Characters: simple cryptographic algorithms
Lecture 09

Waterford Institute of Technology

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Presentation outline

Estimated duration presentation

Questions at end presentation

Topics discussed:

- Character encoding
  - ASCII
  - ANSII
  - Unicode
- Caesar cipher
- Vigenere cipher
- One time pad

Character encoding

Brief description

- Method to represent character in computing systems
- Character referred to as code point
- Example: letter A typically represented by decimal 65 (0x41)

```
char ch = 'A'; // print ch -> outputs A
byte chb = (byte)ch; // print chb -> outputs 65
```

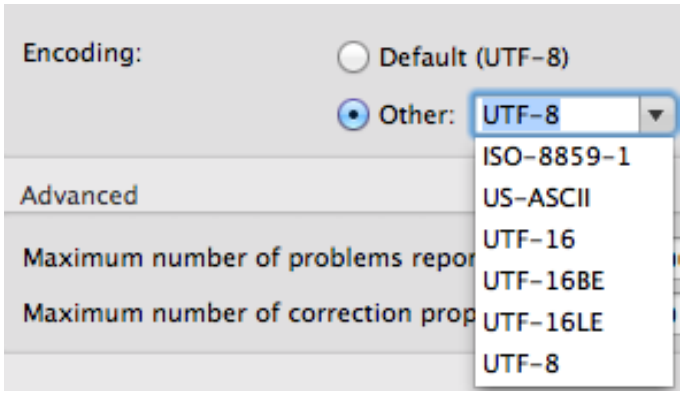
String object

Closely coupled to its encoding

String display:

- Essential to choose suitable character encoding.
- Example ISO/IEC 8859-1 does not contain € symbol.

```
<?xml version="1.0" encoding="UTF-8"?>
```



String object

BlueJ editor: effect different character encodings

UTF-8

```
public class Encoding
{
    public static String euroSymbol = "€";

    public static void euroSymbol()
    {
        System.out.println("Euro symbol: " + euroSymbol);
    }
}
```

ISO-8859-1

```
public class Encoding
{
    public static String euroSymbol = "â ¬";

    public static void euroSymbol()
    {
        System.out.println("Euro symbol: " + euroSymbol);
    }
}
```

Character encoding standards

Hisorical perspective

- EBCDIC (IBM)
- ASCII (128 characters)
  - May be stored in 7 bits
  - Storable in primitive **byte**
  - Contains 95 printable characters
  - Remaining 33 non-printable
- ANSI (a misnomer)
  - May be stored in 8 bits
  - First 7 same as ASCII
  - Term used for several encodings
- Unicode
  - Computing industry standard for the consistent encoding,

$$[A - Z] \rightarrow [65 - 90]$$
$$[a - z] \rightarrow [97 - 122]$$

Character encoding standards

Choose your favourite term

Code page : alternative names

- codepage
- encoding
- charset
- character set
- coded character set (CCS)
- graphic character set
- character map

Unicode

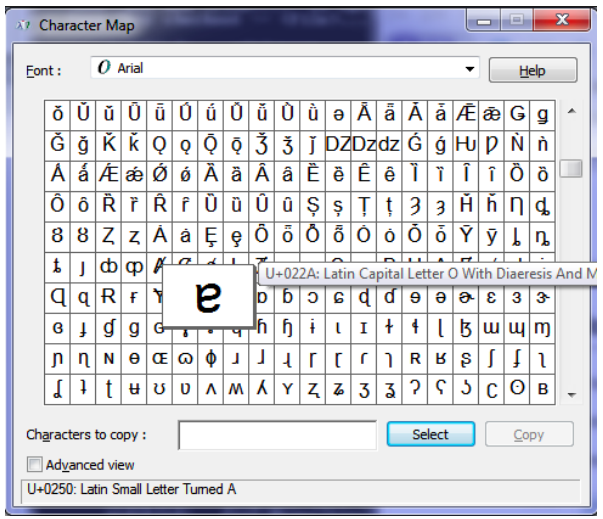
Computing industry encoding standard

Unicode 8.0 (2015)

- more than 120,000 characters
- 129 modern and historic scripts

Unicode implementations

- Unicode transformation format (UTF)
- UTF-8, UTF-16, UTF-32
- UTF-8 uses one byte for any ASCII



