Crypto 2
Aug 25th

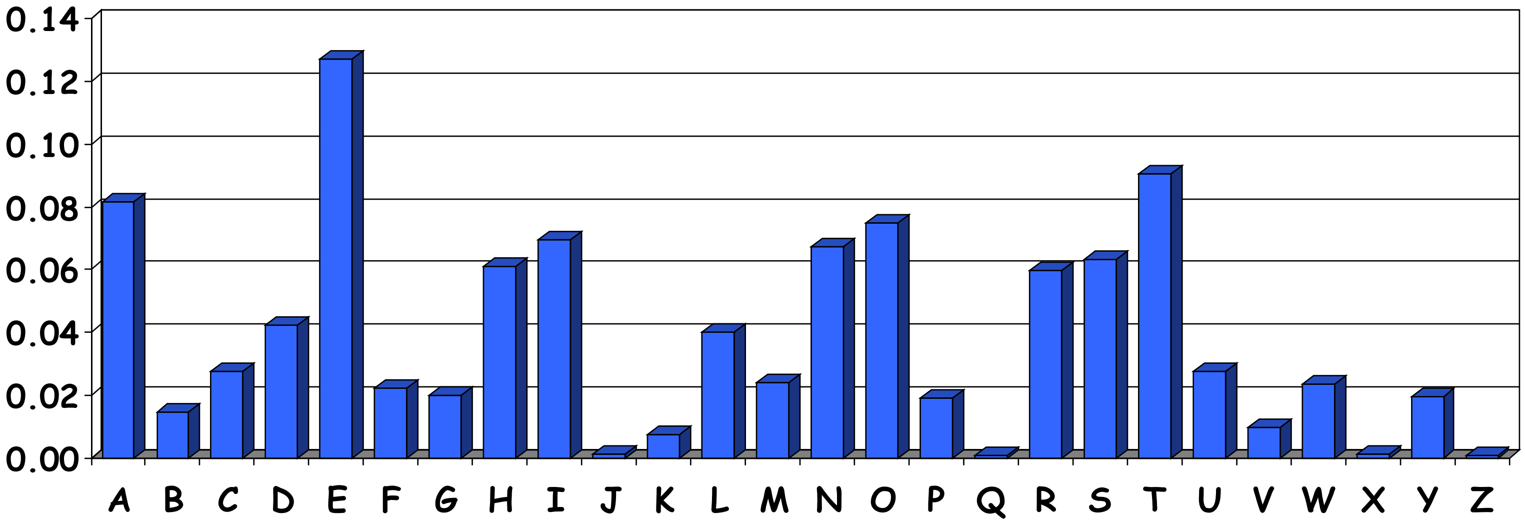
Cryptanalysis II: Be Clever

- We know that a simple substitution is used
- But not necessarily a shift by n
- Can we find the key given ciphertext:

```
PBFPVYFBQXZTYFPBFEQJHDXXQVAPTPQJKTOYQWIPBVWLXTOXBT
    FXQWAXBVCXQWAXFQJVWLEQNTOZQGGQLFXQWAKVWLXQW
    AEBIPBFXFQVXGTVJVWLBTPQWAEBFPBFHCVLXBQUFEVWLXGDP
    EQVPQGVPPBFTIXPFHXZHVFAGFOTHFEFBQUFTDHZBQPOTHXTY
    FTODXQHFTDPTOGHFQPBQWAQJJTODXQHFOQPWTBDHHIXQV
    APBFZQHCFWPFHPBFIPBQWKFABVYYDZBOTHPBQPQJTQOTOGH
    FQAPBFEQJHDXXQVAVXEBQPEFZBVFOJIWFFACFCCFHQWAUVW
    FLQHGFXVAFXQHFUFHILTTAVWAFFAWTEVOITDHFHFQAITIXP
    FHXAFQHEFZQWGFLVWPTOFFA
```

Cryptanalysis II

- Can't try all 2^{88} simple substitution keys
- Can we be more clever?
- English letter frequency counts…



