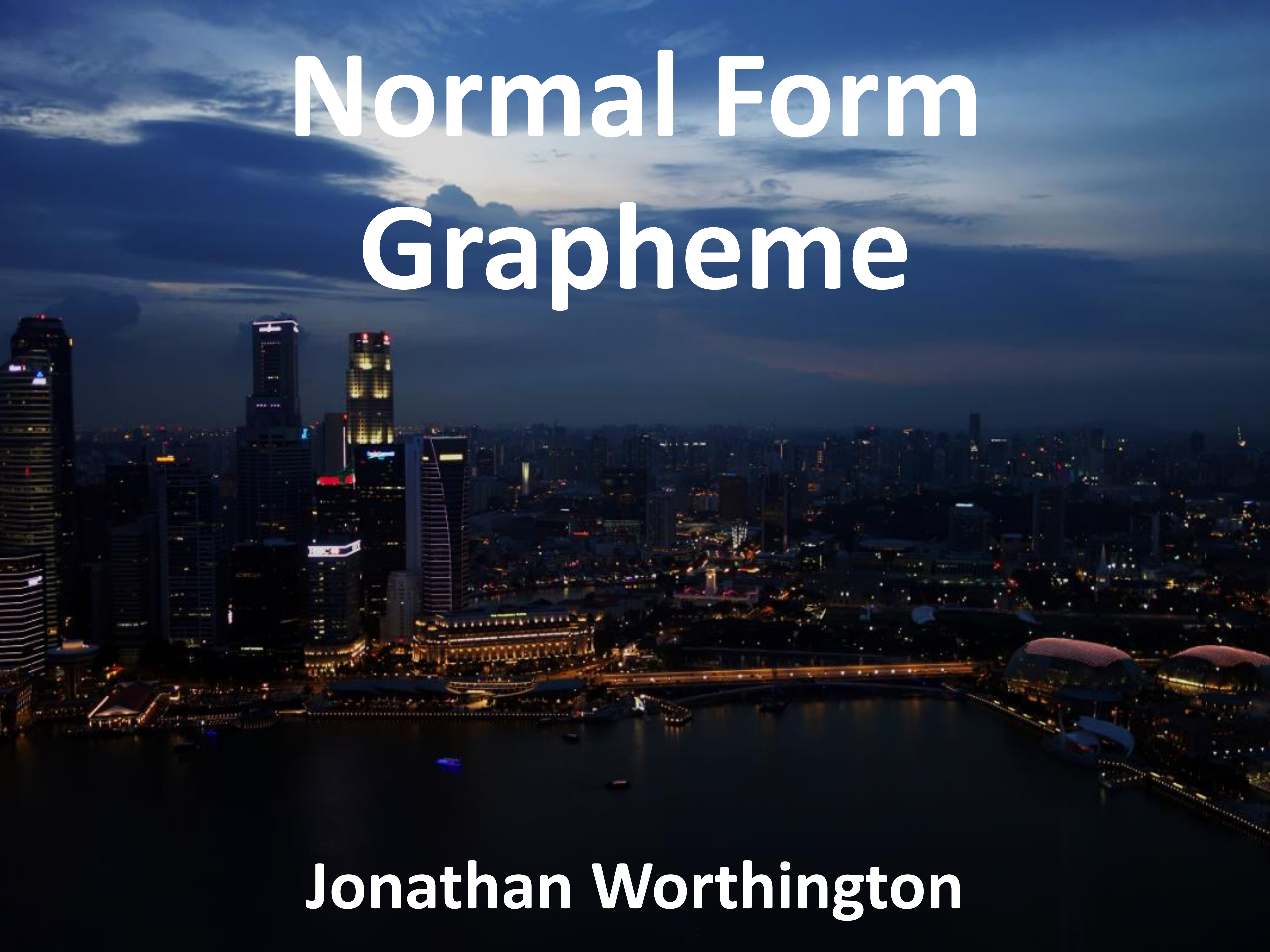


Normal Form Grapheme

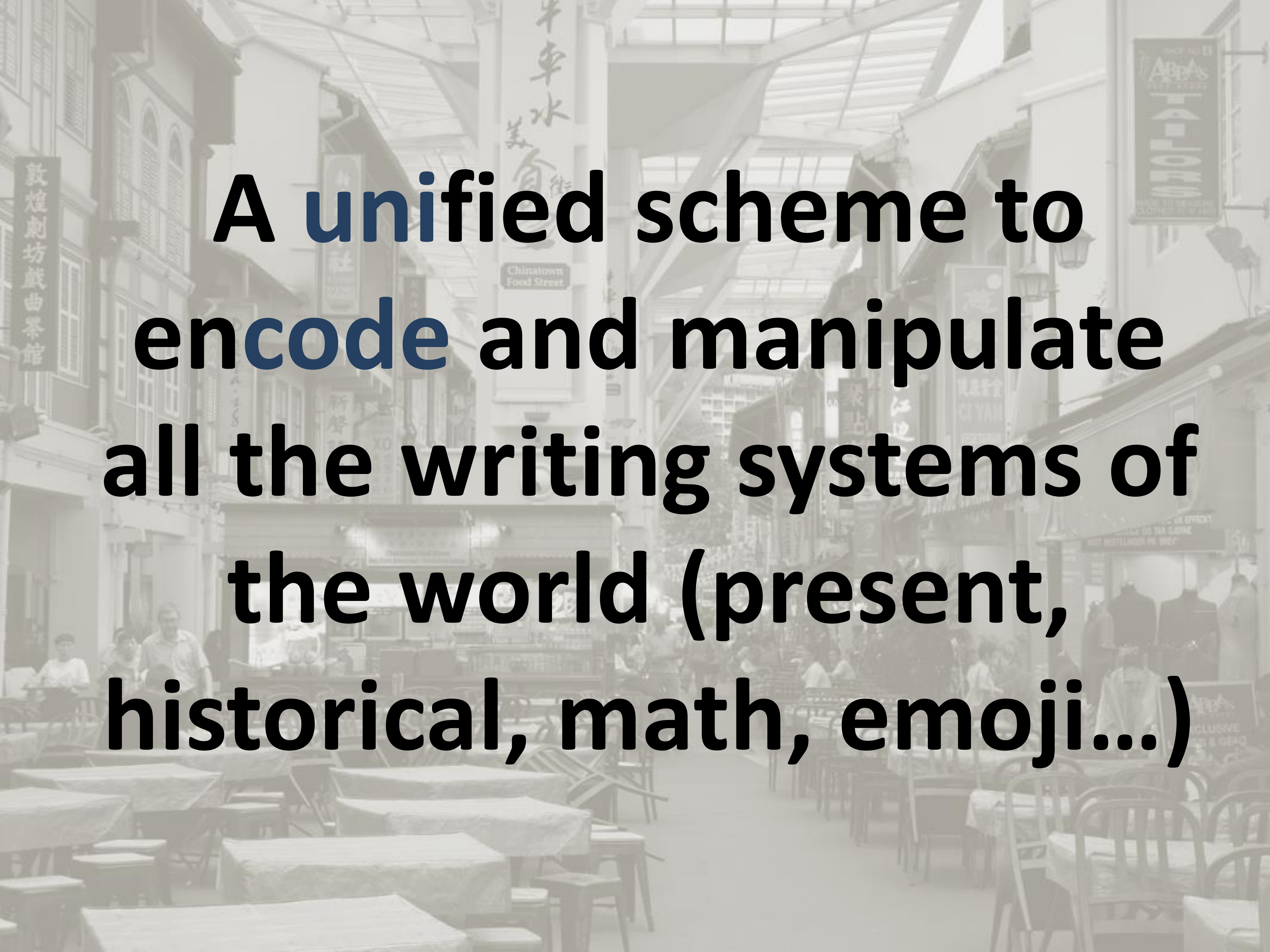
Jonathan Worthington

Hi!

