CSE 484 (Winter 2011)

Introduction to Cryptography (Continued)

Tadayoshi Kohno

Thanks to Dan Boneh, Dieter Gollmann, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

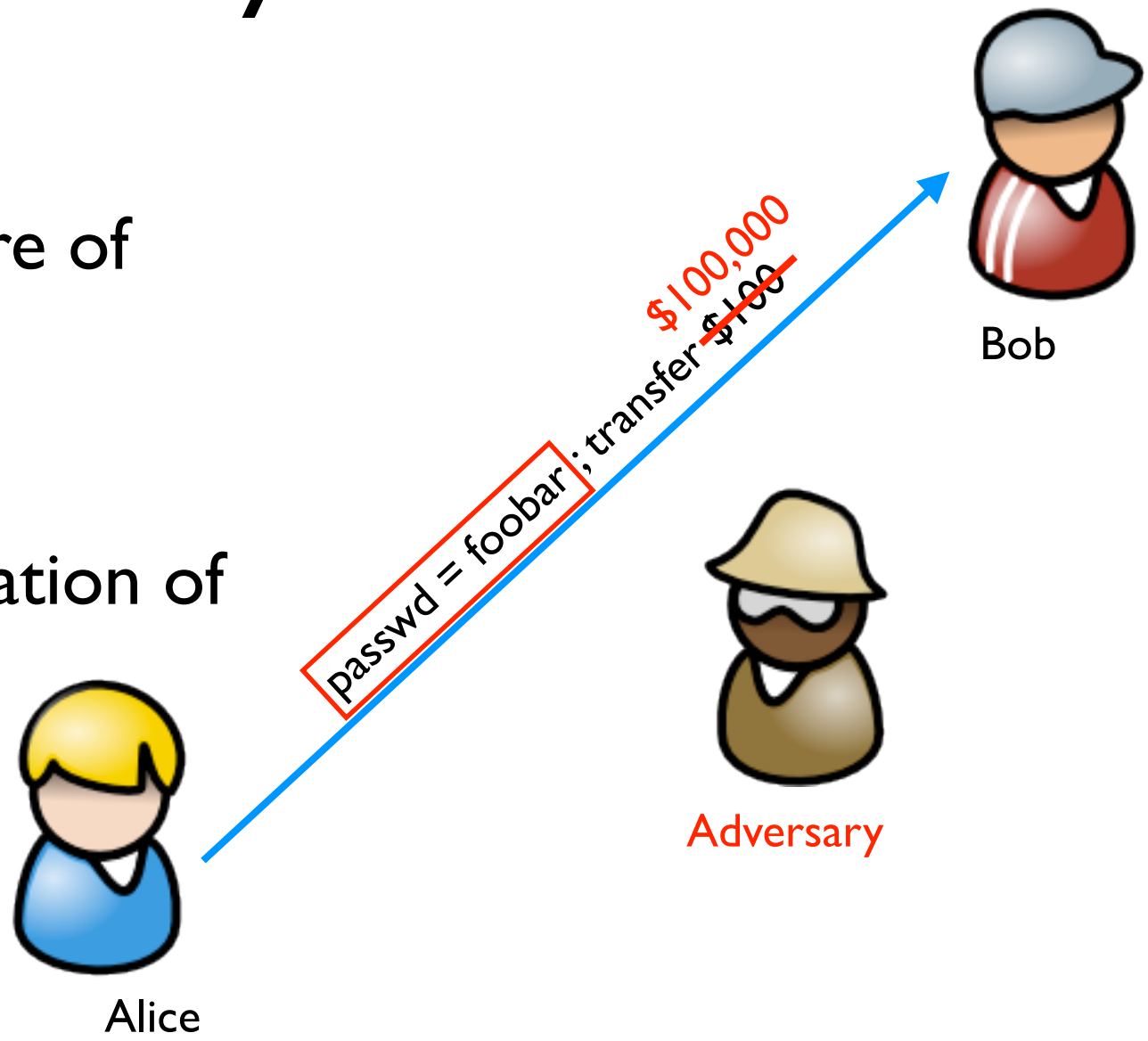
Goals for Today

- Cryptography Overview (Continued)
  - Begin with quick review from last time
  - Then some more overview
- Brief History
- Under the hood: Symmetric cryptography

