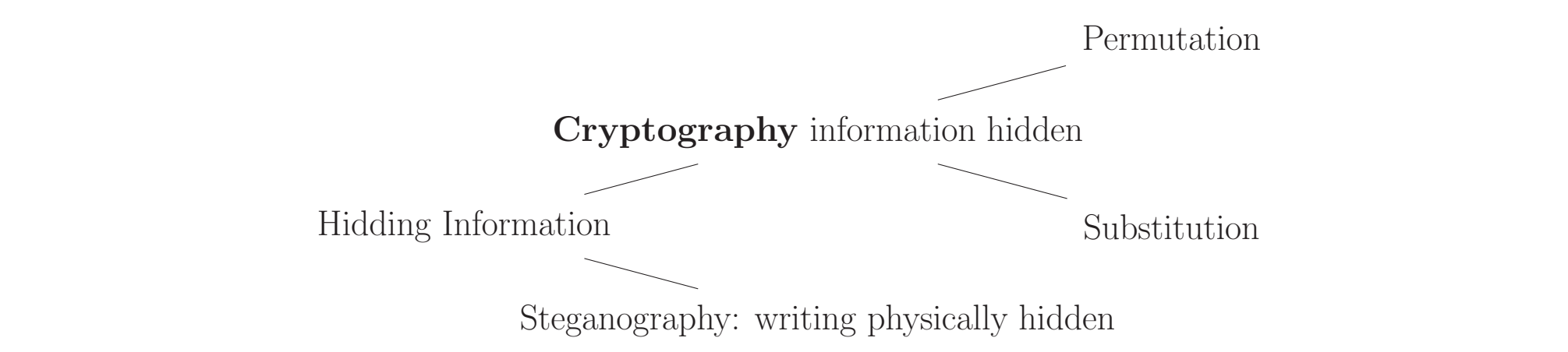


Categories of Secrecy



Cryptography hiding content of a message without hiding the writing itself by replacing letters with others (substitution) or scrambling the letters of the message (permutation).

Steganography physically hiding the message (invisible ink, ...)

Scytale: a transposition cipher

The message “Help me, I am under attack” is written on the scytale in rows

	H	E	L	P	M
	E	I	A	M	U
	N	D	E	R	A
	T	T	A	C	K

After unwinding the band it is scrambled to

HENTEIDTLAEAPMRCMUAK

The scytale is thus a permutation cipher.

The Caesar Shift Cipher

The simplest substitution cipher is the Caesar Cipher. Caesar shifted all the letters down the alphabet by a fixed step, say for instance 3 letters. The plaintext and ciphertext alphabet are associated as follows

Plaintext:	ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher:	XYZABCDEFGHIJKLMNOPQRSTUUV

An example encryption would be

Some important message.
PLJB FJMLQXKQ JBPPXDB.

Vigenere Cipher

In order to reduce redundancy and thus prevent frequency attacks several substitution schemes were used one after the other. For instance the first letter of the plain text would be encrypted with Caesar shift of 3, the second with a shift of 12, ... and eventually starting again with a shift of 3. Once the number of different substitution schemes is known, the cipher is again vulnerable to frequency attacks. Taking a computer or a cipher machine, like Enigma, one can increase the number substitution schemes immensely and thus security.