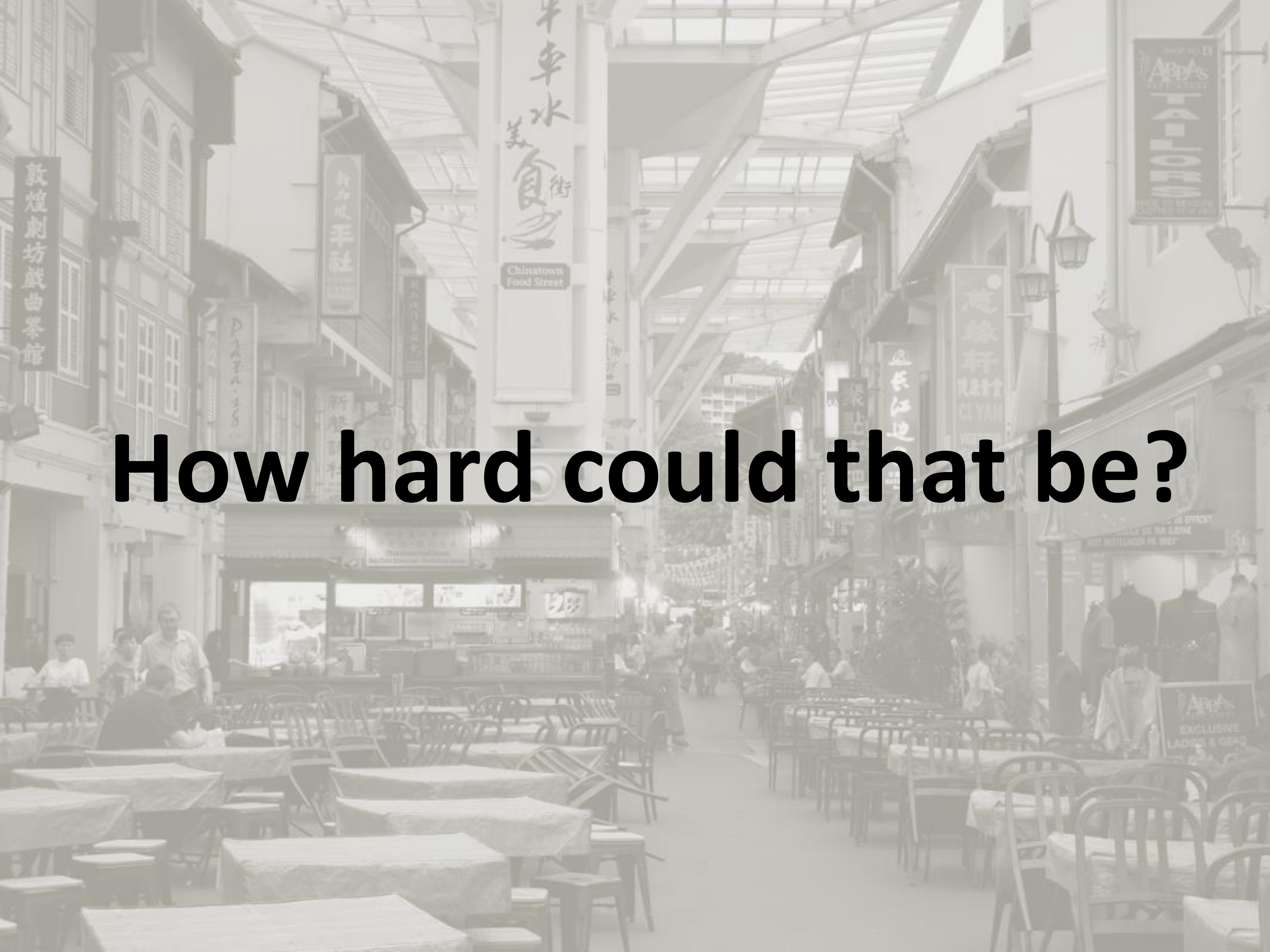
I'm still Jonathan.

Unicode

牛車水美食街
Chinatown Food Street
敦煌劇坊戲曲茶館
新加坡手社
新聲詩社
聚點
長江
慈緣軒
健康素食
CI YAN
VEGETARIAN
ABBAS DEPT STORE
TAILORS
MADE TO MEASURE CLOTHES IN 12 HRS
EXCLUSIVE LADIES & GENT

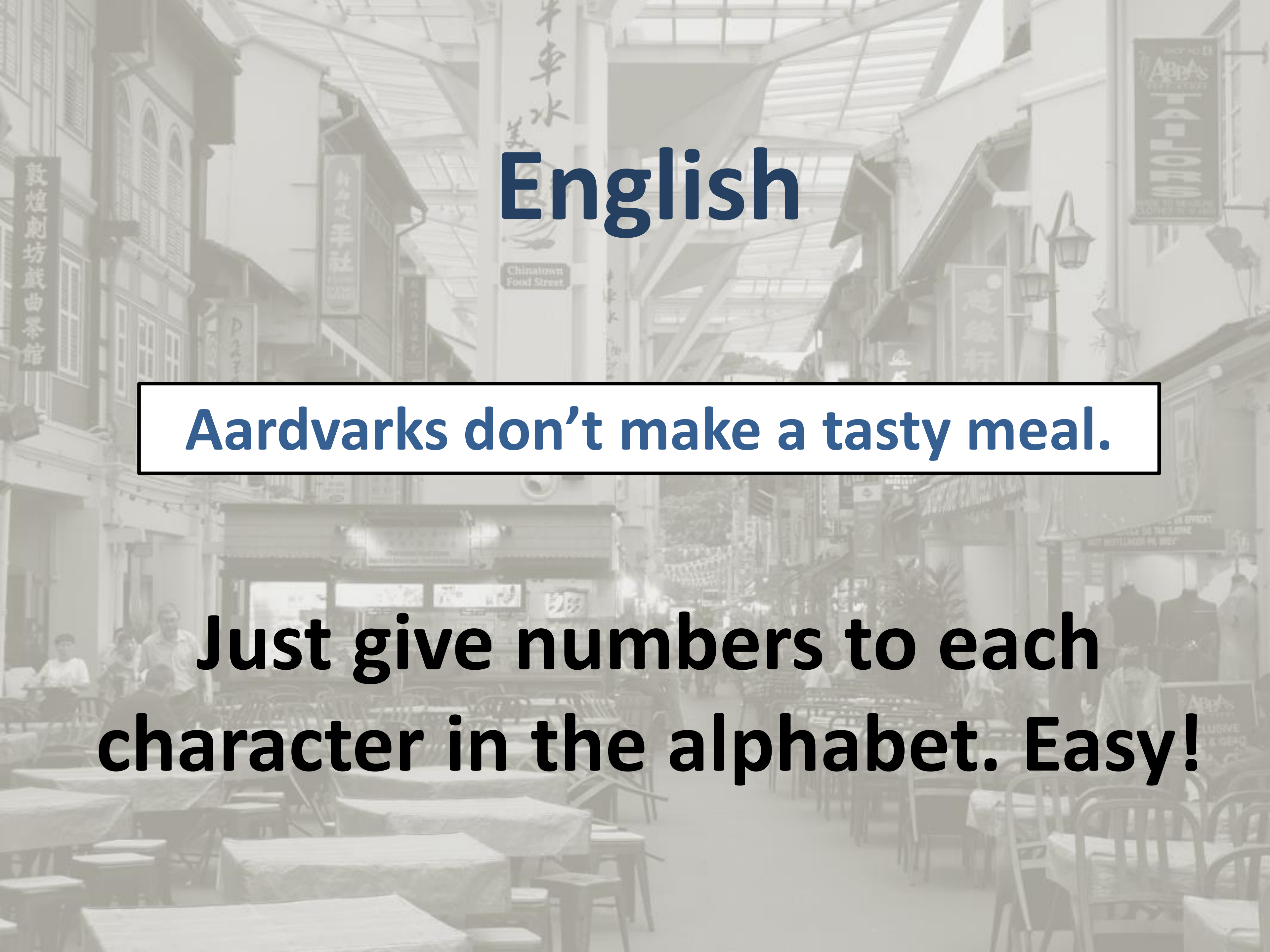


A unified scheme to encode and manipulate all the writing systems of the world (present, historical, math, emoji…)



How hard could that be?

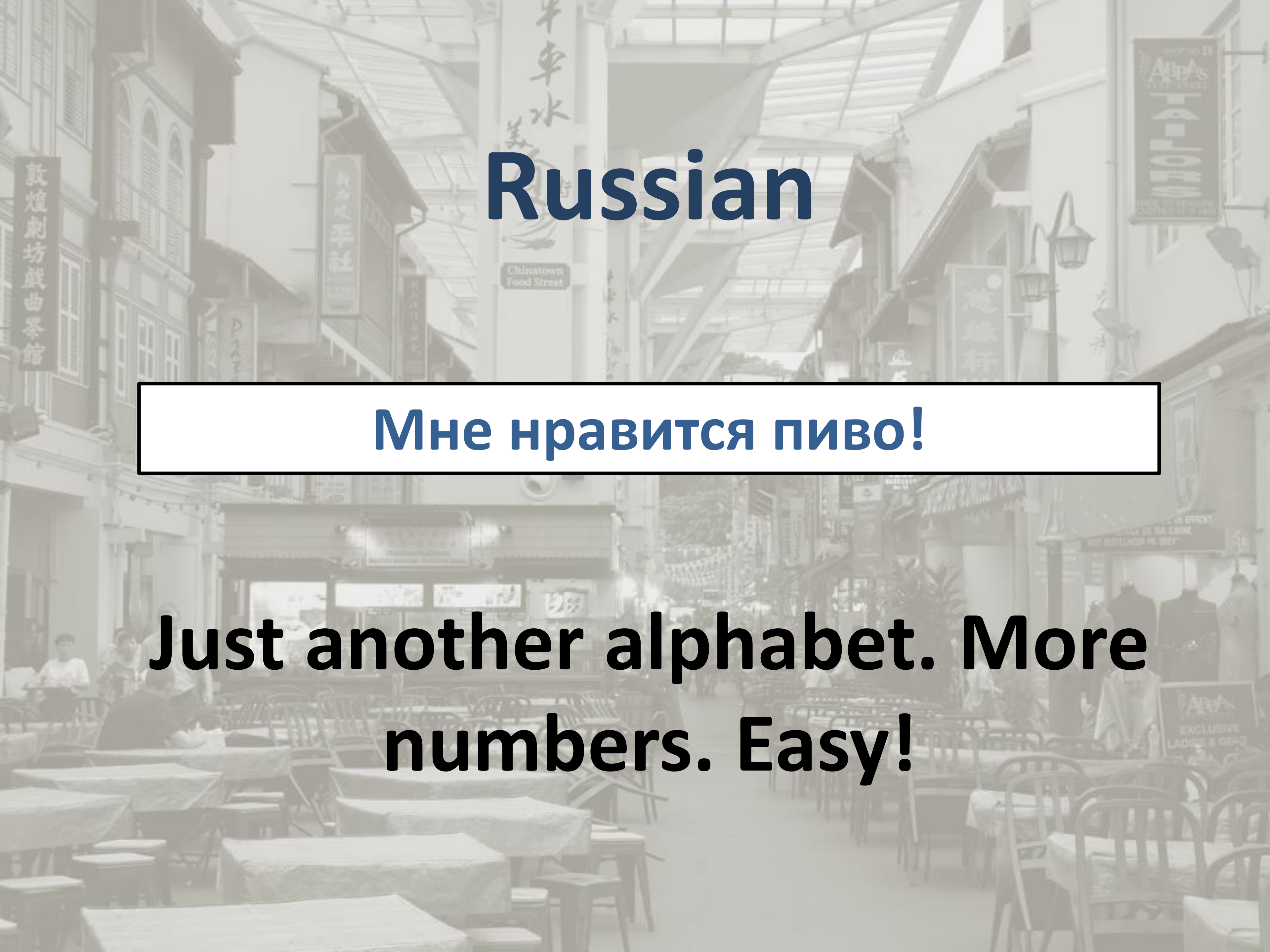
Well, let's look at some languages.