Common Communication Security Goals

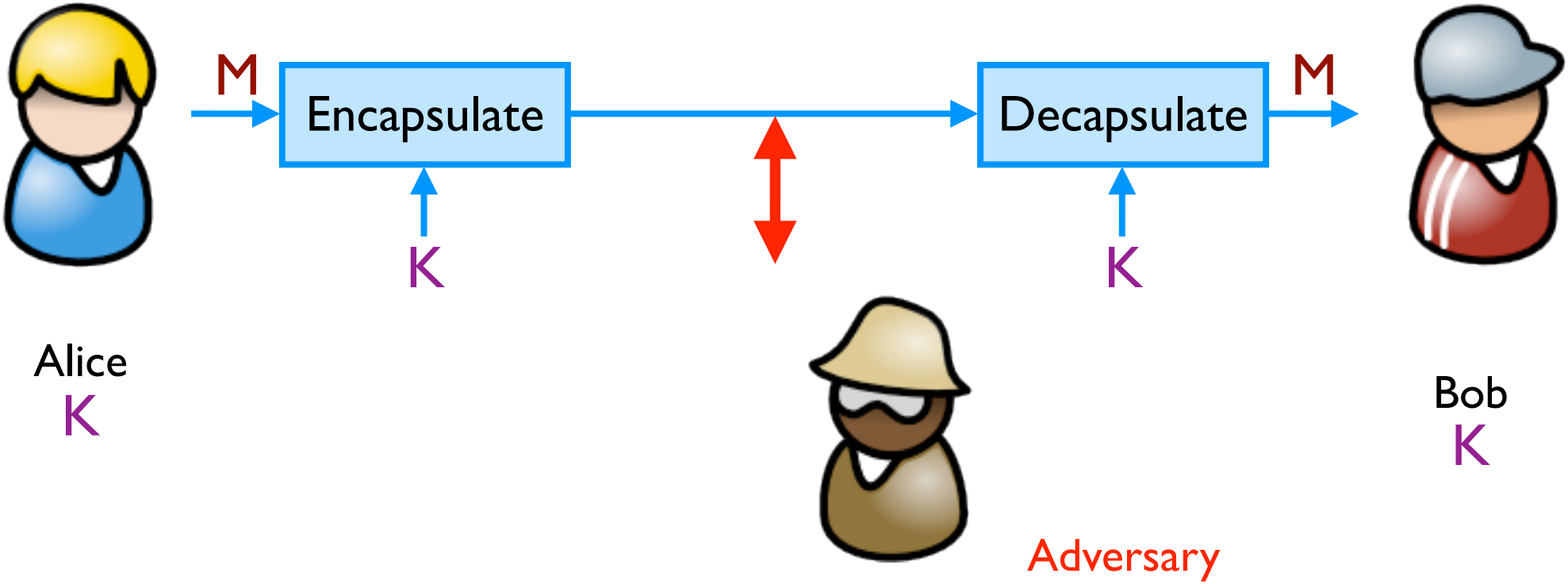
Privacy of data
Prevent exposure of information

Integrity of data
Prevent modification of information



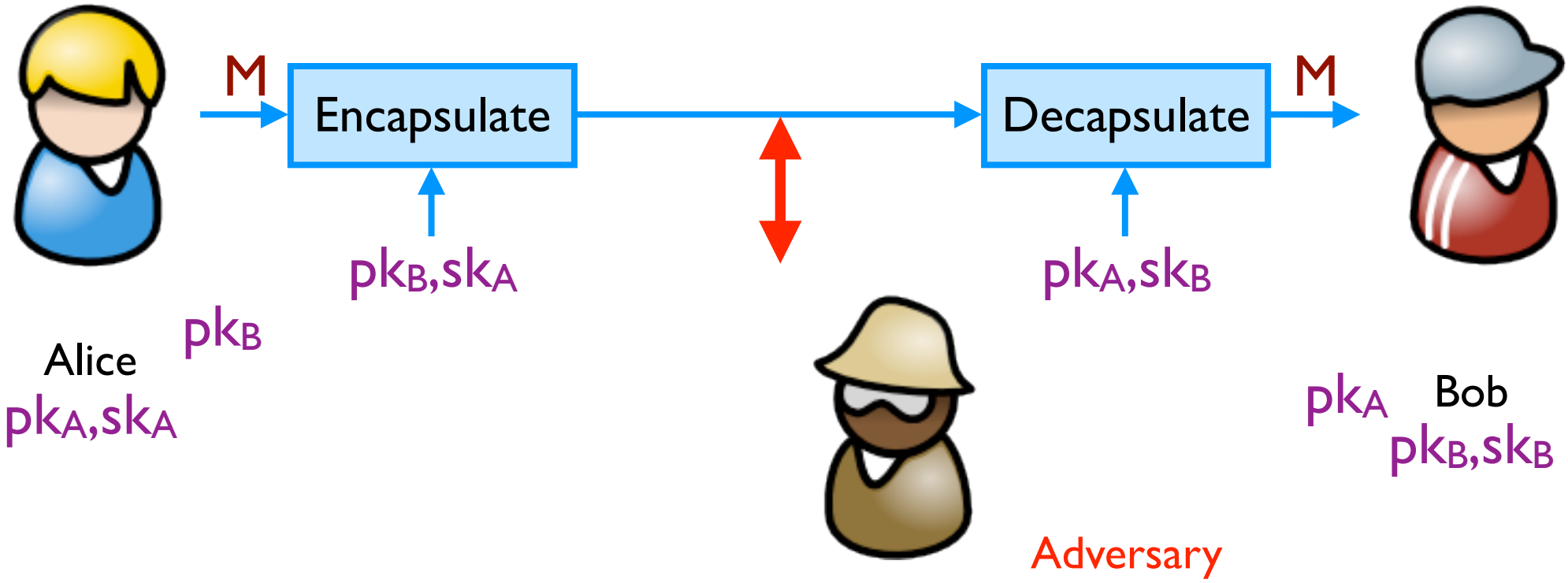
Symmetric Setting

Both communicating parties have access to a shared random string K, called the key.