Cryptanalysis II

- Ciphertext:

```
PBFPVYFBQXZTYFPBFEQJHDXXQVAPTPQJKTOYQWIPBVWLXTOXBTFXQWAX
    BVCXQWAXFQJVWLEQNTOZQGGQLFXQWAKVWLXQWAEBIPBFXFQVXGT
    VJVWLBTPQWAEBFPBFHCVLXBQUFEVWLXGDPEQVPQGVPPBFTIXPFHXZHV
    FAGFOTHFEFBQUFTDHZBQPOTHXTYFTODXQHFTDPTOGHFQPBQWAQJJ
    TODXQHFOQPWTBDHHIXQVAPBFZQHCFWPFHPBFIPBQWKFABVYYDZBOT
    HPBQPQJTQOTOGHFQAPBFEQJHDXXQVAVXEBQPEFZBVFOJIWFFACFCC
    FHQWAUVWFLQHGFXVAFXQHFUFHILTTAVWAFFAWTEVOITDHFHFQAIT
    IXPFHXAFQHEFZQWGFLVWPTOFFA
```

- Decrypt this message using info below

Ciphertext frequency counts:

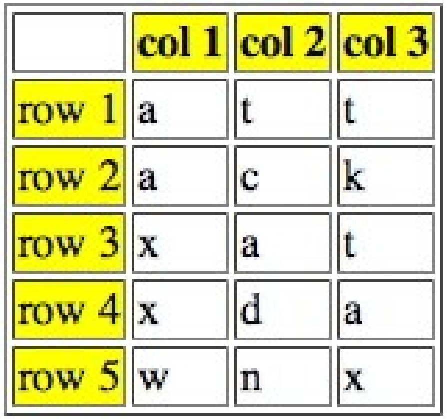
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
21	26	6	10	12	51	10	25	10	9	3	10	0	1	15	28	42	0	0	27	4	24	22	28	6	8

Cryptanalysis: Terminology

- □ Cryptosystem is **secure** if best know attack is to try all keys
- □ Cryptosystem is **insecure** if any shortcut attack is known
- □ By this definition, an insecure system might be harder to break than a secure system!

Double Transposition

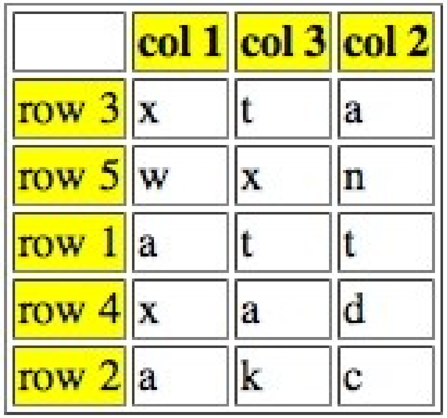
- Plaintext: attackxatxdawn



	col 1	col 2	col 3
row 1	a	t	t
row 2	a	c	k
row 3	x	a	t
row 4	x	d	a
row 5	w	n	x

Permute rows and columns

⇒



	col 1	col 3	col 2
row 3	x	t	a
row 5	w	x	n
row 1	a	t	t
row 4	x	a	d
row 2	a	k	c

- Ciphertext: xtawxnattxadakc
- Key: matrix size and permutations (3,5,1,4,2) and (1,3,2)

One-time Pad Encryption

e=000   h=001   i=010   k=011   l=100   r=101   s=110   t=111

Encryption: Plaintext ⊕ Key = Ciphertext

	h	e	i	l	h	i	t	l	e	r
Plaintext:	001	000	010	100	001	010	111	100	000	101
Key:	111	101	110	101	111	100	000	101	110	000
Ciphertext:	110	101	100	001	110	110	111	001	110	101
	s	r	l	h	s	s	t	h	s	r

One-time Pad Decryption

e=000 h=001 i=010 k=011 l=100 r=101 s=110 t=111

Decryption: Ciphertext ⊕ Key = Plaintext

	s	r	l	h	s	s	t	h	s	r
Ciphertext:	110	101	100	001	110	110	111	001	110	101
Key:	111	101	110	101	111	100	000	101	110	000
Plaintext:	001	000	010	100	001	010	111	100	000	101
	h	e	i	l	h	i	t	l	e	r