English

Aardvarks don’t make a tasty meal.

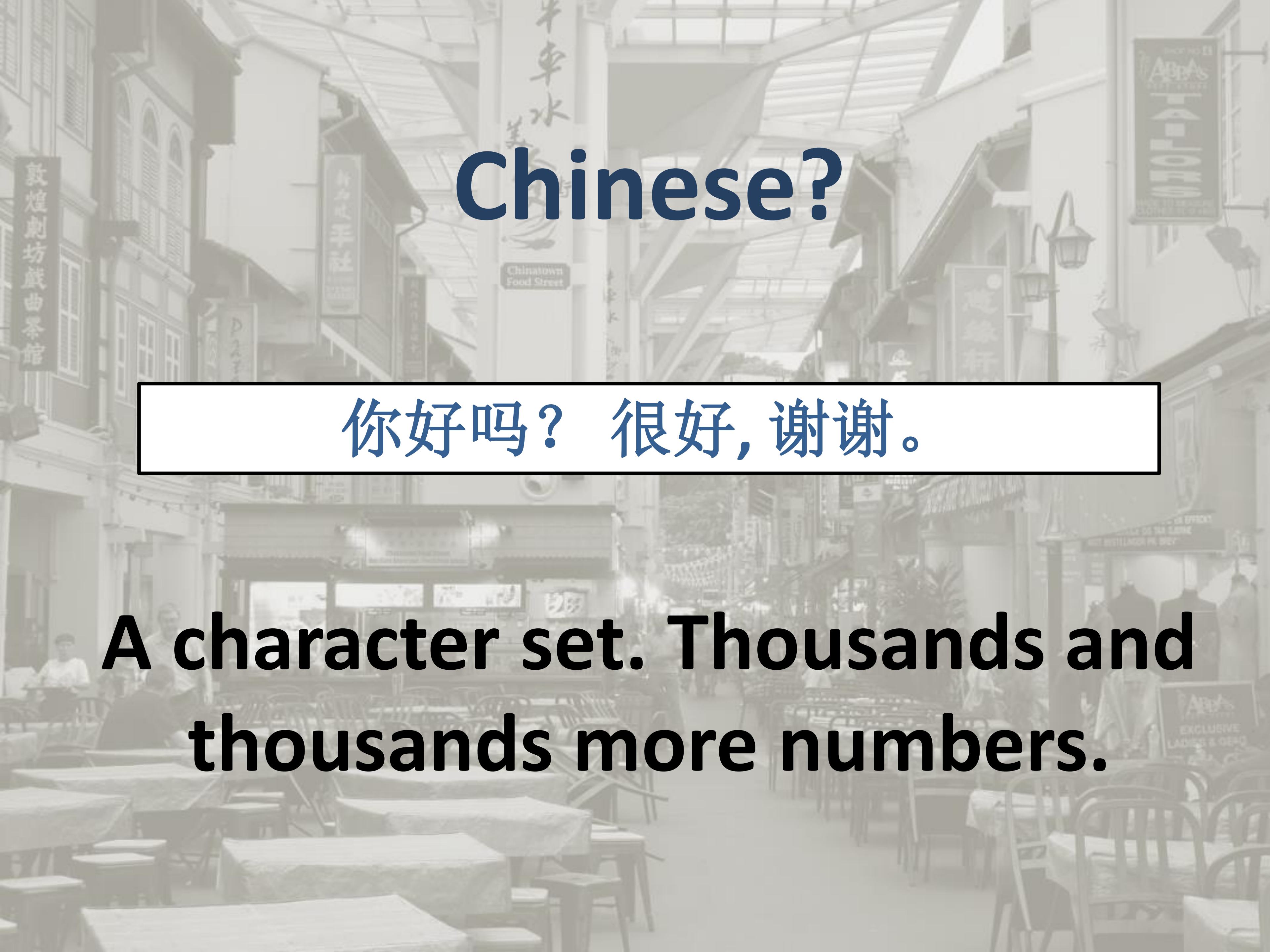
Just give numbers to each character in the alphabet. Easy!



Russian

Мне нравится пиво!

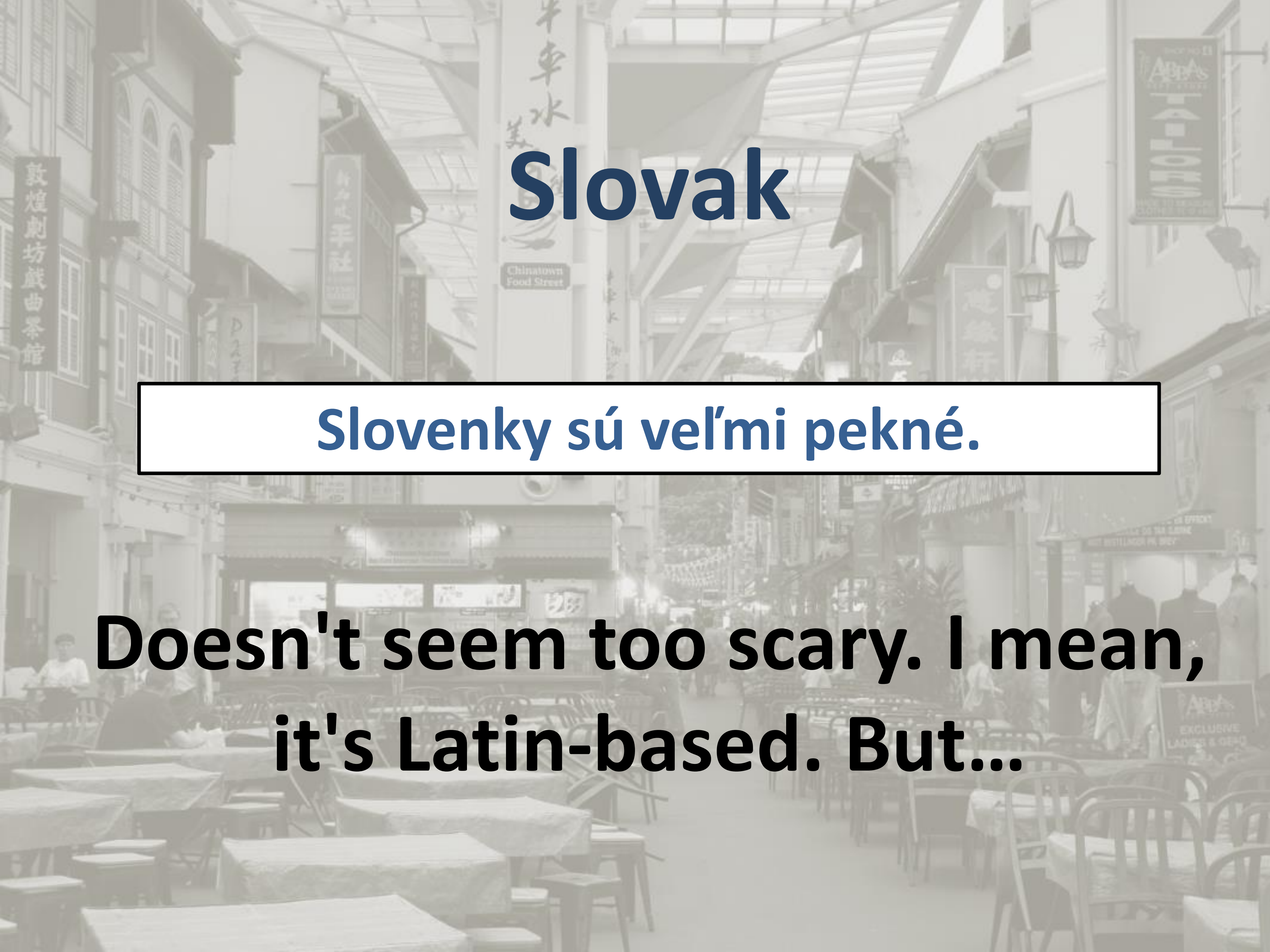
Just another alphabet. More numbers. Easy!



Chinese?