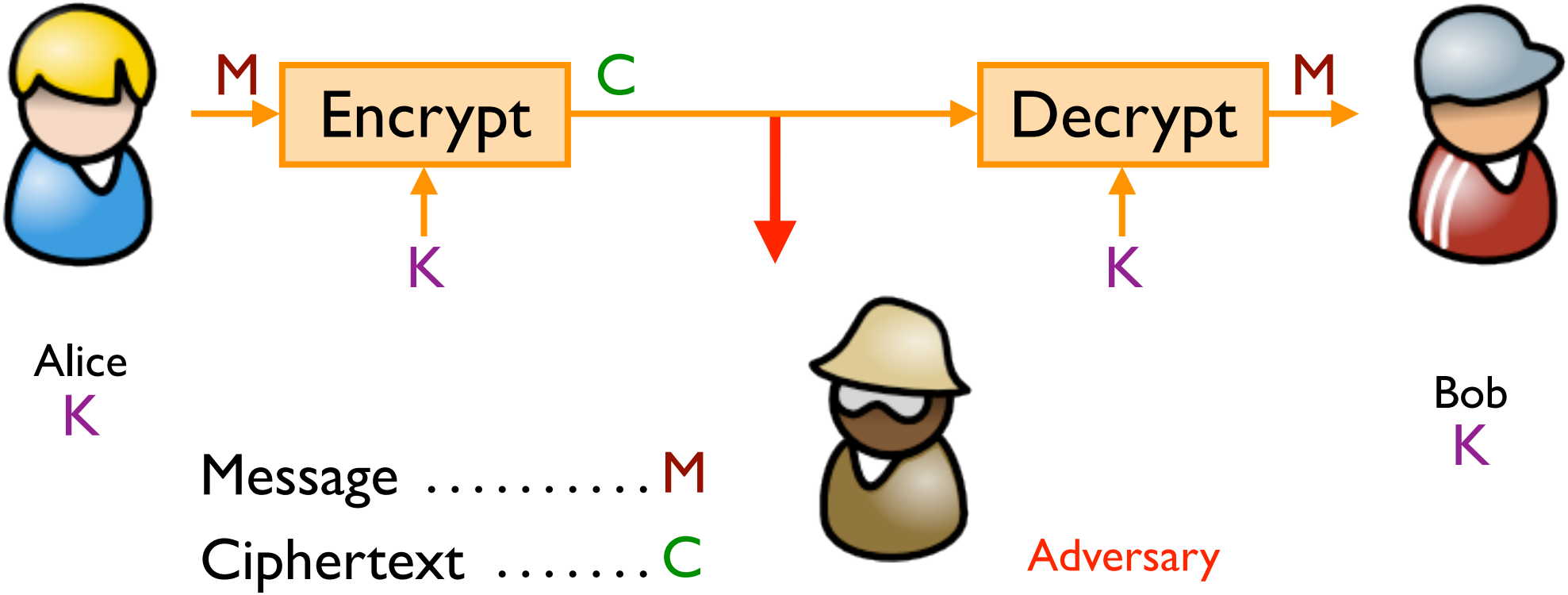
Asymmetric Setting

Each party creates a public key pk and a secret key sk.



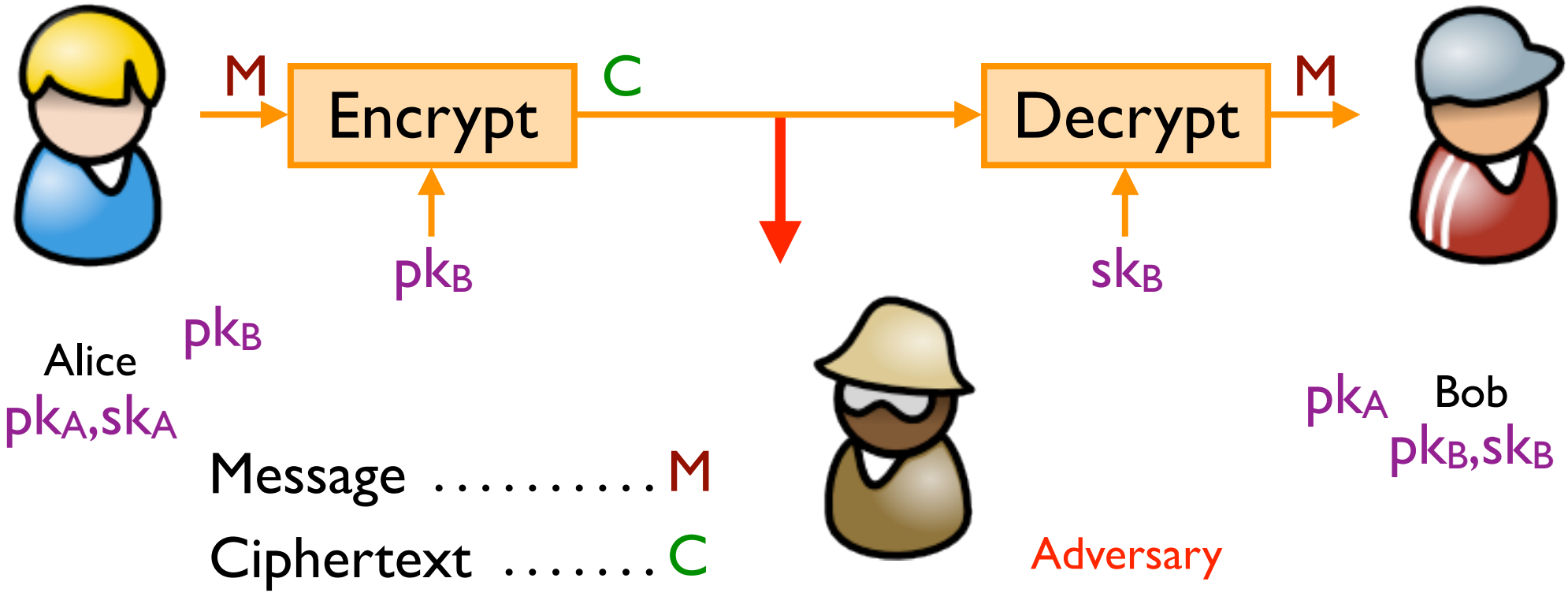
Achieving Privacy (Symmetric)

Encryption schemes: A tool for protecting privacy.