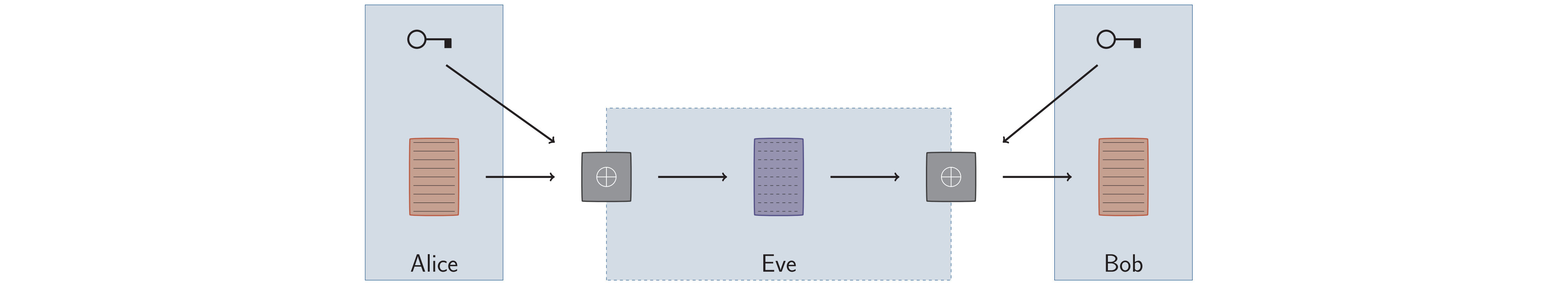
Frequency Analysis

The letters of the alphabet do not occur with the same frequency. In English the letter "e" is the most common and occurs a lot more often than for instance "z". So if one knows in what language a plaintext was written, one can decrypt the ciphertext from a monoalphabetic substitution cipher without knowing the substitution scheme, that is the key. One merely has to count the number of occurrences of any letter of the alphabet, compare this with the frequencies of letters of the given language and match corresponding letters. This works better the longer the cipher text is. (Actually if the ciphertext is very short, the cipher might become a one-time pad which is really secure).

Side Channel Attacks

While frequency attacks or brute force approaches (i.e. trying out a large number of keys) aim at the cipher itself, side channel attacks exploit weaknesses in the implementation of the cipher. For instance one might surveil the power consumption of the processor during encryption. This might reveal patterns that allow to break the cipher.

The Scheme of Cryptography



First a player, usually called Alice, encrypts the plaintext according to the encryption algorithm using her key. The ciphertext Alice generated is then sent to another party, often called Bob. With his key he can execute the decryption algorithm in order to obtain the plaintext again.

Security What does it mean for a cipher to be secure? The notion of security depends on the abilities we imagine an adversary has to attack the cipher. The adversary, often referred to as Eve, can at least read the ciphertext, i.e. tap the wire between Alice and Bob. Usually Eve also knows the encryption and decryption algorithms. Obviously Alice and Bob have to keep their key secret. If Eve's knowledge of the algorithms and the ciphertext suffices to retrieve the plaintext, the cipher is insecure. Otherwise Alice and Bob can communicate secretly.

Authenticity What if Eve doesn't merely read the ciphertext but also changes it? Or sends something to Bob, claiming to be Alice? These considerations lead for instance to *digital signatures* aiming to insure Bob that what he had sent was not altered or faked.