你好吗？ 很好, 谢谢。

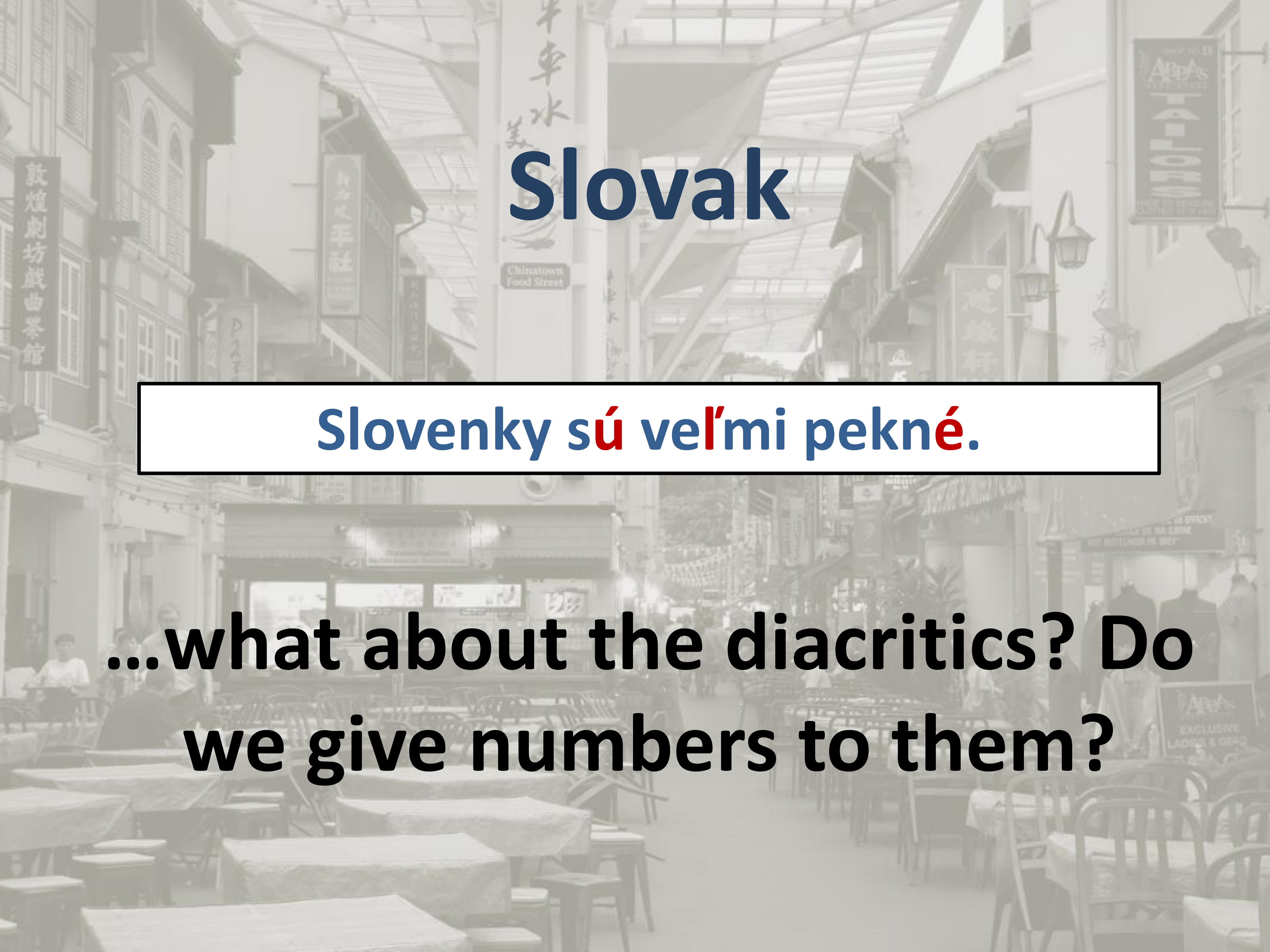
A character set. Thousands and thousands more numbers.



Slovak

Slovenky sú veľmi pekné.

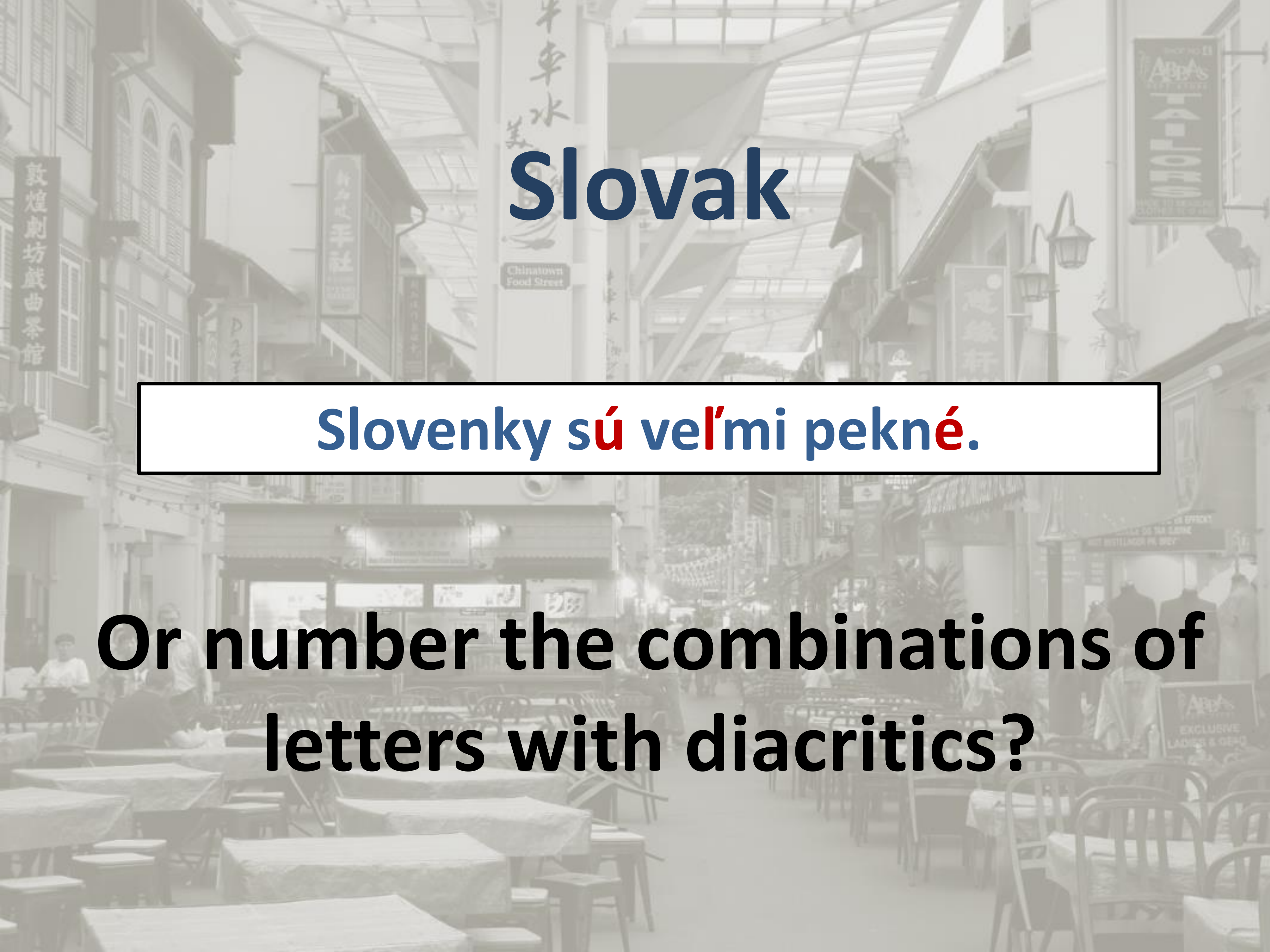
Doesn't seem too scary. I mean, it's Latin-based. But…



Slovak

Slovenky sú veľmi pekné.

…what about the diacritics? Do we give numbers to them?