Character manipulation

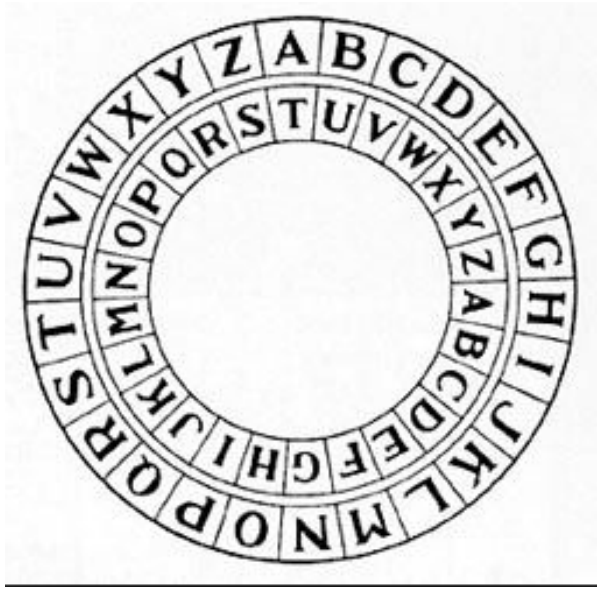
Caesar cipher: a substitution cipher (no key)

Terminology

- Message text or plain text
- Cipher text: encrypted plain text
- Key: integral to encrypt decrypt

Encryption & Decryption

- Encrypt: shift plain text character
- Example: shift by 3 thus A becomes D
- Arithmetic operations on char valid



Caesar Cipher

Plain text comprises only upper case letters in this example

- The fields

```
public class CaesarCipher {
  // The number of characters to shift
  int shift;
  // Defines the printable range of ASCII characters
  private int minAsciiUpper = 65;
  private int maxAsciiUpper = 90;
  ...
}
```

Caesar Cipher

Plain text comprises only upper case letters in this example

- The constructor

```
/**
 * Constructs a CaesarCipher object
 *
 * @param shift A positive digit by which to shift plain text.
 */
public CaesarCipher(int shift)
{
  this.shift = Math.abs(shift);
}
```

Caesar Cipher

Plain text comprises only upper case letters in this example

- Encrypt string

```
/**
 * Encrypts the plain text string using helper method
 * Helper method: char encrypt(char ch)
 * @param The plaintext string
 * @return The ciphertext: encrypted plaintext
 */
String encrypt(String string)
{
  char[] chars = string.toCharArray();
  char[] encryptedChars = new char[chars.length];
  for (int i = 0; i < chars.length; i += 1) {
    encryptedChars[i] = encrypt(chars[i]);
  }
  return new String(encryptedChars);
}
```

Caesar Cipher

Plain text comprise only upper case letters

- Encrypt single character

```
/**
 * Encrypts a single character
 * @param ch The plaintext character
 * @return The encrypted character
 */
private char encrypt(char ch) {
  int encryptedChar = ch + shift;
  if (encryptedChar > maxAsciiUpper) {
      encryptedChar = minAsciiUpper + encryptedChar % maxAsciiUpper - 1;
  }
  return (char)encryptedChar;
}
```

Caesar Cipher

Plain text comprise only upper case letters

- Decrypt string

```
/**
 * Decrypts the plain text string using helper method
 * Helper method: char decrypt(char ch)
 * @param The ciphertext string
 * @return The plaintext: decrypted plaintext
 */
String decrypt(String string)
{
  char[] chars = string.toCharArray();
  char[] encryptedChars = new char[chars.length];
  for (int i = 0; i < chars.length; i += 1) {
    decryptedChars[i] = decrypt(chars[i]);
  }
  return new String(decryptedChars);
}
```

Caesar Cipher

Plain text comprise only upper case letters

- Decrypt single character

```
/**
 * Decrypts a single character
 * @param ch The ciphertext character
 * @return The decrypted character
 */
 char decrypt(char ch) {
    int range = maxAsciiUpper - minAsciiUpper;
    int decryptedChar = ch + range - shift + 1;
    if (decryptedChar > maxAsciiUpper) {
      decryptedChar = minAsciiUpper + decryptedChar % maxAsciiUpper - 1;
    }
    return (char)decryptedChar;
}
```