One-time Pad

Double agent claims sender used "**key**":

	s	r	l	h	s	s	t	h	s	r
Ciphertext:	110	101	100	001	110	110	111	001	110	101
"**key**":	101	111	000	101	111	100	000	101	110	000
"Plaintext":	011	010	100	100	001	010	111	100	000	101
	k	i	l	l	h	i	t	l	e	r

e=000	h=001	i=010	k=011	l=100	r=101	s=110	t=111

One-time Pad

Sender is captured and claims the key is:

	s	r	l	h	s	s	t	h	s	r
Ciphertext:	110	101	100	001	110	110	111	001	110	101
"Key":	111	101	000	011	101	110	001	011	101	101
"Plaintext":	001	000	100	010	011	000	110	010	011	000
	h	e	l	i	k	e	s	i	k	e

e=000 h=001 i=010 k=011 l=100 r=101 s=110 t=111

One-time Pad Summary

- Provably secure, when used correctly
  - Ciphertext provides no info about plaintext
  - All plaintexts are equally likely
  - Pad must be random, used only once
  - Pad is known only by sender and receiver
  - Pad is same size as message
  - No assurance of message integrity
- Why not distribute message the same way as the pad?

Real-world One-time Pad

- Project VENONA
  - Soviet spy messages from U.S. in 1940's
  - Nuclear espionage, etc.
  - Thousands of messaged
- Spy carried one-time pad into U.S.
- Spy used pad to encrypt secret messages
- Repeats within the "one-time" pads made cryptanalysis possible

VENONA Decrypt (1944)

[C% Ruth] learned that her husband [v] was called up by the army but he was not sent to the front. He is a mechanical engineer and is now working at the ENORMOUS [ENORMOZ] [vi] plant in SANTA FE, New Mexico. [45 groups unrecoverable]

detain VOLOK [vii] who is working in a plant on ENORMOUS. He is a FELLOWCOUNTRYMAN [ZEMLYaK] [viii]. Yesterday he learned that they had dismissed him from his work. His active work in progressive organizations in the past was cause of his dismissal. In the FELLOWCOUNTRYMAN line LIBERAL is in touch with CHESTER [ix]. They meet once a month for the payment of dues. CHESTER is interested in whether we are satisfied with the collaboration and whether there are not any misunderstandings. He does not inquire about specific items of work [KONKRETNAYa RABOTA]. In as much as CHESTER knows about the role of LIBERAL's group we beg consent to ask C. through LIBERAL about leads from among people who are working on ENOURMOUS and in other technical fields.

- "Ruth" == Ruth Greenglass
- "Liberal" == Julius Rosenberg
- "Enormous" == the atomic bomb

