

History of Cryptography and Cryptanalysis

Kurt Pan

March 21, 2025

Table of Contents

- 1 The birth of cryptography
- 2 The Evolution of Secret Writing
 - Steganography
 - Codes
 - Ciphers
 - Passwords
- 3 History of Cryptanalysis
- 4 Modern Cryptography

*It must be that as soon as a culture has reached a certain level, probably measured largely by its **literacy**, **cryptography** appears spontaneously - as its parents, **language** and **writing**, probably also did.*

*The multiple human needs and desires that demand **privacy** among two or more people in the midst of social life must inevitably lead to cryptology wherever men thrive and wherever they write.*

*Cultural diffusion seems a less likely explanation for its occurrence in so many areas, many of them distant and isolated.
(Kahn 1967, p. 84).*

Table of Contents

1 The birth of cryptography

2 The Evolution of Secret Writing

- Steganography
- Codes
- Ciphers
- Passwords

3 History of Cryptanalysis

4 Modern Cryptography

Steganography

Steganography

Secret communication achieved by hiding the *existence* of a message.

- (Greek) Scraping the wax off a pair of wooden folding tablets, writing on the wood underneath and then covering the message over with wax again.
- (Chinese) Wrote messages on fine silk, which was scrunched into a tiny ball and covered in wax.
- Writing in invisible ink.

<https://emoji.paulbutler.org/?mode=decode>

(Can you find the invisible msg in the 3rd bullet point?)

Interception of the message immediately compromises all security.

Code

A code always takes the form of a book where a numerical or alphabetic codeword is substituted for a complete word or phrase from the plaintext.

e.g Morse code, Commercial code, Base58

- The best way to break a code is to
~~steal the codebook!~~

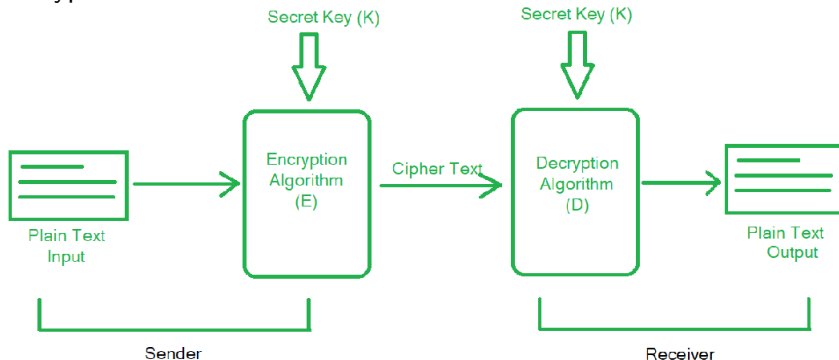
*In contemporary public discourse, it is quite common to refer to **crypto** as **encryption**, but encryption is just one term in the broader science of **cryptology**, the science of making and breaking ciphers.*

- cryptography: making ciphers , by cryptographers
- cryptanalysis: breaking ciphers, by cryptanalysts
- cipher: a mathematical function that allows its user to transform a plaintext message into a ciphertext message (Encryption/Decryption)
- cryptographer : to design ciphers strong enough so unauthorized persons cannot figure out how to transform ciphertexts back into plaintext and read the messages without permission.
- cryptanalyst : to figure out how the cipher is designed so they can transform ciphertexts back into plaintext and read the messages without permission, usually without the sender even knowing

Cipher

The aim of cryptography is not to hide the *existence* of a message, but rather to hide its *meaning*, a process known as **encryption**.

Without knowing the scrambling protocol, the enemy should find it difficult, if not impossible, to re-create the original message from the encrypted text.



Transposition

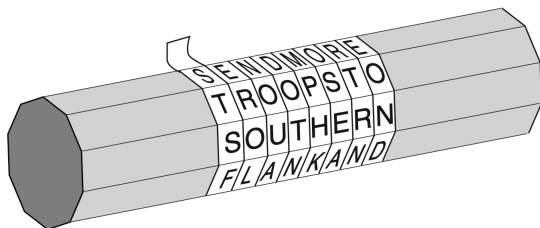
The letters of the message are simply *rearranged*, effectively generating an anagram.

