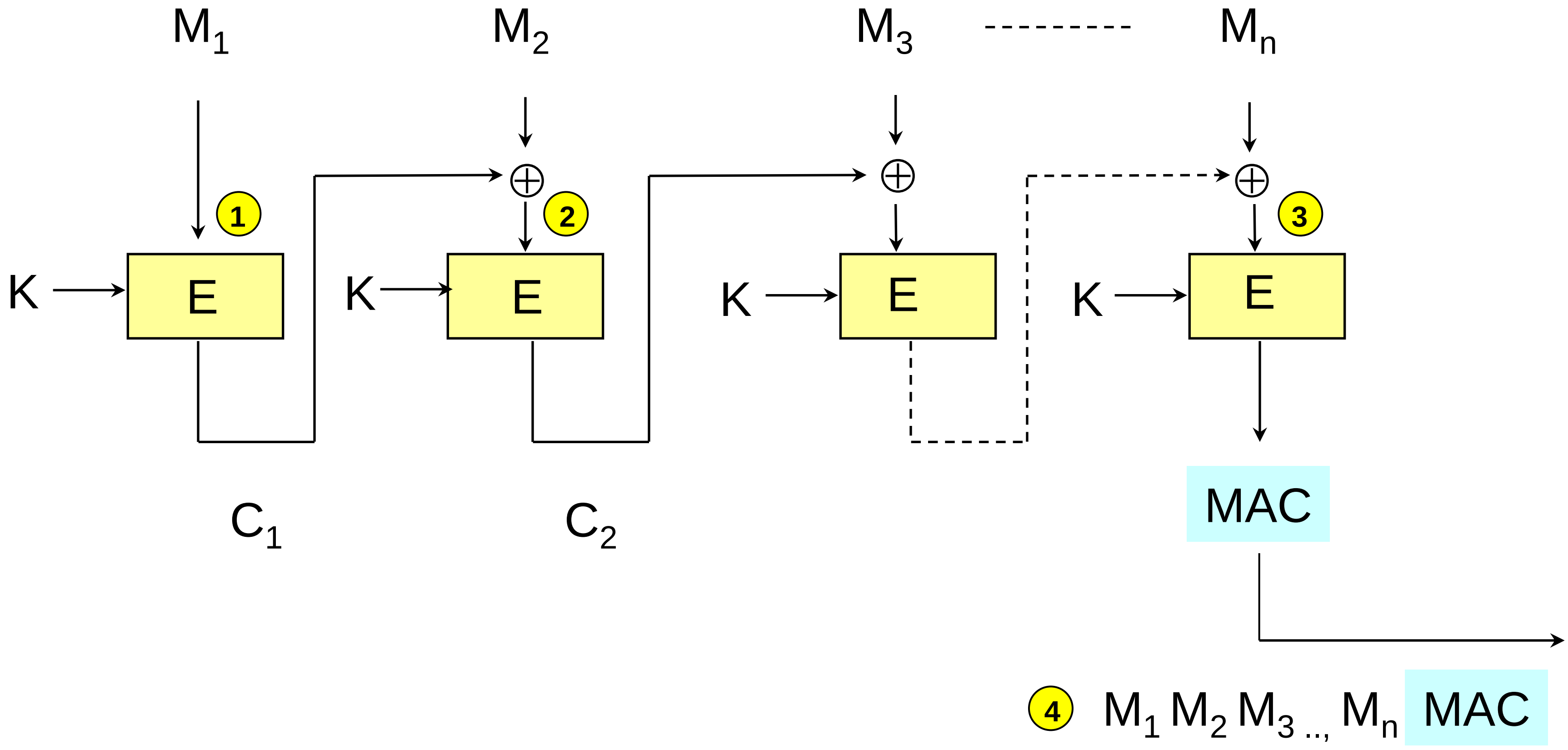
The ISBN number

$$x_{10} \equiv 11 - (10x_1 + 9x_2 + 8x_3 + 7x_4 + 6x_5 + 5x_6 + 4x_7 + 3x_8 + 2x_9) \bmod 11$$