Caesar Cipher

Plain text comprise only upper case letters

- A unit test

```
final int NMR_ALPHABET_CHARS = 26;
public static void test {
  // Unit test: The full alphabet range of shifts and then some.
  for (int shift = 1; shift < NMR_ALPHABET_CHARS; shift += 1) {
    CaesarCipher caesarCipher = new CaesarCipher(shift);
    String cipherTxt = caesarCipher.encrypt(plainText);
    String dcryptTxt = caesarCipher.decrypt(cipherTxt);
    if (!dcryptTxt.equals(plainText)) {
      System.out.println("Oh oh: problem at GCHQ");
    }
    else {
      System.out.println("Success using shift " + shift);
    }
  }
}
```

Caesar Cipher

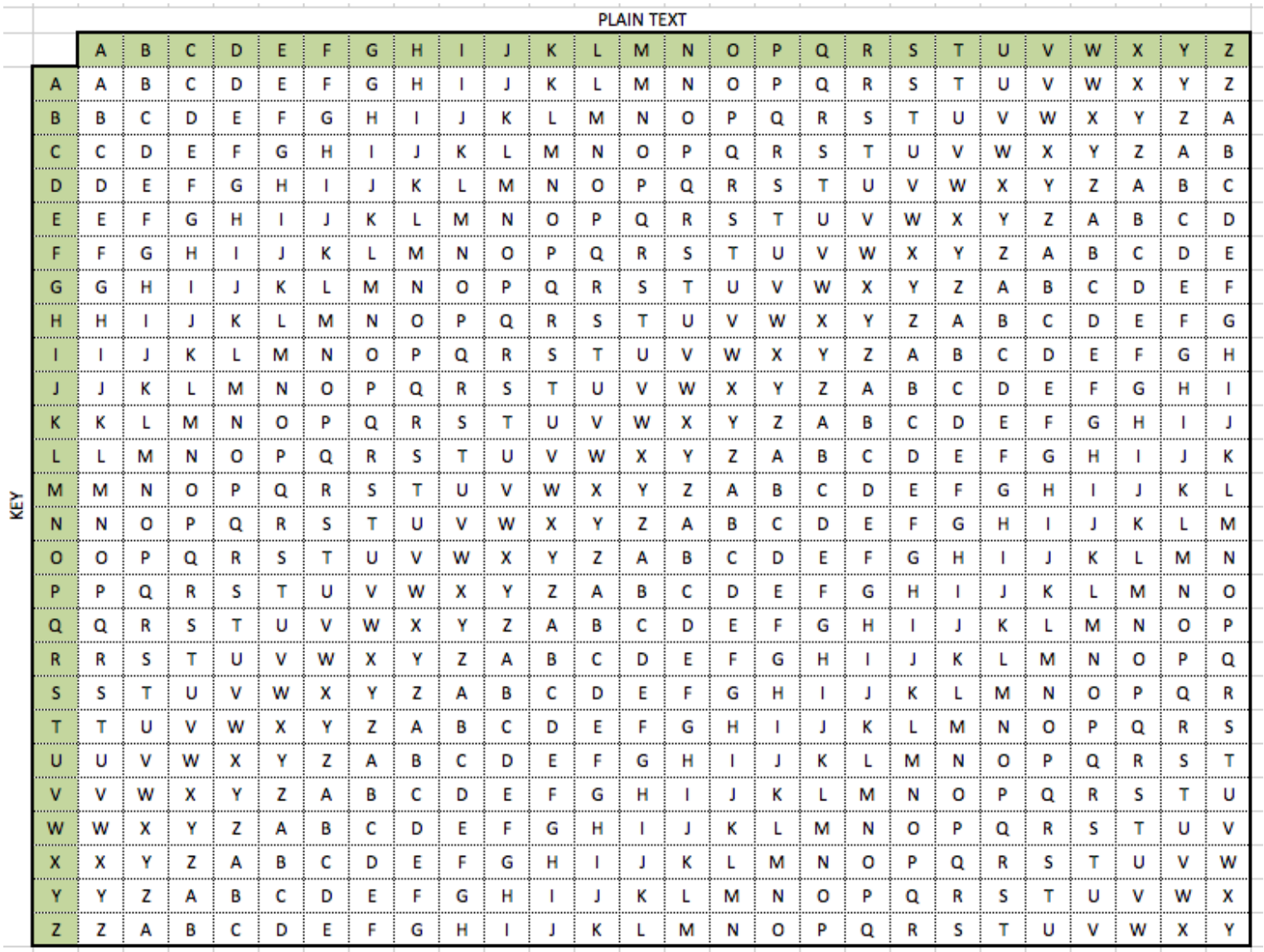
Decryption without knowledge of shift

- Cipher-text only attack
- Very simple this case since only 26 possible values