Achieving Privacy (Asymmetric)

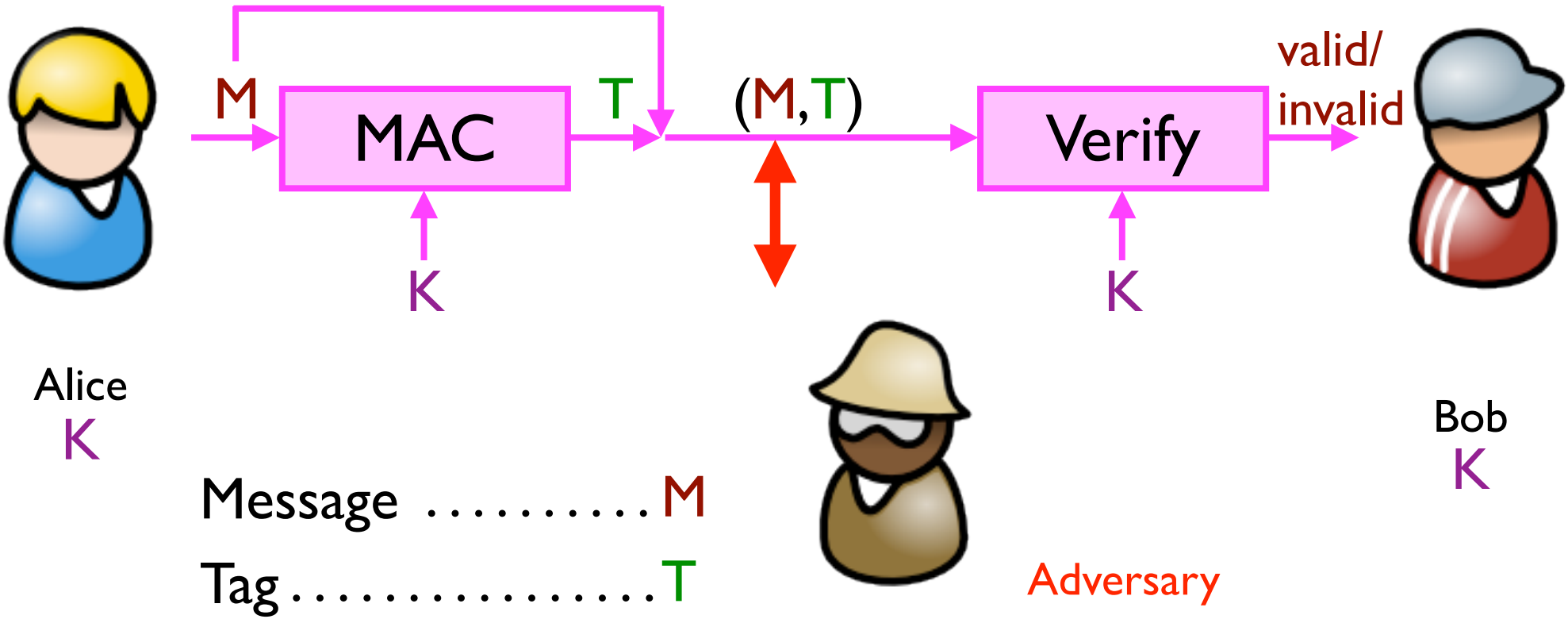
Encryption schemes: A tool for protecting privacy.



Achieving Integrity (Symmetric)