The One-Time Pad

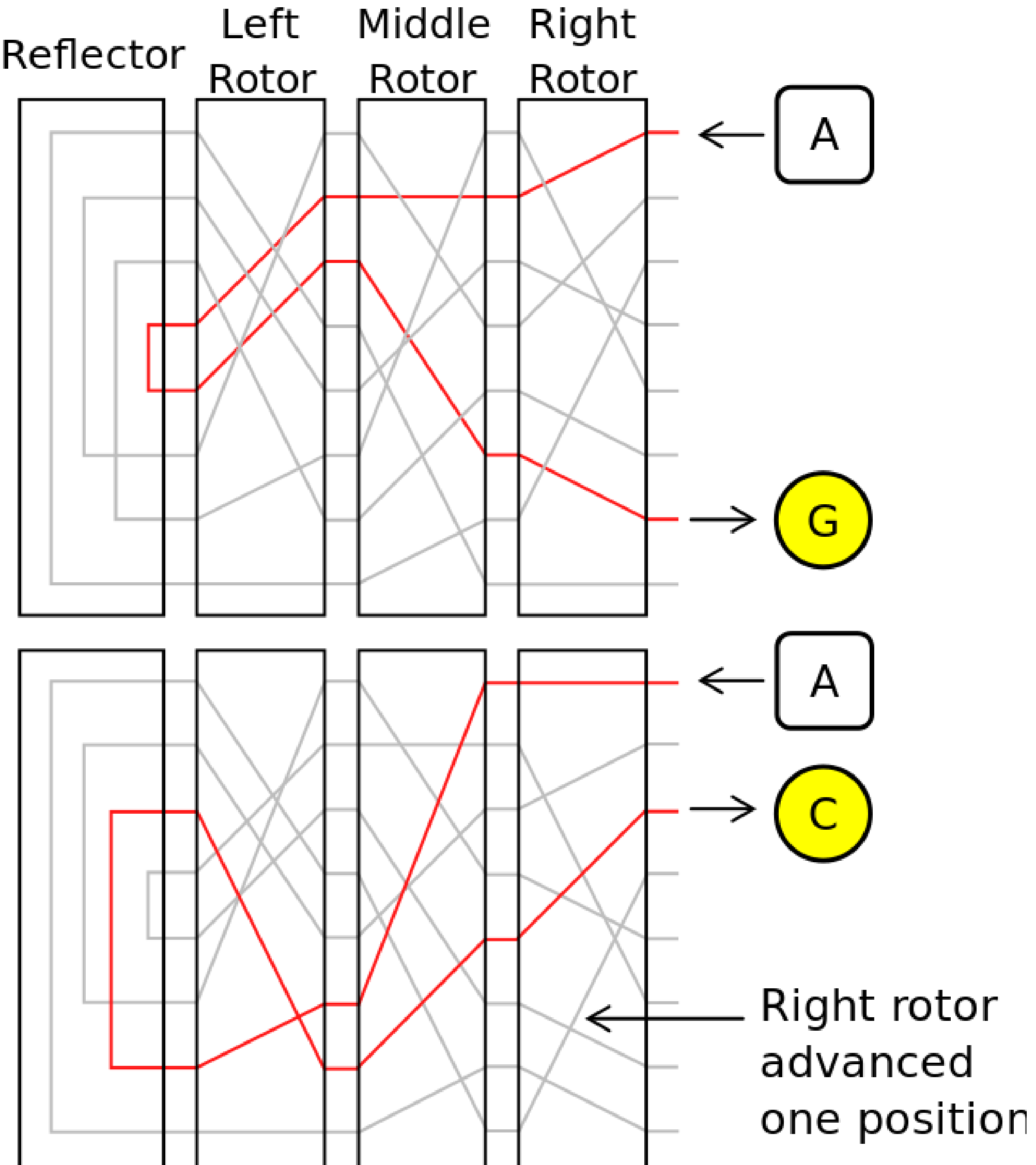
How could we get a substitution cipher with proper security? The issue of most substitution ciphers is their redundancy. For example the letter "e" might always be substituted by "m". This clearly allows frequency attacks as the number of occurrences of "e" is just shifted to "m". In order to get rid of any redundancy or other structures that might be helpful to break the cipher the one-time pad uses an entirely random key that is just as long as the message itself. A binary example as it occurs in any computer is then

Text	Ciao
Plaintext	01000011 01101001 01100001 01101111
	⊕
Key	10011011 11110011 10011100 11011011
	gives
Ciphertext	11011000 10011010 11111101 10110100

So adding the random key (i.e. applying the XOR (either ... or ...) operation) makes the ciphertext look completely random too. Even — not knowing the key — could not say whether the ciphertext would stem from the word 'oggi' or the word 'ciao' (or any other four letter word), as they are all equally likely to appear. Thus the one-time pad is properly secure. But — as the name already suggest: never ever use it even twice. This would introduce structure and therefore turn the cipher insecure. Why isn't the OTP used all over the place if it is completely secure? Well, you need to distribute a lot of keys secretly. This is very inconvenient.

Enigma: a first machine cipher

The Enigma was the first electronic device used for encryption enabling far stronger ciphers. The idea was similar to the Vigenere Cipher to continuously change the substitution scheme. As the number of possible schemes was rather large this increased security considerably (provided the implementation did not reveal any information). In a sense the enigma could be considered as a predecessor of modern computers.



The core of the Enigma contained three disks with internal wirings. Every time a key on the keyboard was hit the first rotated by 1/26 of a circle. After 26 rotations of the first disk the second rotated once and after 26 × 26 keystrokes the third one moved forward. If a key was hit, a small current basically followed the internal wirings until a lamp indicated the corresponding letter of the cipher alphabet. The cipher alphabet changes with every keystroke and repeated only after 26³ input letters. The “mirror” on the left enabled to use the machine as its own decipher machine. Therefore the key contained the simply the initial settings, i.e. which disks were to be inserted at what position and with which initial rotation.