- Brute-force attack tests all possible shift values
- Easy to refactor existing code

```
// Example brute force attack on ciphertext
// Invoke encrypt to obtain sample ciphertext.
// We then have plaintext against which to check outputs below.
String ciphertext = "GUVFVFNCYNVAGRKGFGEVATVGFHERYLVF";
for (int shift = 1; shift < NMR_ALPHABET_CHARS; shift += 1)
{
  System.out.println(cc.decrypt(ciphertext, shift));
}
```

Vigenere Cipher

Vigenere Table

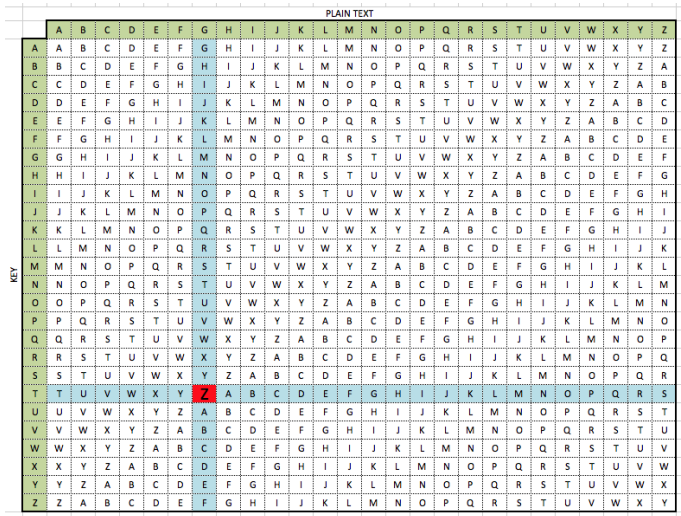


KEY \ PLAIN TEXT	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
B	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
C	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
D	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
E	E	F	G	H	I	J	K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