Deliberate errors

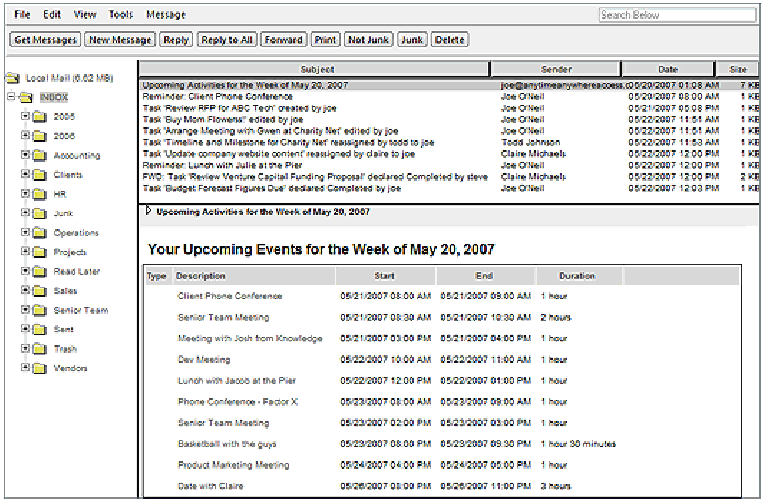
CBC-MAC

(Padded) message divided into blocks



The need for authentication

A problem with email



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Can you be sure that an email from a friend is really from your friend?

A need for authentication!

Types of entity authentication

The most common methods use (a combination of):

- **something that you have**
- **something that you are**
- **something that you know**

Passwords

Choose a password....

PASSWORD1

ABCDEFG

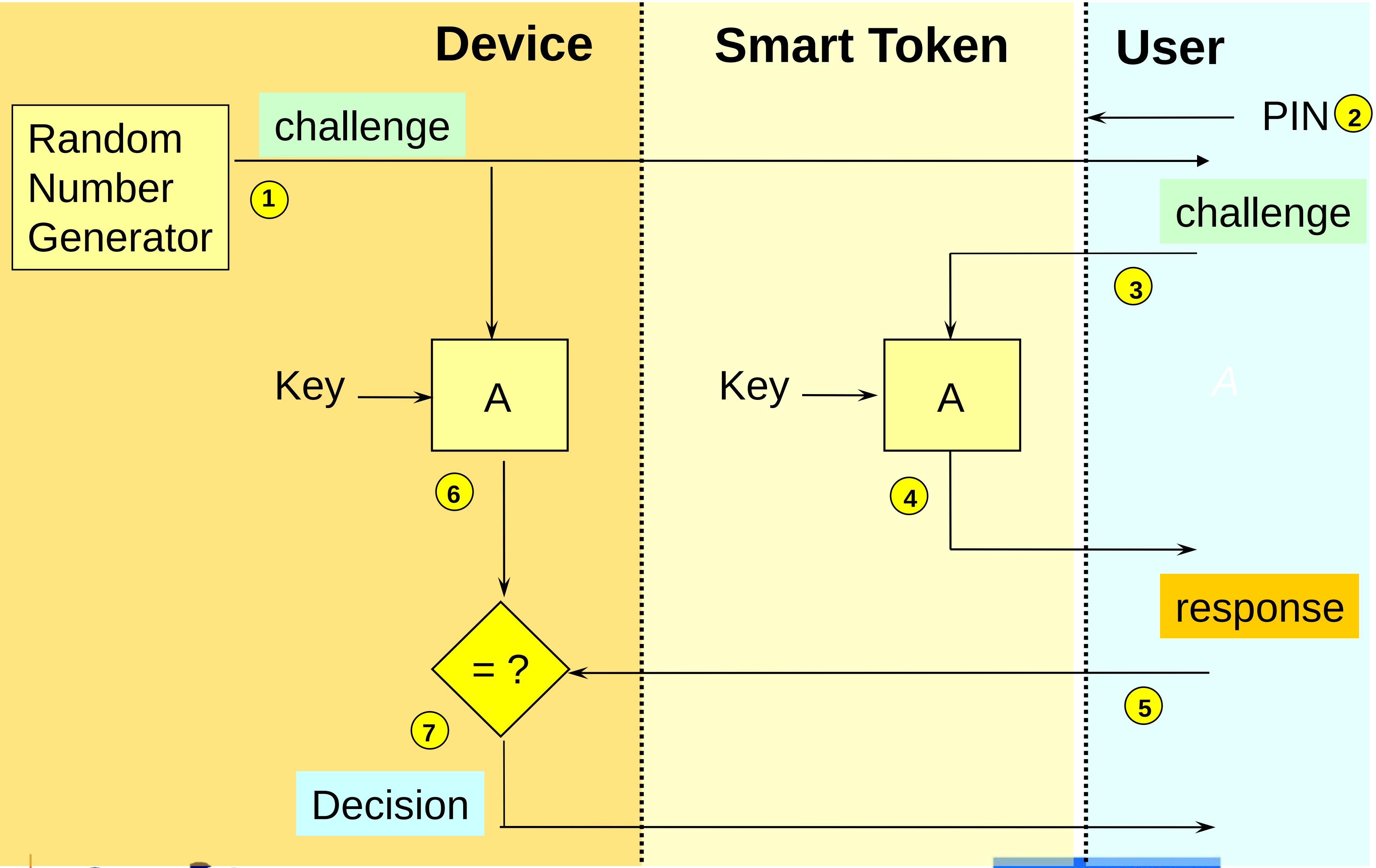
WILLIAMKATE

STATION778

MARSBAR

CV8**G9Pa2

One-time password mechanisms



Real world applications need

Confidentiality

Data Integrity

Authentication

...to varying degrees

So…
what did
Sophie Neveu learn
at Royal Holloway ?