Rail Fence Transposition

THY SECRET IS THY PRISONER; IF THOU LET IT GO, THOU ART A PRISONER TO IT

↓
T Y E R T S H P I O E I T O L T T O H U R A R S N R O T
H S C E I T Y R S N R F H U E I G T O A T P I O E T I

↓
TYERTSHPIOEITOLTTOHURARSNROTHSCEITYRSNRFHUEIGTOATPIOETI



The Spartan scytale

Substitution Cipher

To pair letters of the alphabet at *random*.

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

- In transposition each letter retains its *identity* but changes its *position*,
- In substitution each letter changes its *identity* but retains its *position*.

e.g. Caesar , Vigenere, OTP

Cipher

Cipher is the name given to any form of *cryptographic substitution* in which *each letter* is replaced by another letter or symbol.

Password Authentication

A method of *proving identity* rather than encrypting messages.

- Unlike codes and ciphers, passwords are used for **authentication**
- Key differences:
 - ▶ Codes: Replace words/phrases with other symbols
 - ▶ Ciphers: Transform message content
 - ▶ Passwords: Verify user identity
- Historical examples:
 - ▶ Military watchwords ("Who goes there?")
 - ▶ Secret societies' passphrases
 - ▶ Ancient guard posts' challenge-response systems

Modern Password Systems

Key Concepts

Modern passwords are stored as *cryptographic hashes*, not plaintext.

- Security features:
 - ▶ One-way hash functions
 - ▶ Salt values
 - ▶ Key stretching
- Common vulnerabilities:
 - ▶ Dictionary attacks
 - ▶ Rainbow tables
 - ▶ Social engineering

Table of Contents

- 1 The birth of cryptography
- 2 The Evolution of Secret Writing
 - Steganography
 - Codes
 - Ciphers
 - Passwords
- 3 History of Cryptanalysis
- 4 Modern Cryptography

The Cipher of Mary Queen of Scots

The birth of cryptography, the substitution cipher and the invention of codebreaking by frequency analysis.

(October 15, 1586) , Mary Queen of Scots was on trial for treason. She had been accused of plotting to assassinate Queen Elizabeth in order to take the English crown for herself.

Elizabeth would sanction Mary's execution only if Walsingham could prove beyond any hint of doubt that she had been part of the assassination plot. ...The challenge for Walsingham was to demonstrate a clear link between Mary and the plotters.

(Mary) had been careful to ensure that all her correspondence with the conspirators had been written in cipher. ... Mary believed that even if Walsingham had captured the letters, he could have no idea of the meaning of the words within them.

*Not for the first time, **a life hung on the strength of a cipher.***

(Singh 2002, p. 6-8).

a b c d e f g h i k l m n o p q r s t u x y z
 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 10

Nulles $\text{ff} \text{ — } \text{ — } \text{d}$ Dowbleth σ

and for with that if but where as of the from by

so not when there this in wich is what say me my wyrt

 A row of twelve medieval script characters, each corresponding to a letter in the phrase 'so not when there this in wich is what say me my wyrt'. The characters are: 's' (a simple loop), 'o' (a cross), 'n' (two vertical strokes), 'o' (a loop), 't' (a loop), 'h' (a loop), 'e' (a loop), 'r' (a loop), 'e' (a loop), 't' (a loop), 'h' (a loop), 'i' (a loop), 's' (a loop), 'i' (a loop), 'n' (a loop), 'w' (a loop), 'i' (a loop), 'c' (a loop), 'h' (a loop), 'i' (a loop), 's' (a loop), 'w' (a loop), 'h' (a loop), 'a' (a loop), 't' (a loop), 's' (a loop), 'a' (a loop), 'y' (a loop), 'm' (a loop), 'e' (a loop), 'm' (a loop), 'y' (a loop), 'w' (a loop), 'y' (a loop), 'r' (a loop), 't' (a loop).


send lre receive bearer I pray you Mte your name myne




Figure 9 The execution of Mary Queen of Scots.

Breaking the Caesar Cipher

brute force attack !

	VIEW	...		ENCODE DECODE	...		VIEW	...	
	Ciphertext ▾			Caesar cipher ▾			Plaintext ▾		
DWWD FNDW GDZQ.			<div>SHIFT</div> <div>- 3 a→d +</div>				ATTA CKAT DAWN.		
			<div>ALPHABET</div> <div>abcdefghijklmnopqrstuvwxyz</div>						
			<div>CASE STRATEGY</div> <div>Maintain case ▾</div>		<div>FOREIGN CHARS</div> <div>Include Ignore</div>				

Breaking Substitution Cipher

random permutation

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

127 billion years for brute force attack.