Codebook

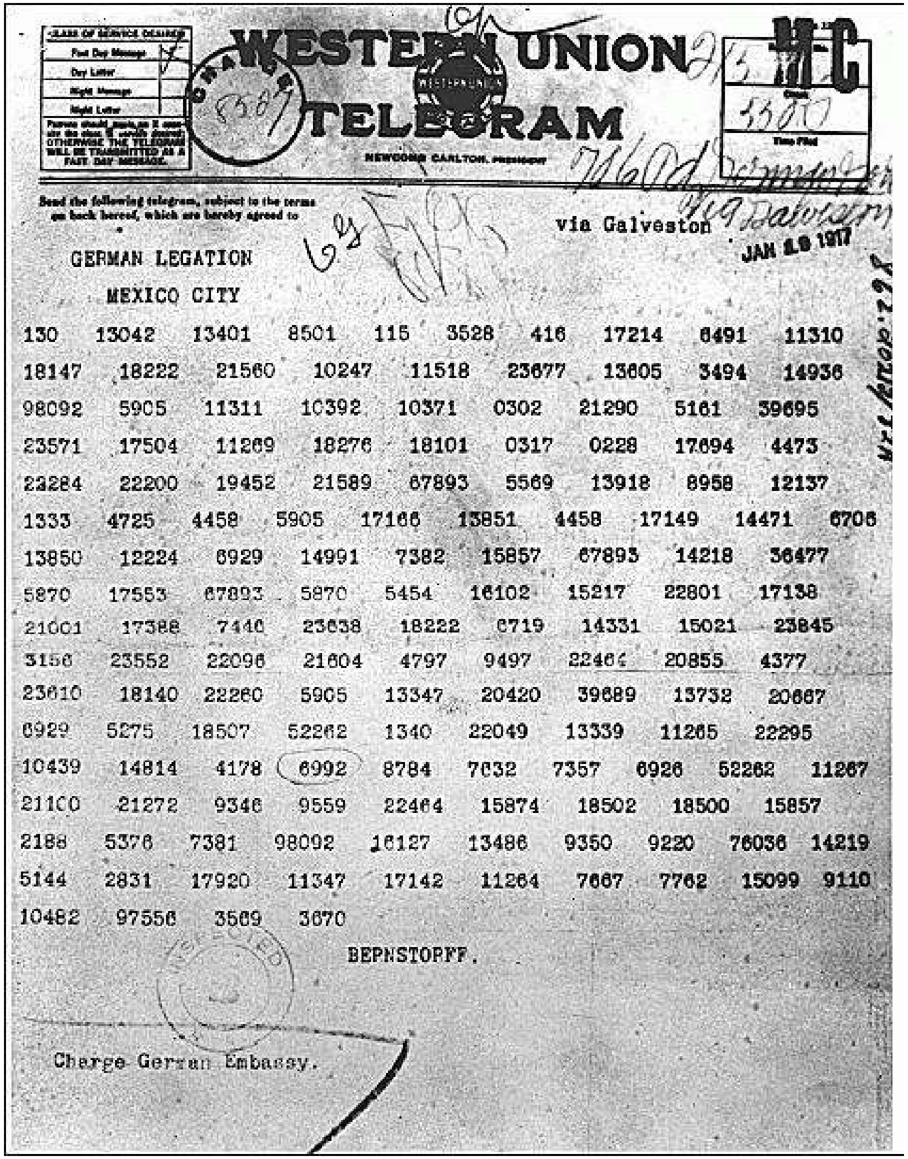
- ❑ Literally, a book filled with "codewords"
- ❑ Zimmerman Telegram encrypted via codebook

Februar	13605
fest	13732
finanzielle	13850
folgender	13918
Frieden	17142
Friedenschluss	17149
:	:

- ❑ Modern block ciphers are codebooks!
- ❑ More on this later…

Zimmerman Telegram

- One of most famous codebook ciphers ever
- Led to US entry in WWI
- Ciphertext shown here...



CLASS OF SERVICE DESIRED
Fast Day Message
Day Letter
Night Message
Night Letter
Patrons should mark an X opposite the class of service desired; OTHERWISE THE TELEGRAM WILL BE TRANSMITTED AS A FAST DAY MESSAGE.

WESTERN UNION TELEGRAM

NEWCOMB CARLTON, PRESIDENT

Send the following telegram, subject to the terms on back hereof, which are hereby agreed to