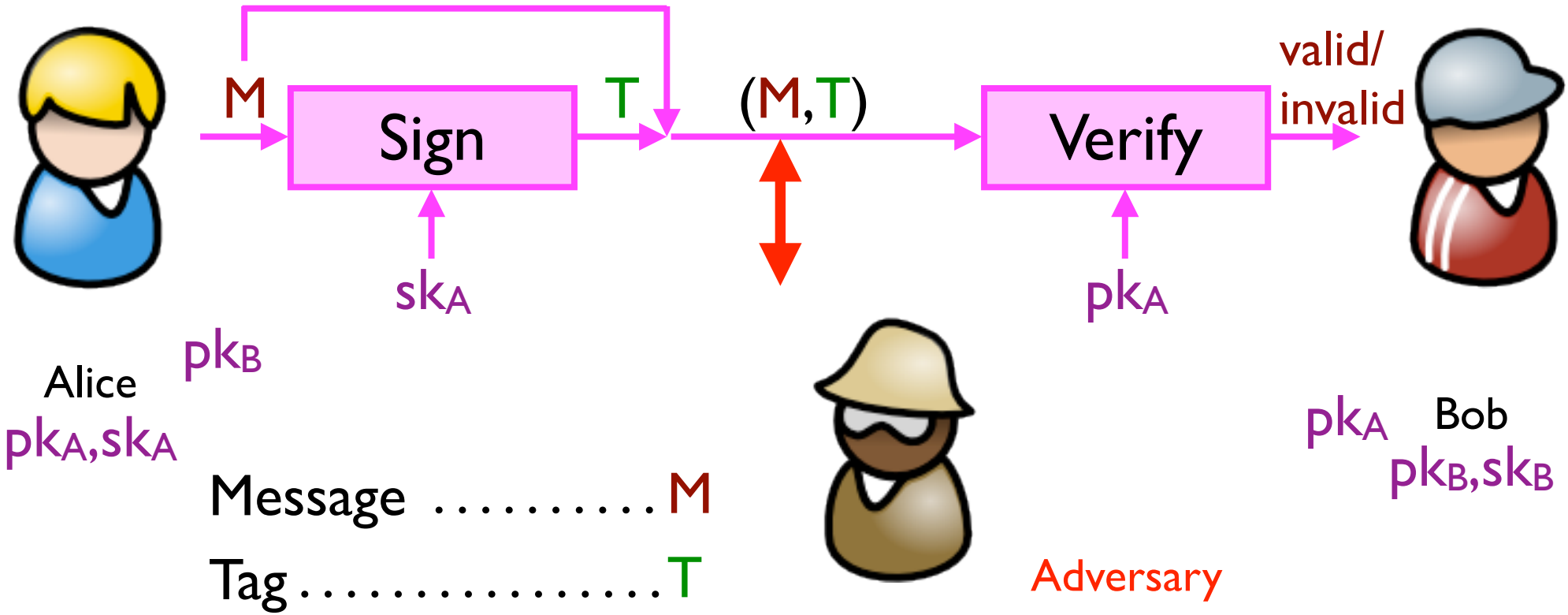
Message authentication schemes: A tool for protecting integrity.

(Also called message authentication codes or MACs.)



Achieving Integrity (Asymmetric)

Digital signature schemes: A tool for protecting integrity and authenticity.