Slovak

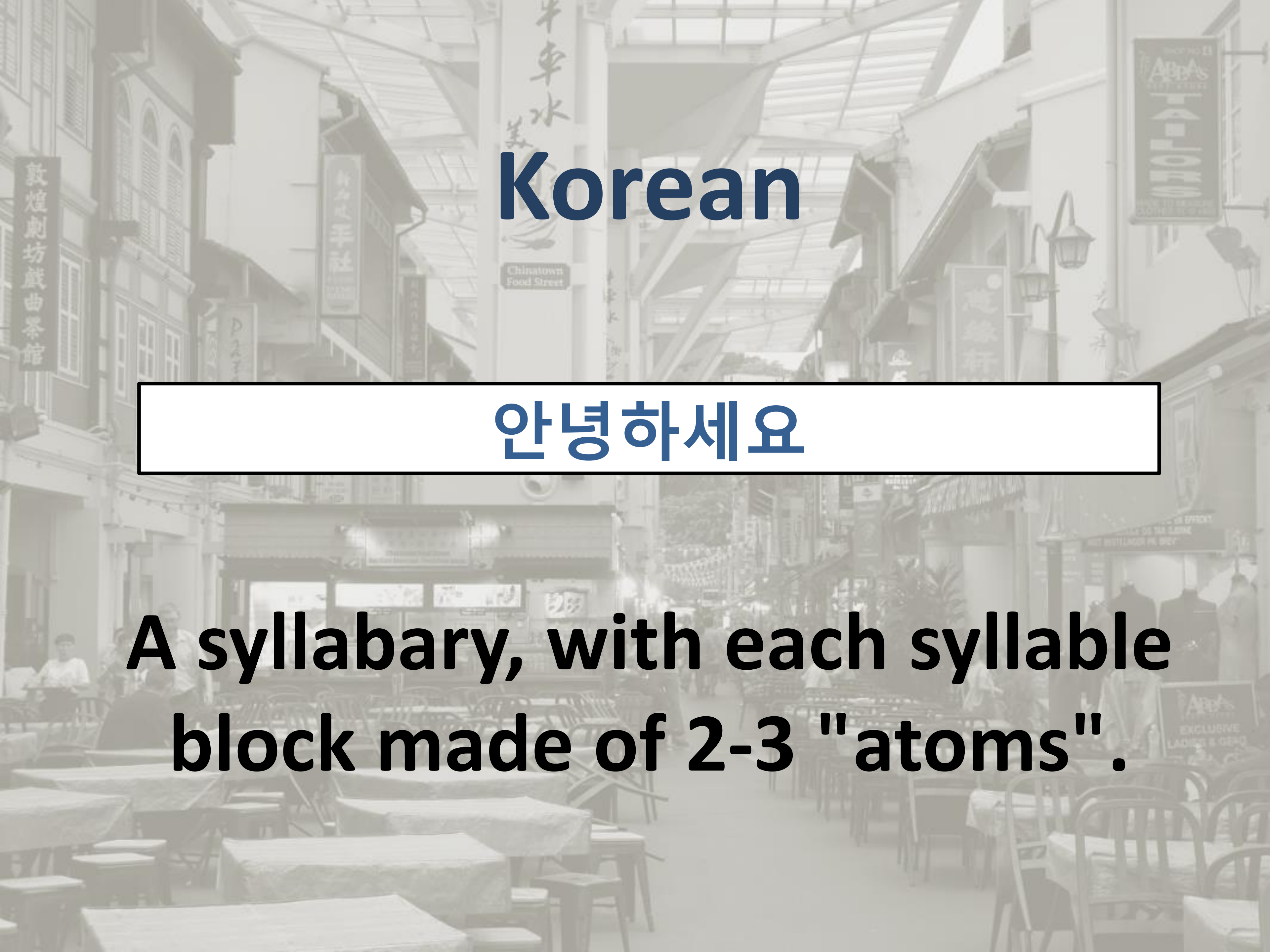
Slovenky sú veľmi pekné.

Or number the combinations of letters with diacritics?

Slovak

Slovenky sú veľmi pekné.

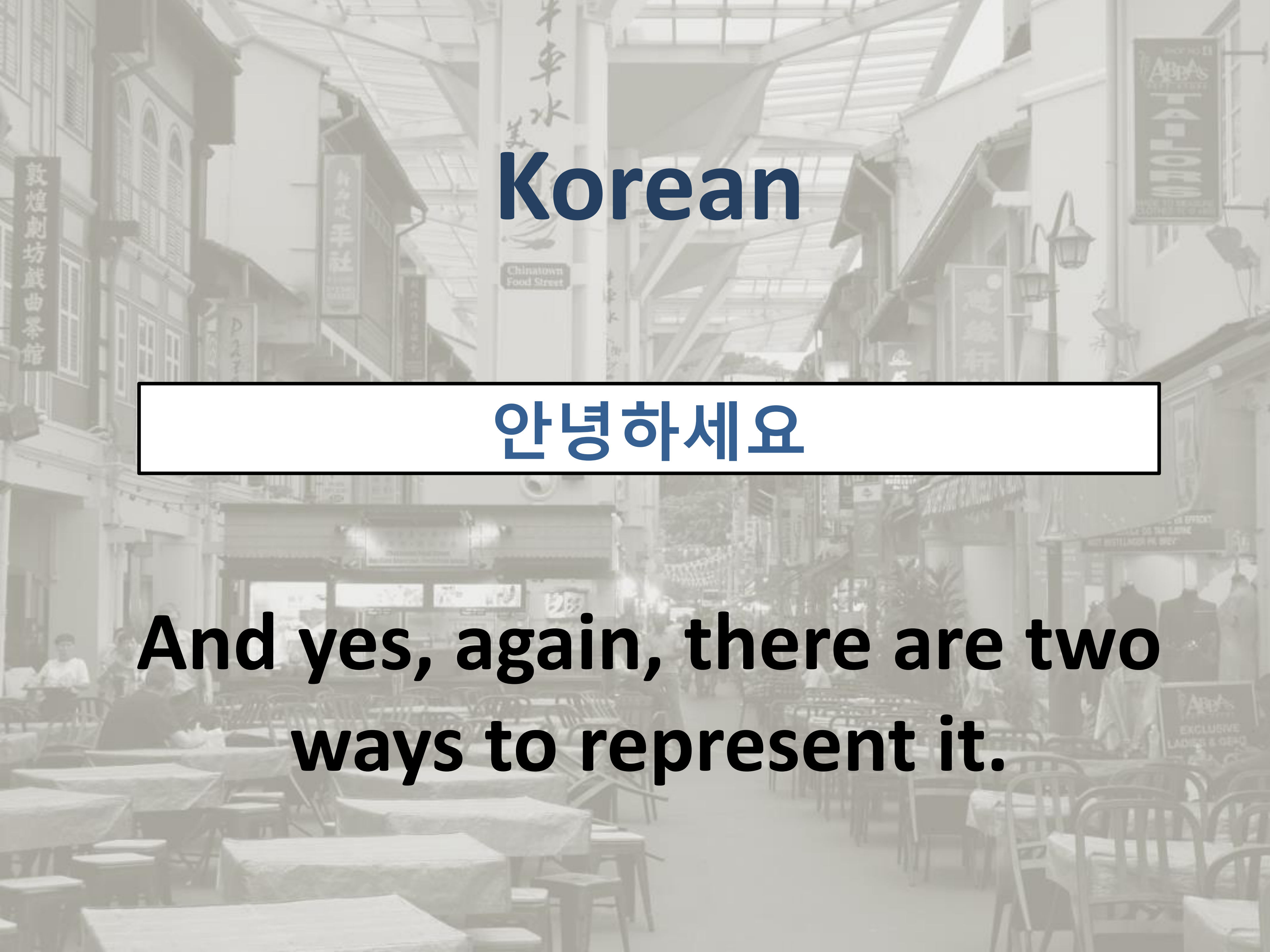
Spoiler: it's Unicode, so of course we…do *both*!



Korean

안녕하세요

A syllabary, with each syllable block made of 2-3 "atoms".