Vigenere Cipher

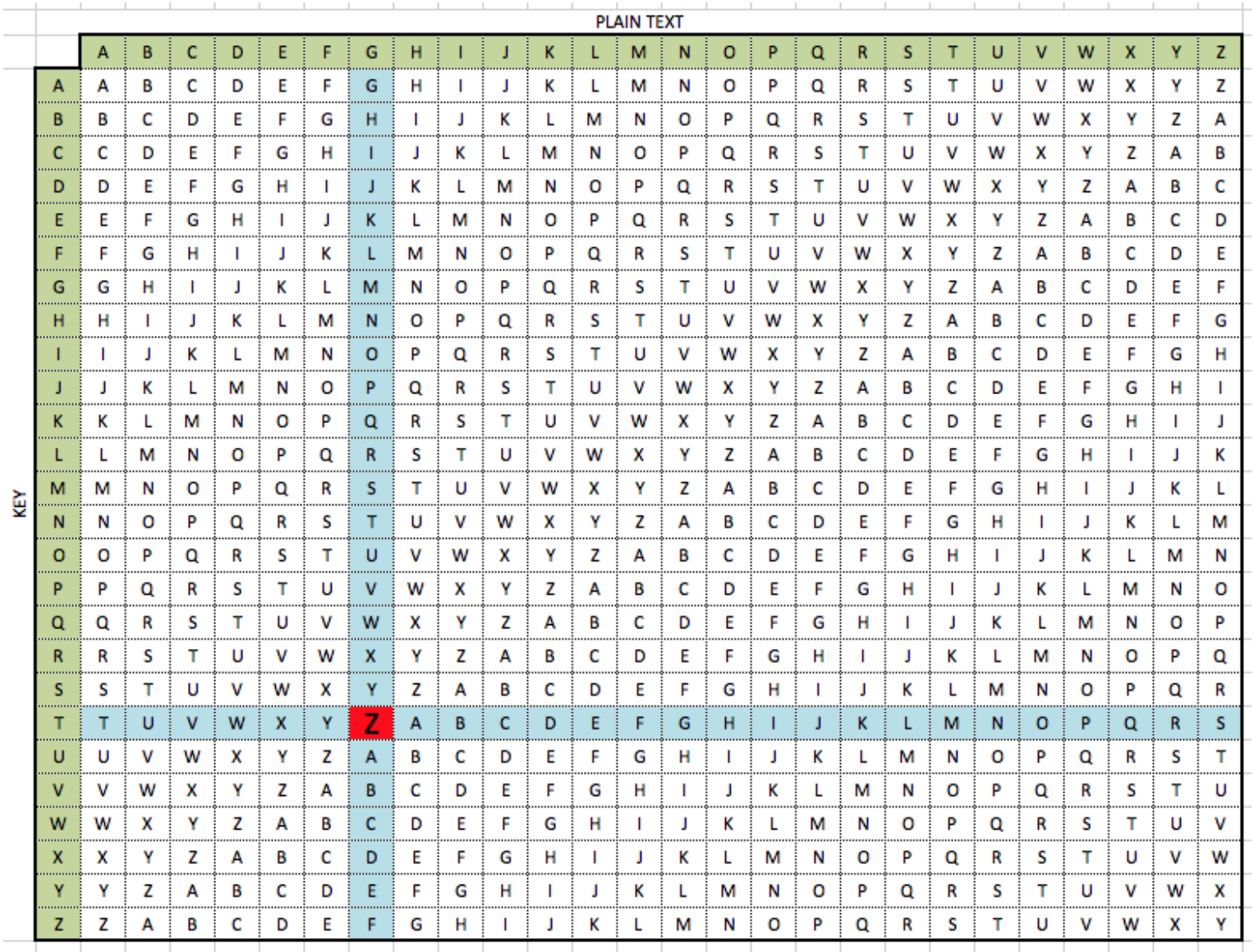
Key length matches plain text

- Plain text
  - VIGENERECIPHEREXAMPLE
- Key same length plaintext
  - ATTACKATDAWNATTACKATD