Atbash Cipher

a	b	c	d	e	f	g	h	i	j	k	l	m
Z	Y	X	W	V	U	T	S	R	Q	P	O	N
n	o	p	q	r	s	t	u	v	w	x	y	z
M	L	K	J	I	H	G	F	E	D	C	B	A

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Highly recommended

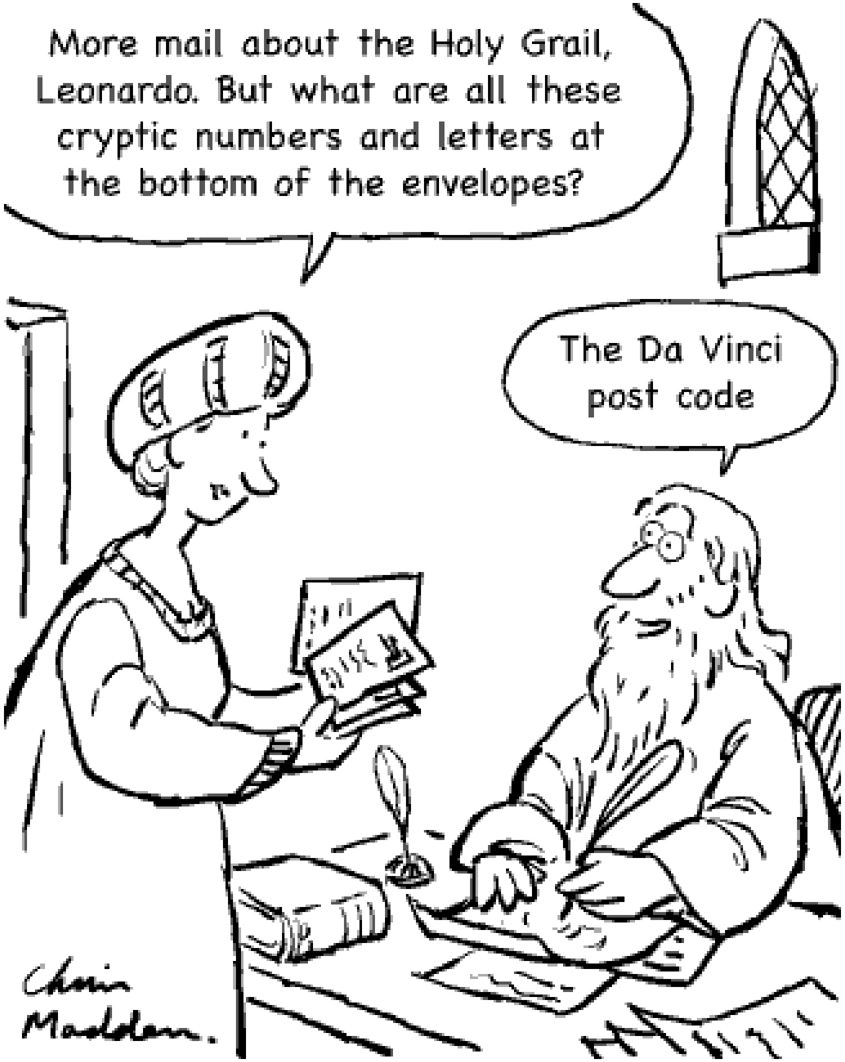
CrypTool 1.4.10

http://www.cryptool.org/

Some bed-time reading

- F. Piper and S. Murphy, **Cryptography: A Very Short Introduction**, Oxford University Press (2002).
- H.X. Mel and D. Baker, **Cryptography Decrypted**, Addison-Wesley (2001).
- D.R. Stinson, **Cryptography: Theory and Practice**, 3rd Edition, Chapman & Hall/CRC Press (2006).
- S. Levy, **Crypto**, Penguin Books (2000).
- S. Singh, **The Code Book**, Fourth Estate (1999).
- N. Ferguson and B. Schneier **Practical Cryptography**, Wiley (2003).

Thank You


More mail about the Holy Grail, Leonardo. But what are all these cryptic numbers and letters at the bottom of the envelopes?
The Da Vinci post code
Chris Madden.