via Galveston

JAN 19 1917

GERMAN LEGATION

MEXICO CITY

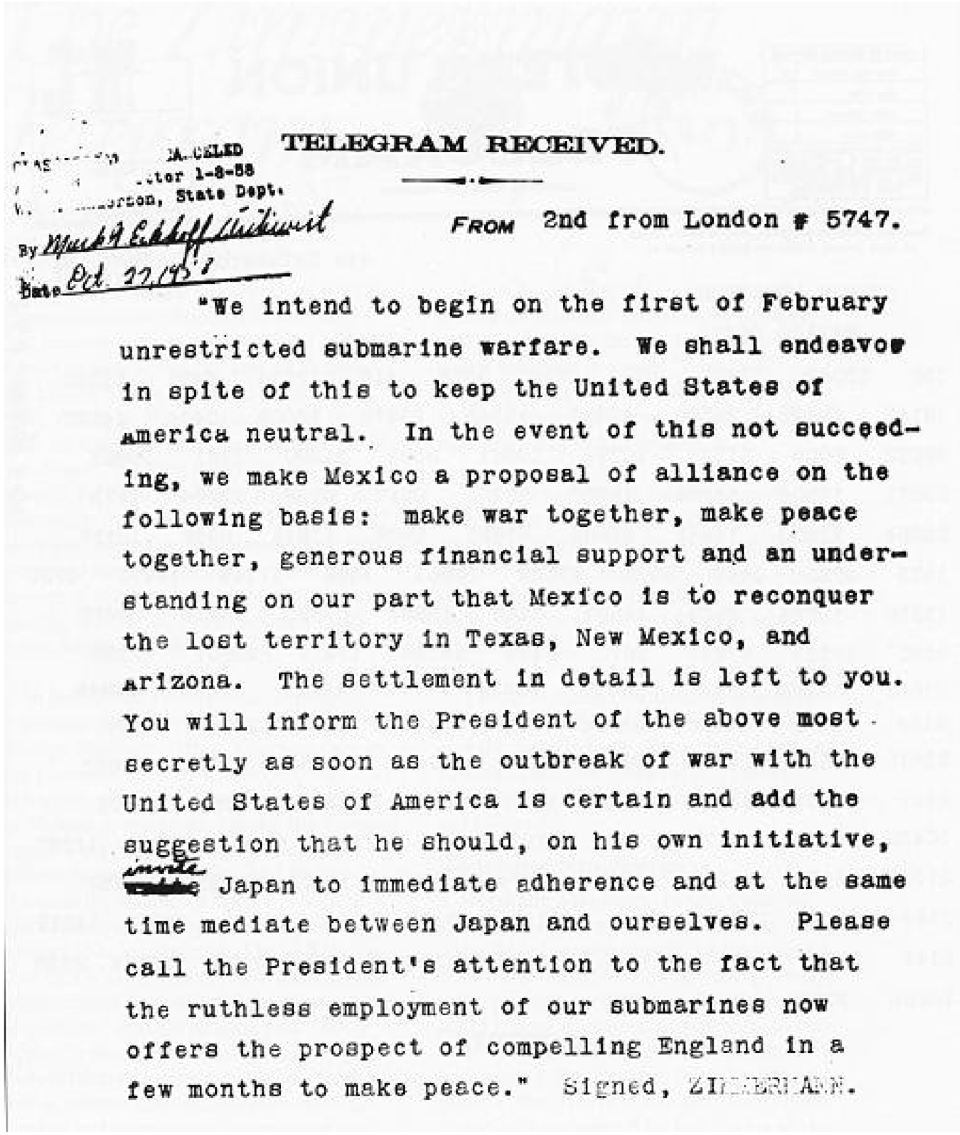
```
130    13042  13401  8501   115    3528   416    17214  6491   11310
18147  18222  21560  10247  11518  23677  13605  3494   14936
98092  5905   11311  10392  10371  0302   21290  5161   39695
23571  17504  11269  18276  18101  0317   0228   17694  4473
23284  22200  19452  21589  67893  5569   13918  8958   12137
1333   4725   4458   5905   17166  13851  4458   17149  14471  6706
13850  12224  6929   14991  7382   15857  67893  14218  36477
5870   17553  67893  5870   5454   16102  15217  22801  17138
21001  17388  7446   23638  18222  6719   14331  15021  23845
3156   23552  22096  21604  4797   9497   22464  20855  4377
23610  18140  22260  5905   13347  20420  39689  13732  20667
6929   5275   18507  52262  1340   22049  13339  11265  22295
10439  14814  4178   6992   8784   7632   7357   6926   52262  11267
21100  21272  9346   9559   22464  15874  18502  18500  15857
2188   5376   7381   98092  16127  13486  9350   9220   76036  14219
5144   2831   17920  11347  17142  11264  7667   7762   15099  9110
10482  97556  3569   3670
```

BERNSTORFF.

Charge German Embassy.

Zimmerman Telegram Decrypted

- British had recovered partial codebook
- Able to fill in missing parts



...ASSIFIED
...ter 1-8-58
...arson, State Dept.

By

Date Oct. 22, 1917

TELEGRAM RECEIVED.