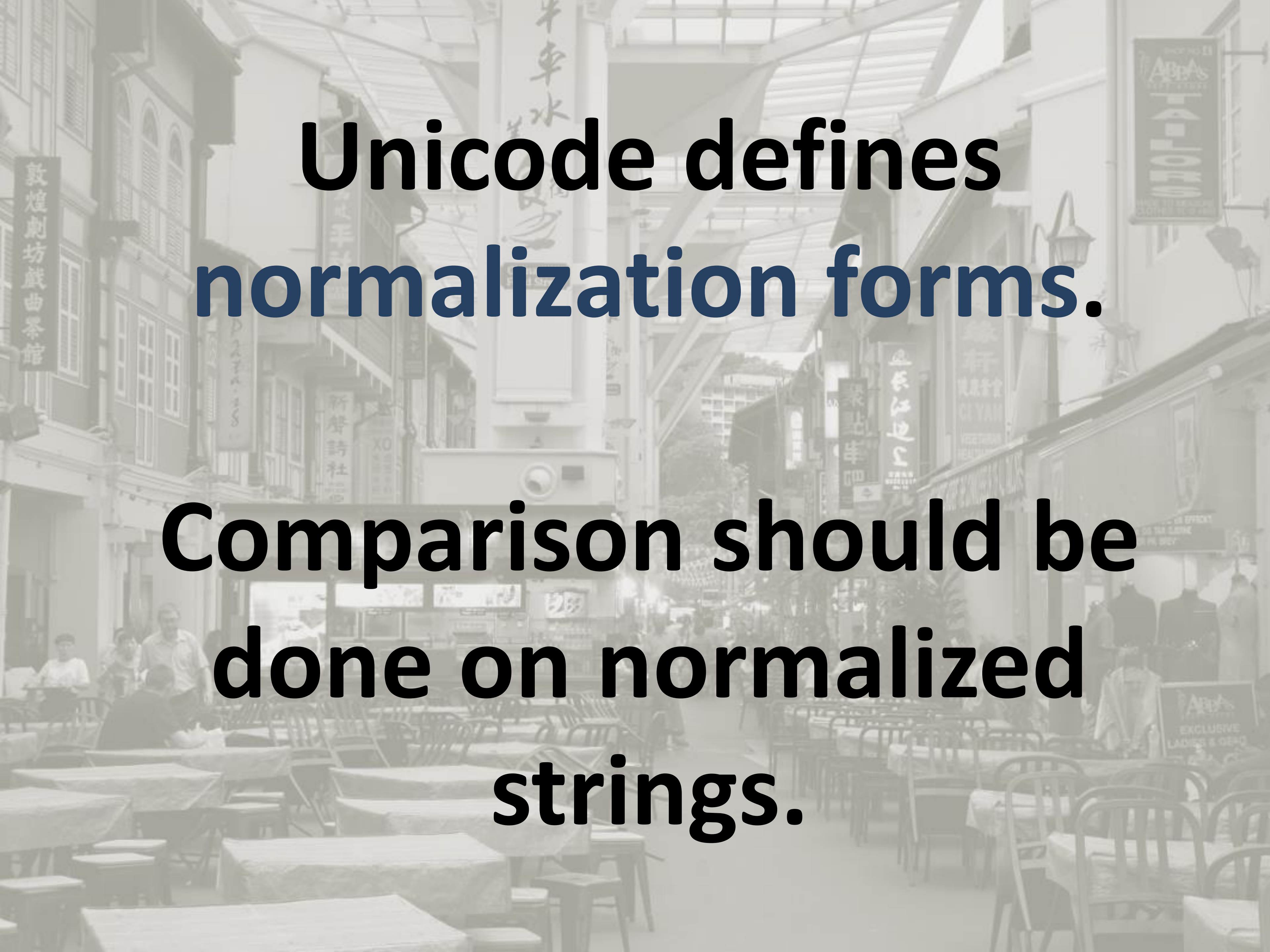


Korean

안녕하세요

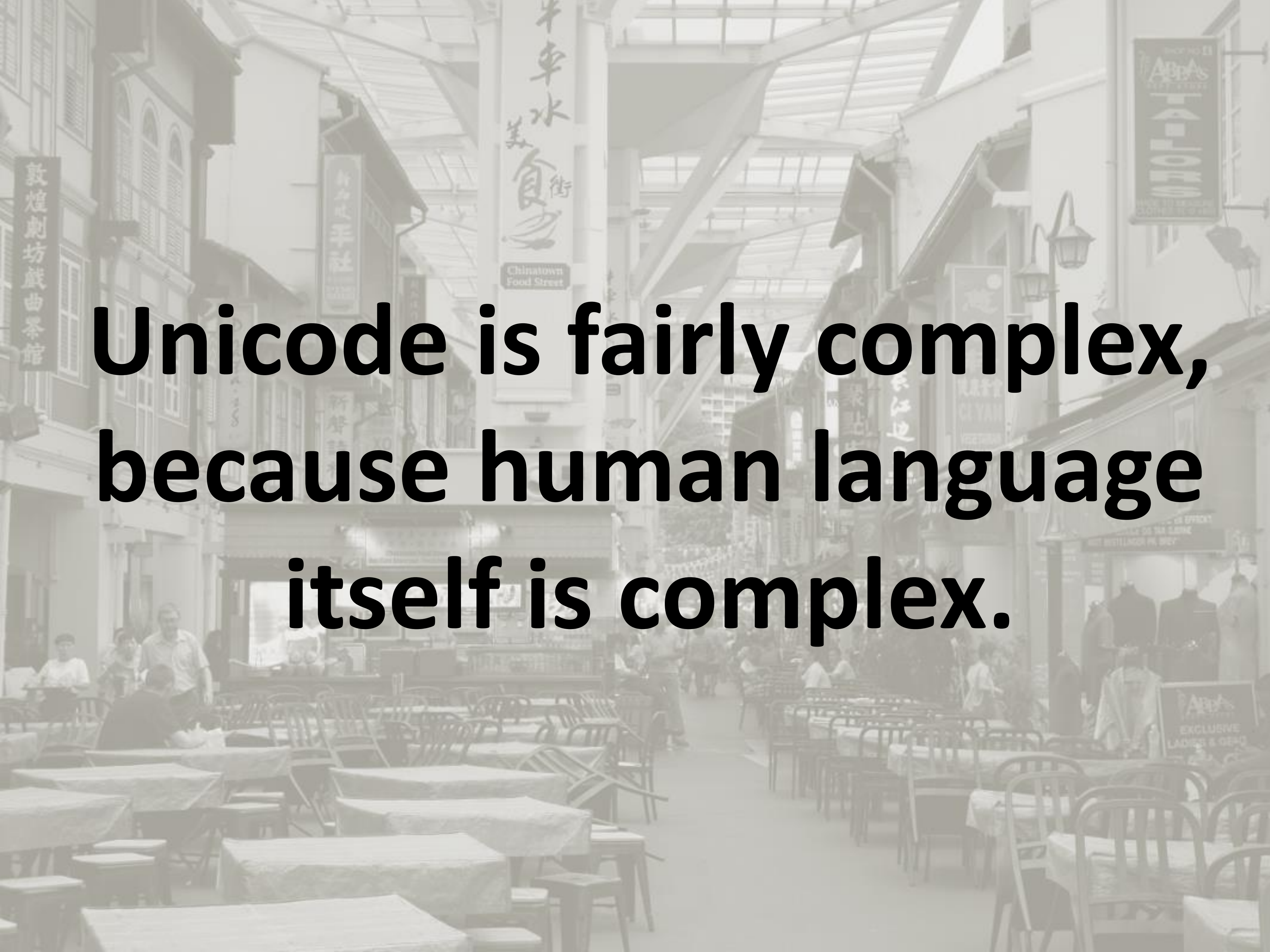
And yes, again, there are two ways to represent it.

So how do we even compare strings?!

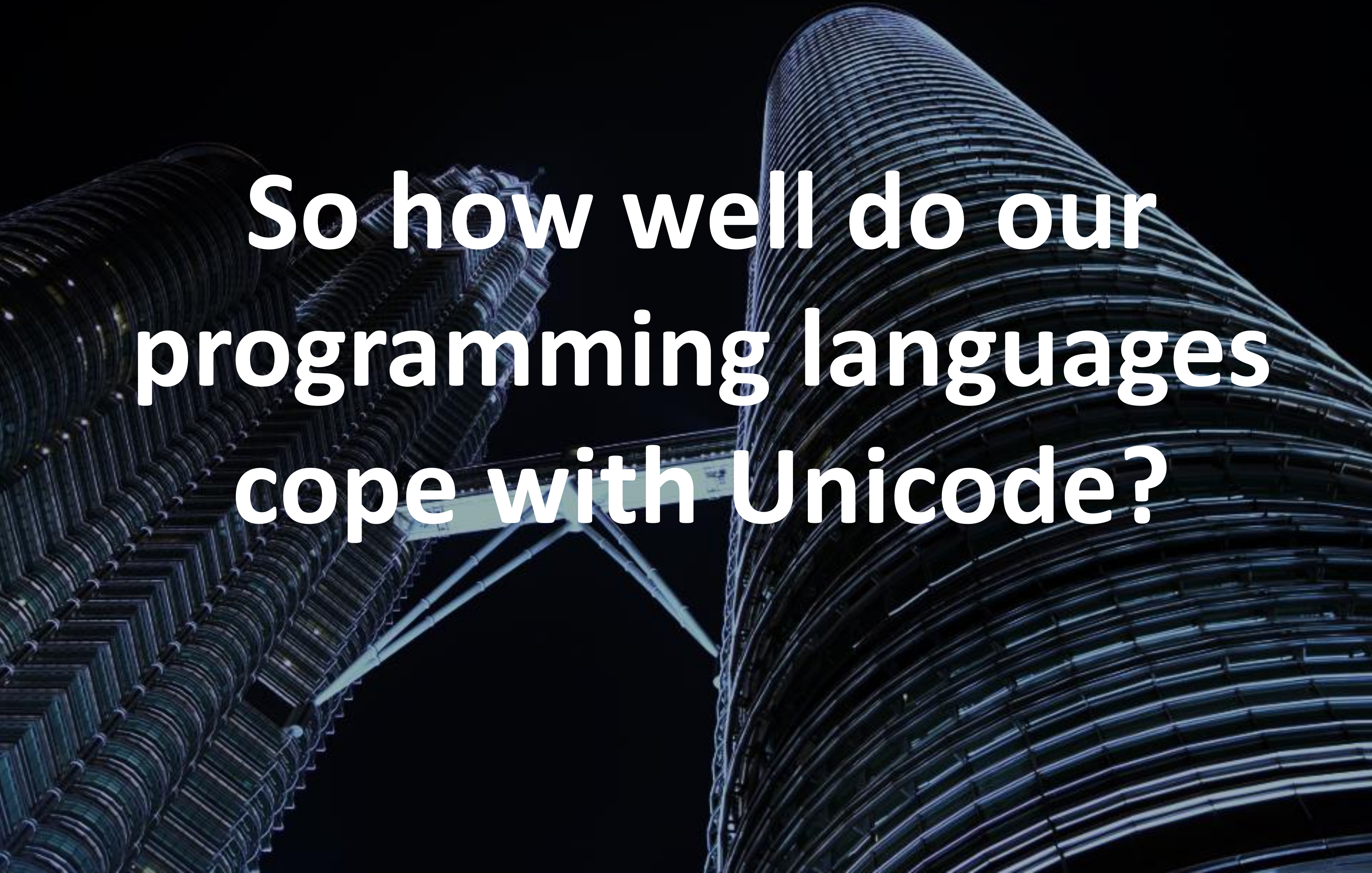


Unicode defines **normalization forms**.

Comparison should be done on normalized strings.



Unicode is fairly complex, because human language itself is complex.



So how well do our programming languages cope with Unicode?