Vigenere Cipher

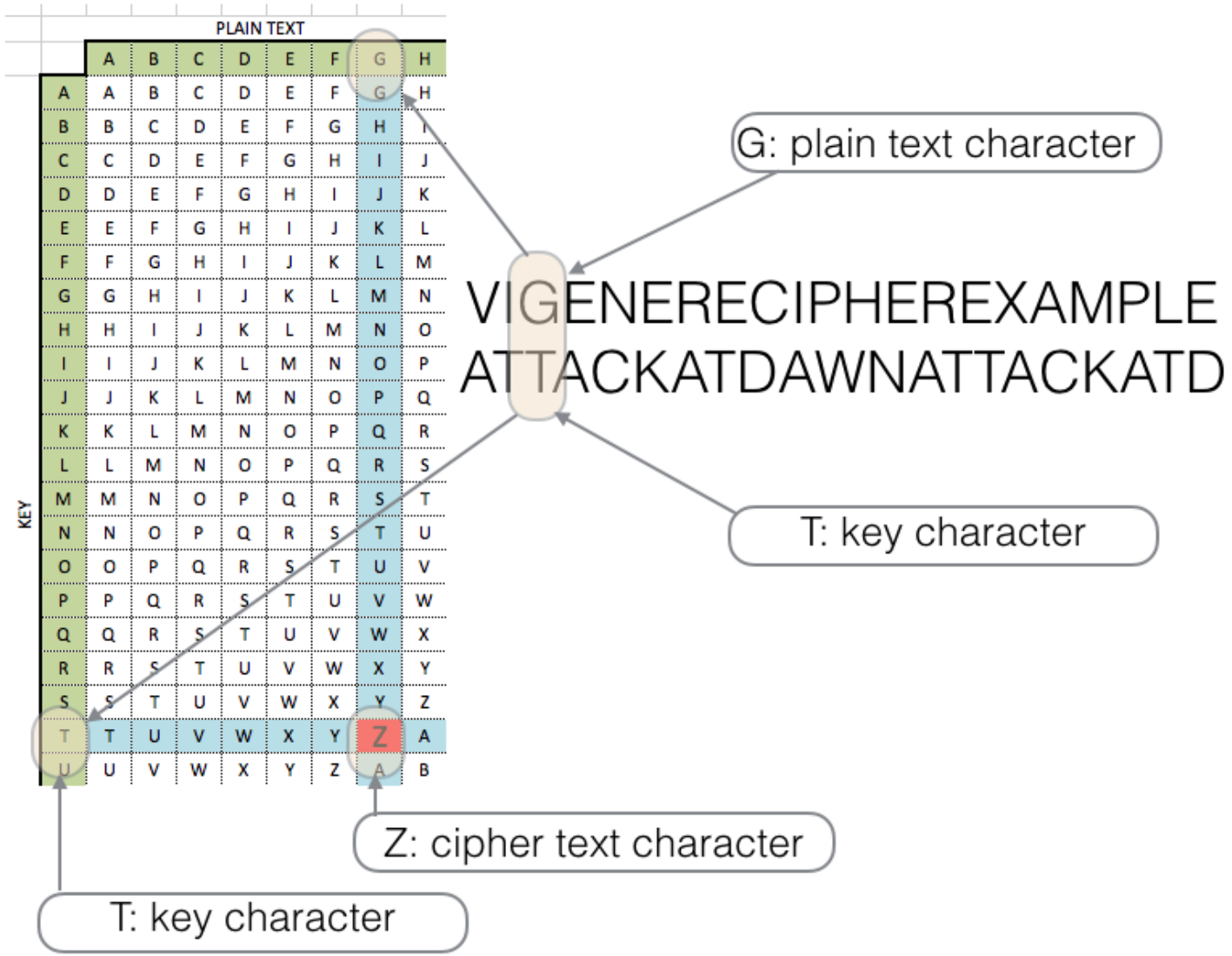
Encryption - Decryption



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

Vigenere Cipher

Encryption - Decryption



One Time Pad

Key same length as plaintext

- m denotes plaintext or message text
- k denotes key
- c denotes the cipher text or encrypted message
- c = m xor k

a	b	a XOR b
0	0	0
0	1	1
1	0	1
1	1	0

m	0	1	1	0	1	1
k	1	0	1	1	0	0
c	1	1	0	1	1	1

One Time Pad

Key same length as plaintext

Observe from table:

- c = m xor k
- m = c xor k

m	0	1	1	0	1	1
k	1	0	1	1	0	0
c	1	1	0	1	1	1
c xor k	0	1	1	0	1	1

One Time Pad

Instantiation

```
public class OneTimePad
{
  byte[] m; // plain text message
  byte[] k; // key
  byte[] c; // cipher text - encrypted message under key
  /**
   * Constructs OneTimePad object
   * Converts message to byte array
   * Generates a secure key
   * Initializes the cipher text byte array
   * @param m The plaintext message
   */
  public OneTimePad(String m)
  {
    this.m = m.getBytes();
    k = new byte[m.length()];
    new SecureRandom().nextBytes(k);
    c = new byte[m.length()];
  }
```

One Time Pad

Encryption

```
/**
 * Encrypts the message
 * @return The cipher text as a byte array
 */
public byte[] encrypt()
{
  for (int i = 0; i < c.length; i++)
  {
    c[i] = (byte) (m[i] ^ k[i]);
  }
  return c;
}
```

One Time Pad

Decryption

```
/**
 * Decrypts the cipher text byte array
 * @return The decrypted byte array
 */
public byte[] decrypt(byte[] ciphertext)
{
  byte[] decrypted = new byte[ciphertext.length];
  for (int i = 0; i < decrypted.length; i+= 1)
  {
    decrypted[i] = (byte) (ciphertext[i] ^ k[i]);
  }
  return decrypted;
}
```

Presentation summary

- Character encoding: UTF-8 a superset of ASCII
- Caesar cipher: gained experience in simple character manipulation
- Vigenere cipher: A more complex character manipulation exercise
- One time pad: Of no practical use but provides insight into gist of encryption using **Exclusive OR** logical operator

Referenced Material

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4. Vigenere Cipher

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[Accessed 2016-02-10]