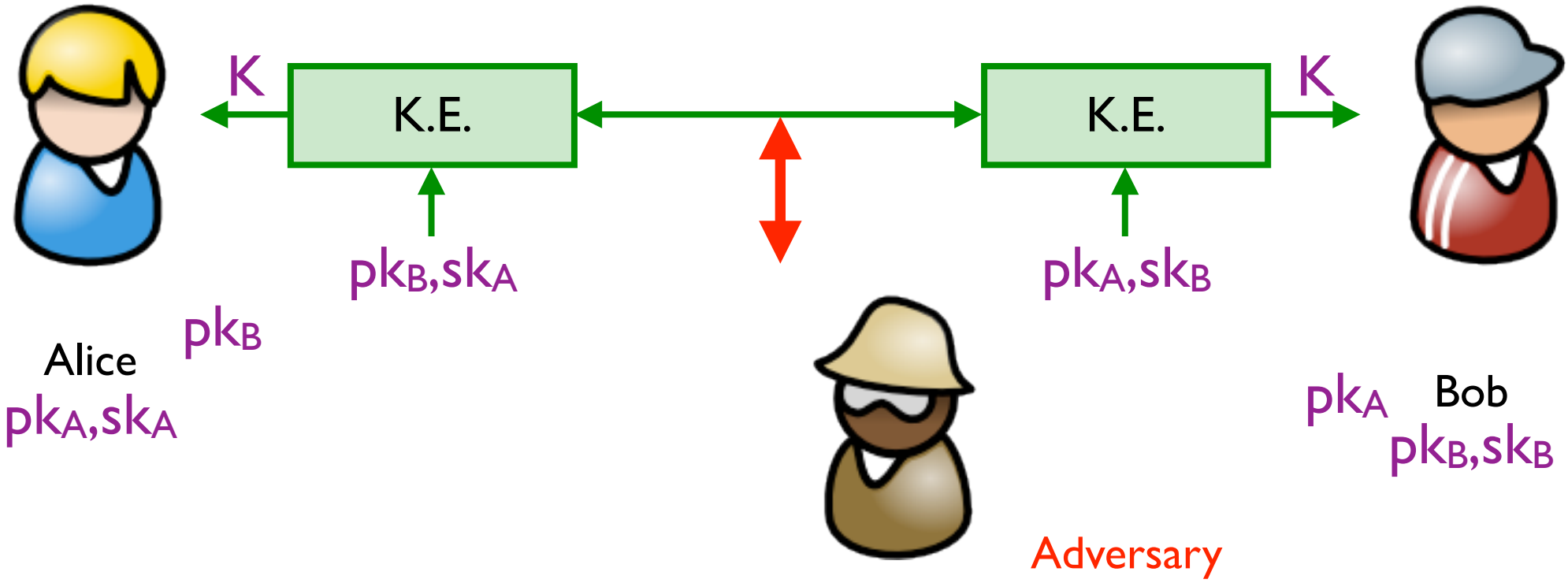
Getting keys: PBKDF

Password-based Key Derivation Functions

Alice

Getting keys: Key exchange

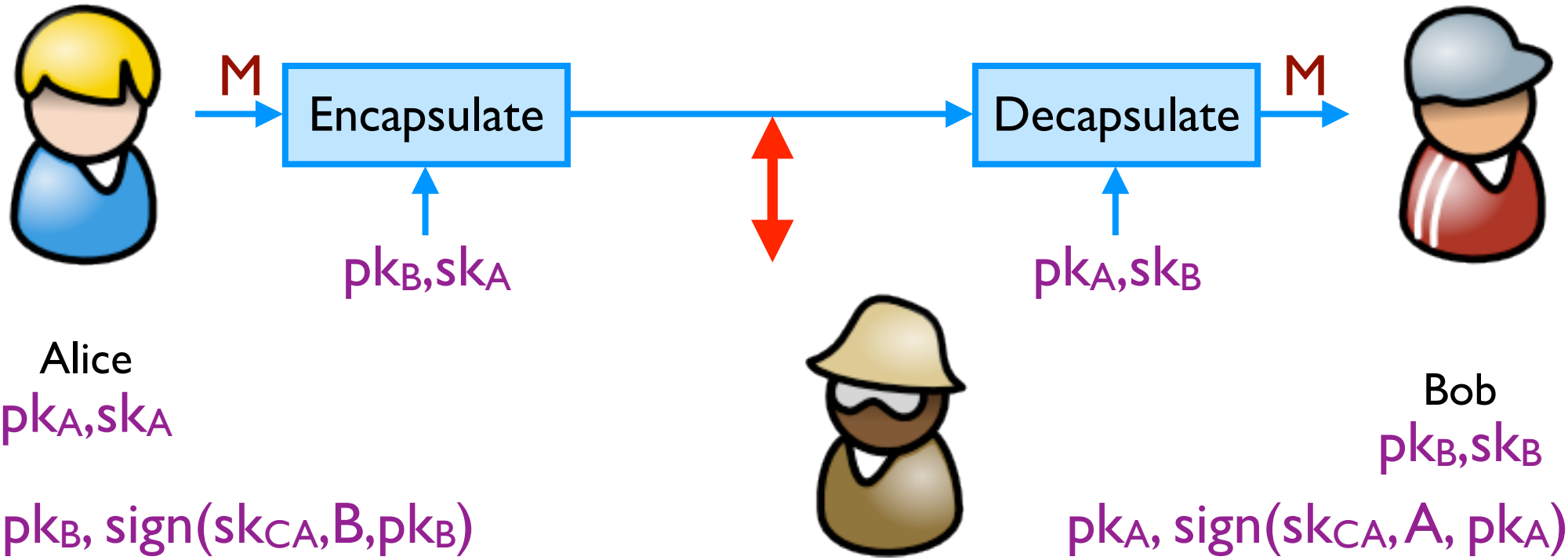
Key exchange protocols: A tool for establishing a share symmetric key



Getting keys: CAs

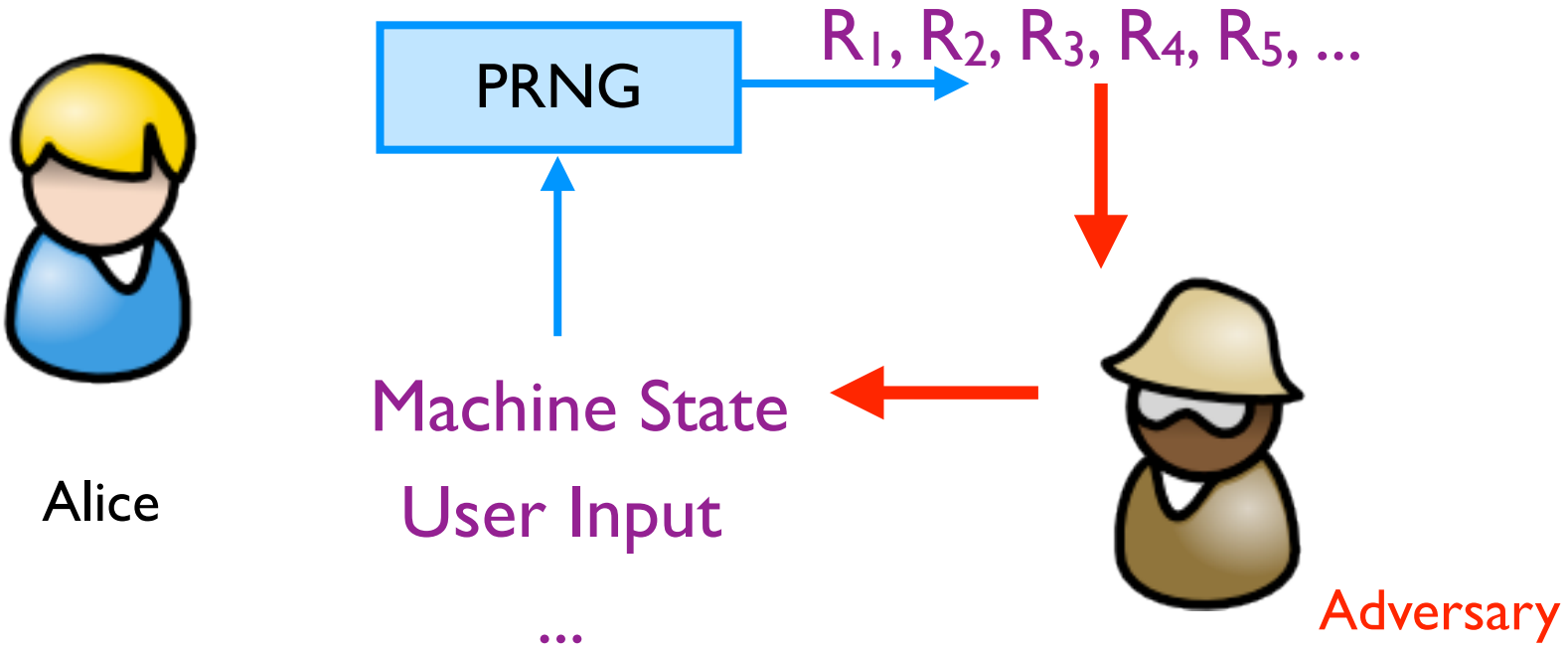
Each party creates a public key pk and a secret key sk.