FROM 2nd from London # 5747.

"We intend to begin on the first of February unrestricted submarine warfare. We shall endeavor in spite of this to keep the United States of America neutral. In the event of this not succeeding, we make Mexico a proposal of alliance on the following basis: make war together, make peace together, generous financial support and an understanding on our part that Mexico is to reconquer the lost territory in Texas, New Mexico, and Arizona. The settlement in detail is left to you. You will inform the President of the above most secretly as soon as the outbreak of war with the United States of America is certain and add the suggestion that he should, on his own initiative, invite Japan to immediate adherence and at the same time mediate between Japan and ourselves. Please call the President's attention to the fact that the ruthless employment of our submarines now offers the prospect of compelling England in a few months to make peace." Signed, ZIMMERMANN.

A Few Historical Items

- Crypto timeline
- Spartan Scytale —transposition cipher
- Caesar's cipher
- Poe's *The Gold Bug*
- Election of 1876

Election of 1876

- “Rutherfraud” Hayes vs “Swindling” Tilden
  - Popular vote was virtual tie
- Electoral college delegations for 4 states (including Florida) in dispute
- Commission: All 4 states to Hayes
- Tilden accused Hayes of bribery
  - Was it true?

Election of 1876

- Encrypted messages by Tilden supporters later emerged
- Cipher: Partial codebook, plus transposition
- Codebook substitution for important words

ciphertext	**plaintext**
Copenhagen	Greenbacks
Greece	Hayes
Rochester	votes
Russia	Tilden
Warsaw	telegram
:	:

Election of 1876

- Apply codebook to original message
- Pad message to multiple of 5 words (total length, 10,15,20,25 or 30 words)
- For each length, a fixed permutation applied to resulting message
- Permutations found by comparing many messages of same length
- Note that the **same key** is applied to all messages of a given length

Election of 1876

- ❑ Ciphertext: **Warsaw they read all unchanged last are idiots can't situation**
- ❑ Codebook: Warsaw == telegram
- ❑ Transposition: 9,3,6,1,10,5,2,7,4,8
- ❑ Plaintext: **Can't read last telegram. Situation unchanged. They are all idiots.**
- ❑ A weak cipher made worse by reuse of key
- ❑ **Lesson: Don't reuse/overuse keys!**

Early 20th Century

- WWI —Zimmerman Telegram
- "Gentlemen do not read each other's mail" — Henry L. Stimson, Secretary of State, 1929
- WWII —golden age of cryptanalysis
  - Midway/Coral Sea
  - Japanese **Purple** (codename **MAGIC**)
  - German **Enigma** (codename **ULTRA**)

Post-WWII History

- ❑ Claude Shannon —father of the science of information theory
- ❑ Computer revolution —lots of data
- ❑ Data Encryption Standard (DES), 70's
- ❑ Public Key cryptography, 70's
- ❑ CRYPTO conferences, 80's
- ❑ Advanced Encryption Standard (AES), 90's
- ❑ Crypto moved out of classified world

Claude Shannon

- The founder of Information Theory
- 1949 paper: *Comm. Thy. of Secrecy Systems*
- Confusion and diffusion
  - **Confusion** —obscure relationship between plaintext and ciphertext
  - **Diffusion** —spread plaintext statistics through the ciphertext
  - Proved that one-time pad is secure
  - One-time pad only uses confusion, while double transposition only uses diffusion

Taxonomy of Cryptography

- **Symmetric Key**
  - Same key for encryption as for decryption
  - Stream ciphers
  - Block ciphers
- **Public Key**
  - Two keys, one for encryption (public), and one for decryption (private)
  - Digital signatures —nothing comparable in symmetric key crypto
- **Hash algorithms**

Taxonomy of Cryptanalysis

- ❑ Ciphertext only
- ❑ Known plaintext
- ❑ Chosen plaintext
  - o "Lunchtime attack"
  - o Protocols might encrypt chosen text
- ❑ Adaptively chosen plaintext
- ❑ Related key
- ❑ Forward search (public key crypto only)
- ❑ Etc., etc.

Next time ...

Symmetric Key Crypto