- letter frequency attack
- known-plaintext attack

Breaking the Vigenre Cipher

The "Unbreakable" Cipher

The Vigenre cipher remained unbroken for 300 years and was known as "le chiffre indchiffable"

Keyword	W H I T E W H I T E W H I T E W H I T E W H I
Plaintext	d i v e r t t r o o p s t o e a s t r i d g e
Ciphertext	Z P D X V P A Z H S L Z B H I W Z B K M Z N M

- Broken by Charles Babbage (1850s):
 - ▶ Discovered repeating patterns in ciphertext
 - ▶ Determined key length using these patterns
 - ▶ Applied frequency analysis to each shift
- Friedrich Kasiski (1863):
 - ▶ Published first public method
 - ▶ Known as the Kasiski examination

Enigma and Midway

[VIDEO]

Mathematical Cryptanalysis

19th Century Methods

- Index of coincidence
- Probability theory
- Pattern recognition

Key Contributions

- William F. Friedman
- Claude Shannon
- Alan Turing

Impact

These mathematical foundations transformed cryptanalysis from an art into a science

Kerckhoffs' Principle

Kerckhoffs' Principle

The security of a cryptosystem **must not** depend on keeping secret the crypto-algorithm. The security depends only on keeping secret the **key**.^a

^aA Brief Biography of Auguste Kerckhoffs by Peng SUN

Table of Contents

- 1 The birth of cryptography
- 2 The Evolution of Secret Writing
 - Steganography
 - Codes
 - Ciphers
 - Passwords
- 3 History of Cryptanalysis
- 4 Modern Cryptography

Modern Era (19th-20th Century)

- Telegraph and radio communication drove cipher development
- World War I: ADFGVX cipher
- World War II:
 - ▶ German Enigma machine
 - ▶ Allied cryptanalysis at Bletchley Park
 - ▶ American SIGABA machine

The Birth of Modern Cryptography

Shannon's Information Theory (1940s)

Claude Shannon established the theoretical foundation of modern cryptography:

- Information entropy
- Perfect secrecy
- Confusion and diffusion principles

Key Developments

- Transition from mechanical to electronic systems
- Development of computer-based encryption
- Birth of public-key cryptography

Symmetric vs Asymmetric Cryptography

Symmetric

- Same key for encryption and decryption
- DES (1977)
- AES (2001)
- Faster computation

Asymmetric

- Public/private key pairs
- RSA (1978)
- ECC (1985)
- Key distribution advantage

Public Key Infrastructure (PKI)

Components

- Digital certificates
- Certificate authorities (CAs)
- Public key directories
- Certificate revocation lists

Applications

- HTTPS/TLS
- Digital signatures
- Secure email (S/MIME)
- Code signing

Modern Security Goals

Core Security Properties

- **Confidentiality**: Preventing unauthorized access
- **Integrity**: Ensuring data hasn't been modified
- **Authenticity**: Verifying the origin of data
- **Non-repudiation**: Cannot deny sending/receiving

Security Models

- IND-CPA (Chosen Plaintext Attack)
- IND-CCA (Chosen Ciphertext Attack)
- Forward Secrecy
- Random Oracle Model

Emerging Technologies

Post-Quantum Cryptography

- Lattice-based cryptography
- Hash-based signatures
- Multivariate cryptography
- NIST standardization process

New Paradigms

- Homomorphic encryption
- Secure multi-party computation
- Blockchain technology
- Quantum key distribution

Future Challenges

Emerging Threats

- Quantum computing threats
- Post-quantum cryptography
- AI-based attacks
- Zero-day vulnerabilities

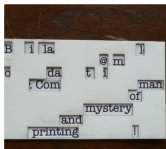
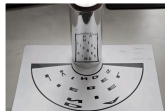
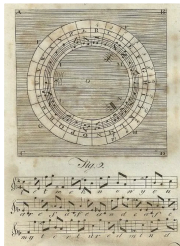
Research Directions

- Quantum-resistant algorithms
- Homomorphic encryption
- Lightweight cryptography
- Privacy-preserving computation

Crypto is both a mathematical science and an artistic practice that enables particular kinds of human relationships.

Crypto is unlike other sciences because cryptography is about intelligent **adversaries** who are actively fighting over whether secrets will be revealed.

From this perspective, crypto can be considered an art, specifically an **art of communication**.



Thanks!