(Public keys signed by a trusted third party: a certificate authority.)



“Random” Numbers

Pseudorandom Number Generators (PRNGs)



Kerckhoff's Principle

- Security of a cryptographic object should depend **only** on the secrecy of the secret (private) key
- Security should not depend on the secrecy of the algorithm itself.
- Why?

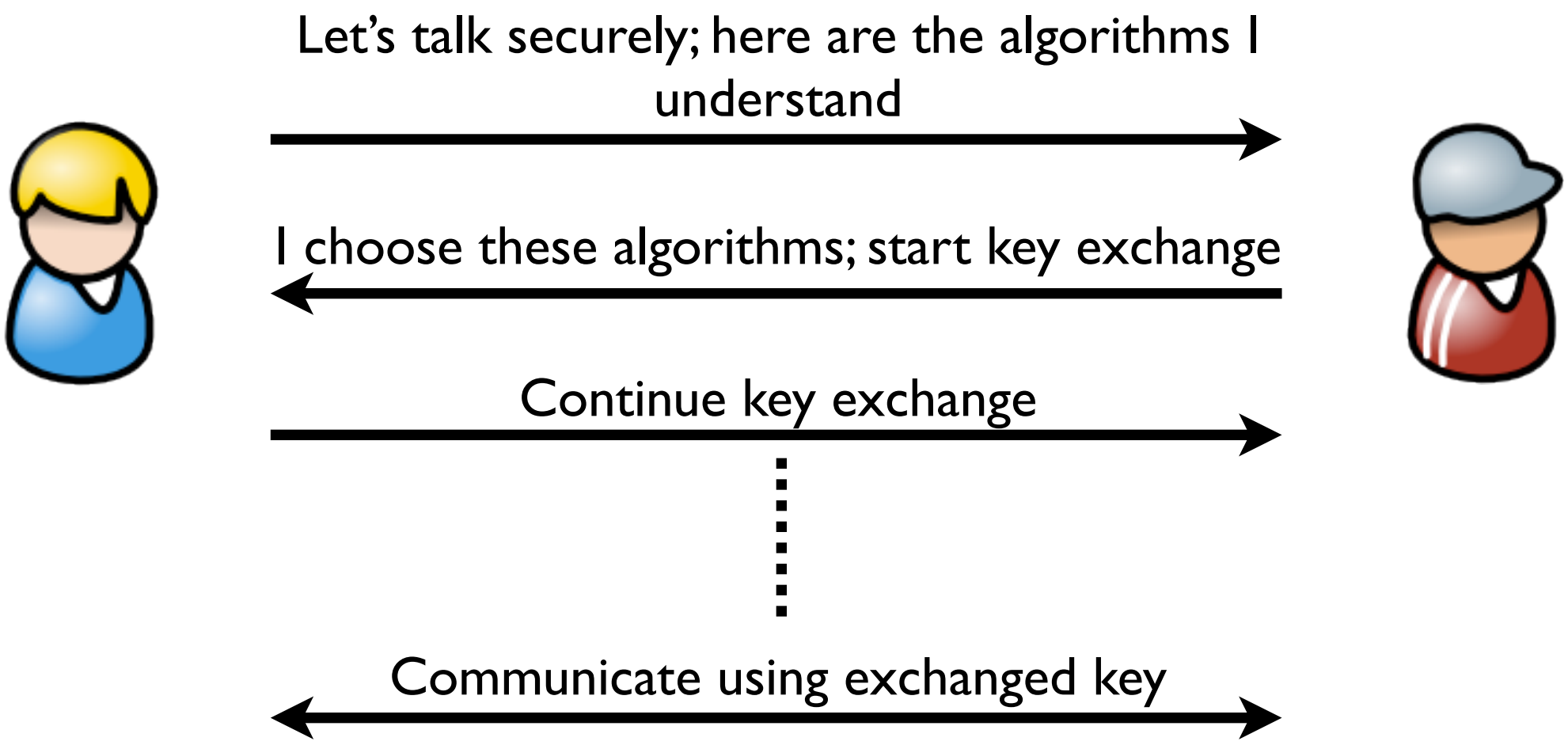
One-way Communications

PGP is a good example

Message encrypted under Bob's public key

Interactive Communications

In many cases, it's probably a good idea to just use a standard protocol/system like SSH, SSL/TLS, etc...