U+1F639

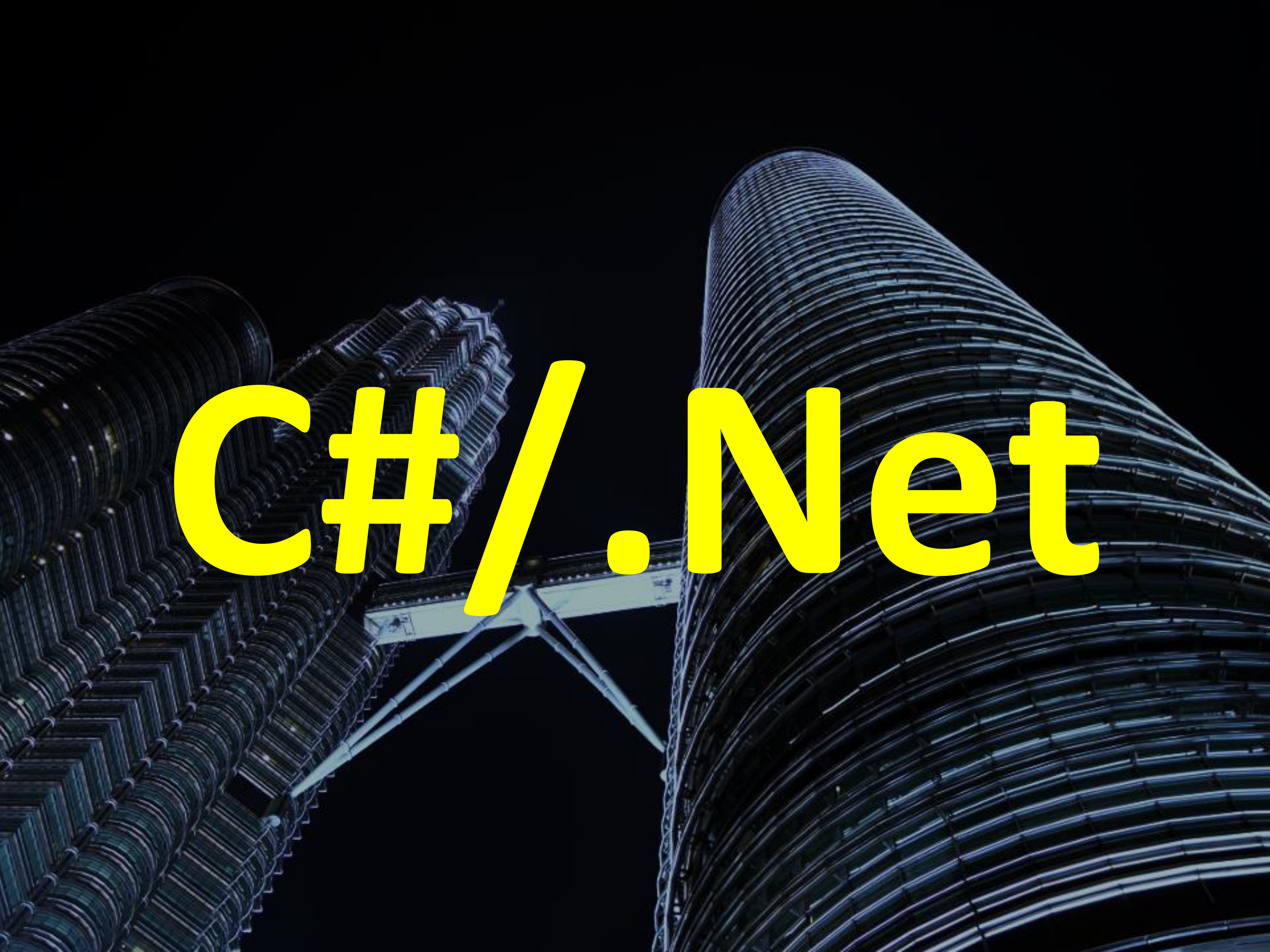
CAT FACE WITH TEARS OF JOY

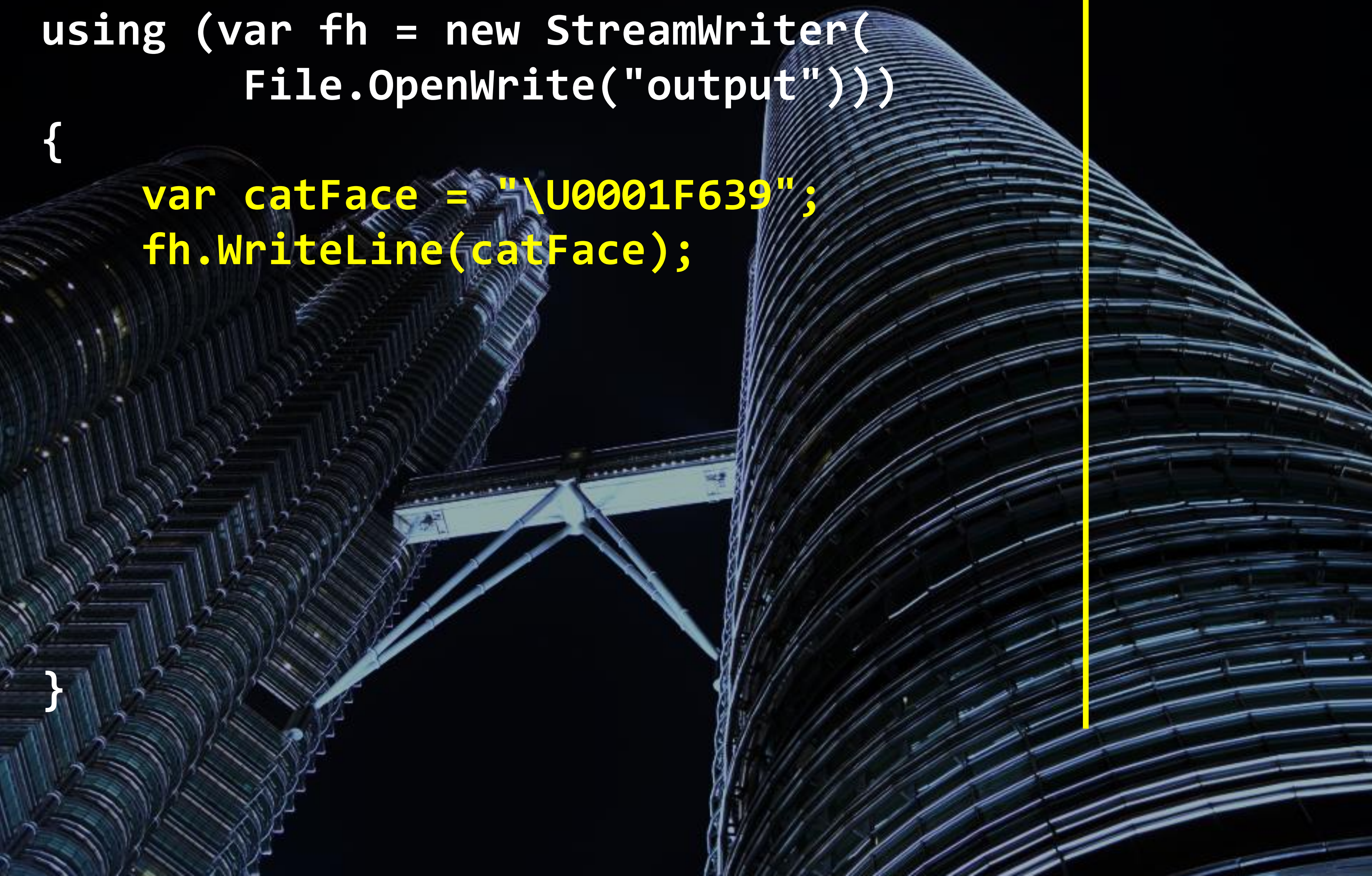
U+0044 U+0323 U+0307

Ḍ̇

LATIN CAPITAL LETTER D
COMBINING DOT BELOW
COMBINING DOT ABOVE

C#/.Net

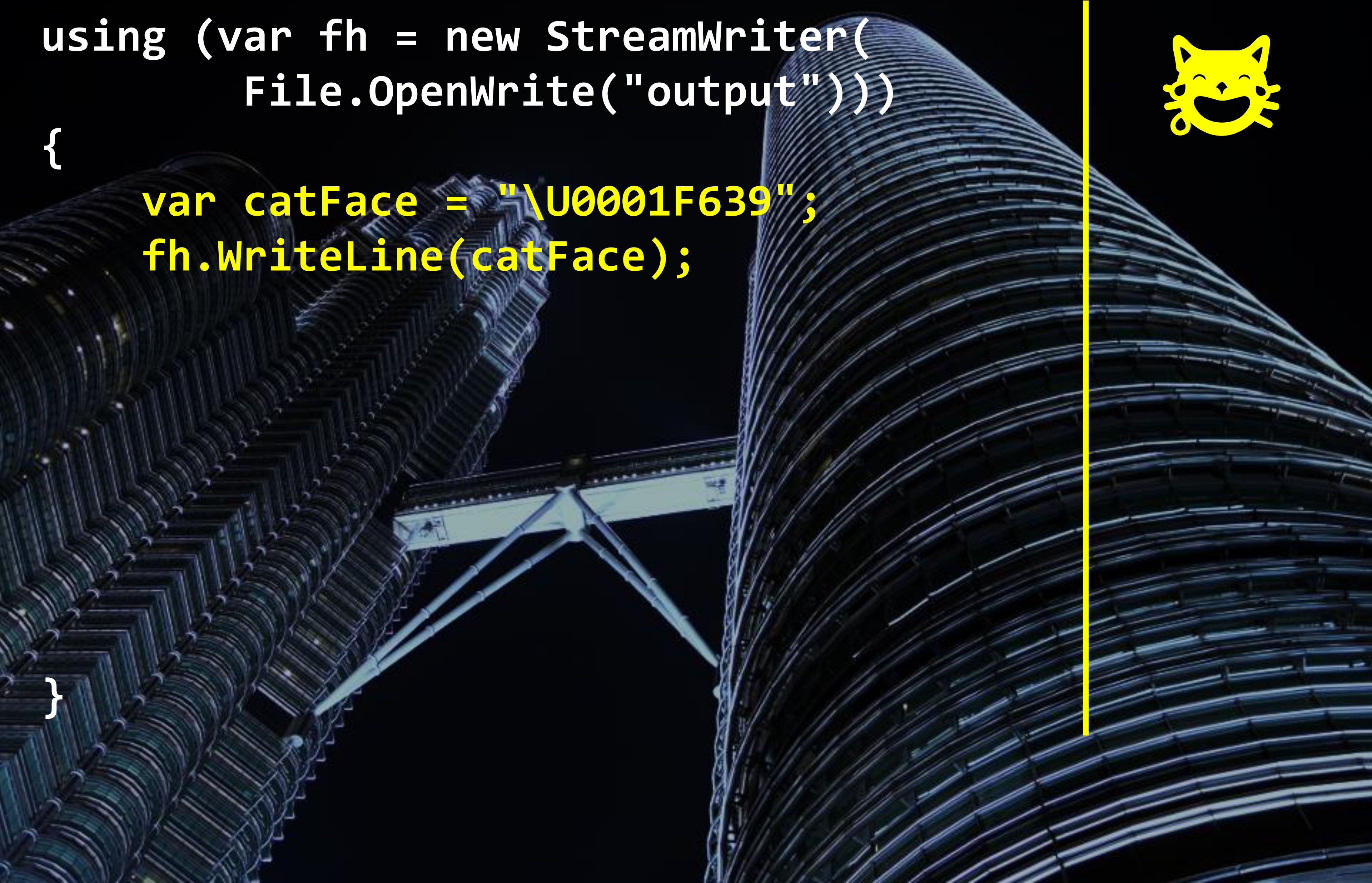




```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);




}
```