Let’s Dive a Bit Deeper

One-way Communications

(*Informal* example; ignoring, e.g., signatures)

1. Alice gets Bob's public key; Alice *verifies* Bob's public key (e.g., via CA)
2. Alice generates random symmetric keys K1 and K2
3. Alice encrypts the message M the key K1; call result C
4. Alice authenticates (MACs) C with key K2; call the result T
5. Alice encrypts K1 and K2 with Bob's public key; call the result D

6. Send D, C, T

(Assume Bob's private key is encrypted on Bob's disk.)

7. Bob takes his password to derive key K3
8. Bob decrypts his private key with key K3
9. Bob uses private key to decrypt K1 and K2
10. Bob uses K2 to verify MAC tag T
11. Bob uses K1 to decrypt C

Interactive Communications

(*Informal* example; details omitted)

1. Alice and Bob exchange public keys and certificates
2. Alice and Bob use CA's public keys to verify certificates and each other's public keys
3. Alice and Bob take their passwords and derive symmetric keys
4. Alice and Bob use those symmetric keys to decrypt and recover their asymmetric private keys (stored on disk)
5. Alice and Bob use their asymmetric private keys and a *key exchange* algorithm to derive a shared symmetric key

(They key exchange process will require Alice and Bob to generate new pseudorandom numbers)

6. Alice and Bob use shared symmetric key to encrypt and authenticate messages

(Last step will probably also use random numbers; will need to rekey regularly; may need to avoid replay attacks,...)

What cryptosystems have you heard of? (Past or present)

History

- Substitution Ciphers
  - Caesar Cipher
- Transposition Ciphers
- Codebooks
- Machines

- Recommended Reading: **The Codebreakers** by David Kahn and **The Code Book** by Simon Singh.
  - Military uses
  - Rumrunners
  - ....

Classic Encryption

- Goal: To communicate a secret message
- Start with an *algorithm*
- Caesar cipher (substitution cipher):

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ

GHIJKLMNOPQRSTUVWXYZABCDEF
```

Then add a secret key

- Both parties know that the secret word is "victory":

  ABCDEFGHIJKLMNOPQRSTUVWXYZ

  VICTORYABDEFGHJKLMNPQSUWXZ

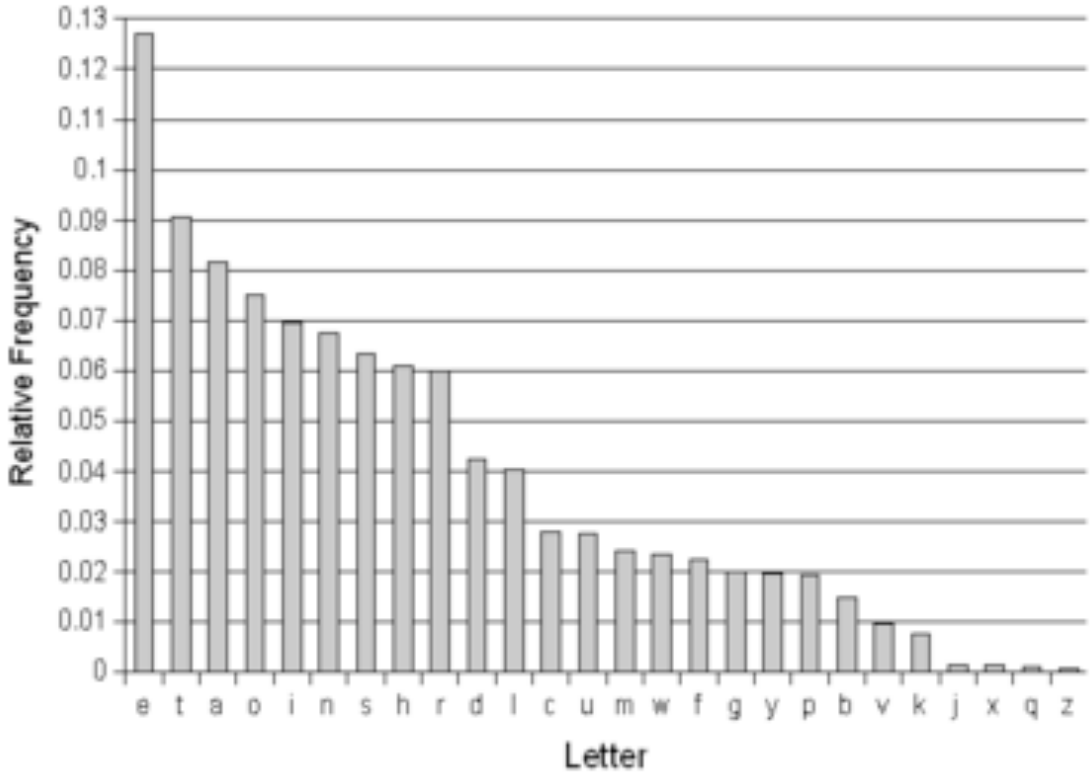
- "state of the art" for thousands of years

Cryptographers vs Cryptanalysts

- A battle that continues today
- Cryptographers try to devise more clever algorithms and keys
- Cryptanalysts search for vulnerabilities
- Early cryptanalysts were linguists:
  - frequency analysis
  - properties of letters

Cryptanalysis and probabilities

Letter	Frequency
a	8.167%
b	1.492%
c	2.782%
d	4.253%
e	12.702%
f	2.228%
g	2.015%
h	6.094%
i	6.966%
j	0.153%
k	0.772%
l	4.025%



From http://en.wikipedia.org/wiki/Letter_frequencies