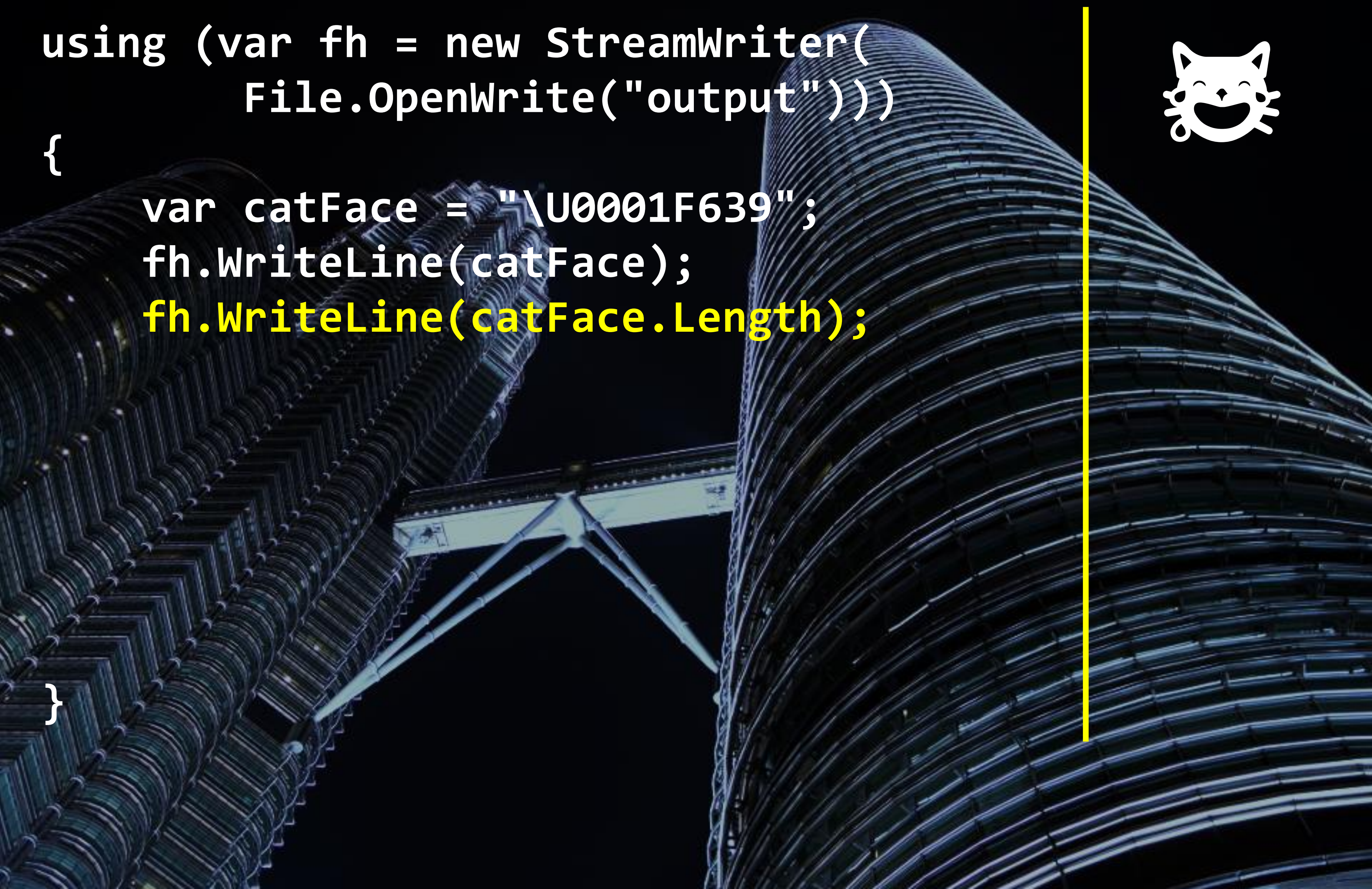


```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);



}
```

😹

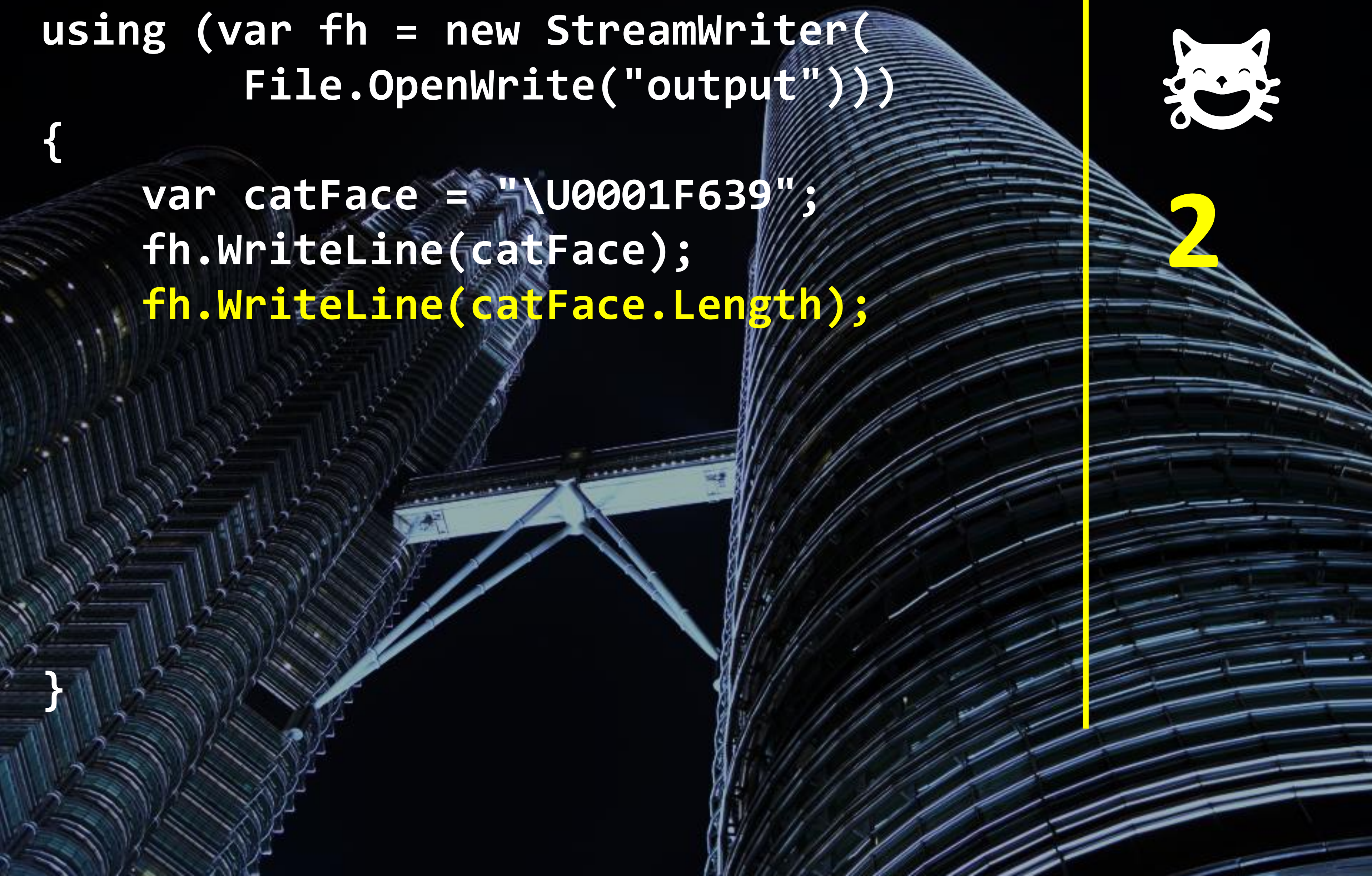


```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);



}
```

😹



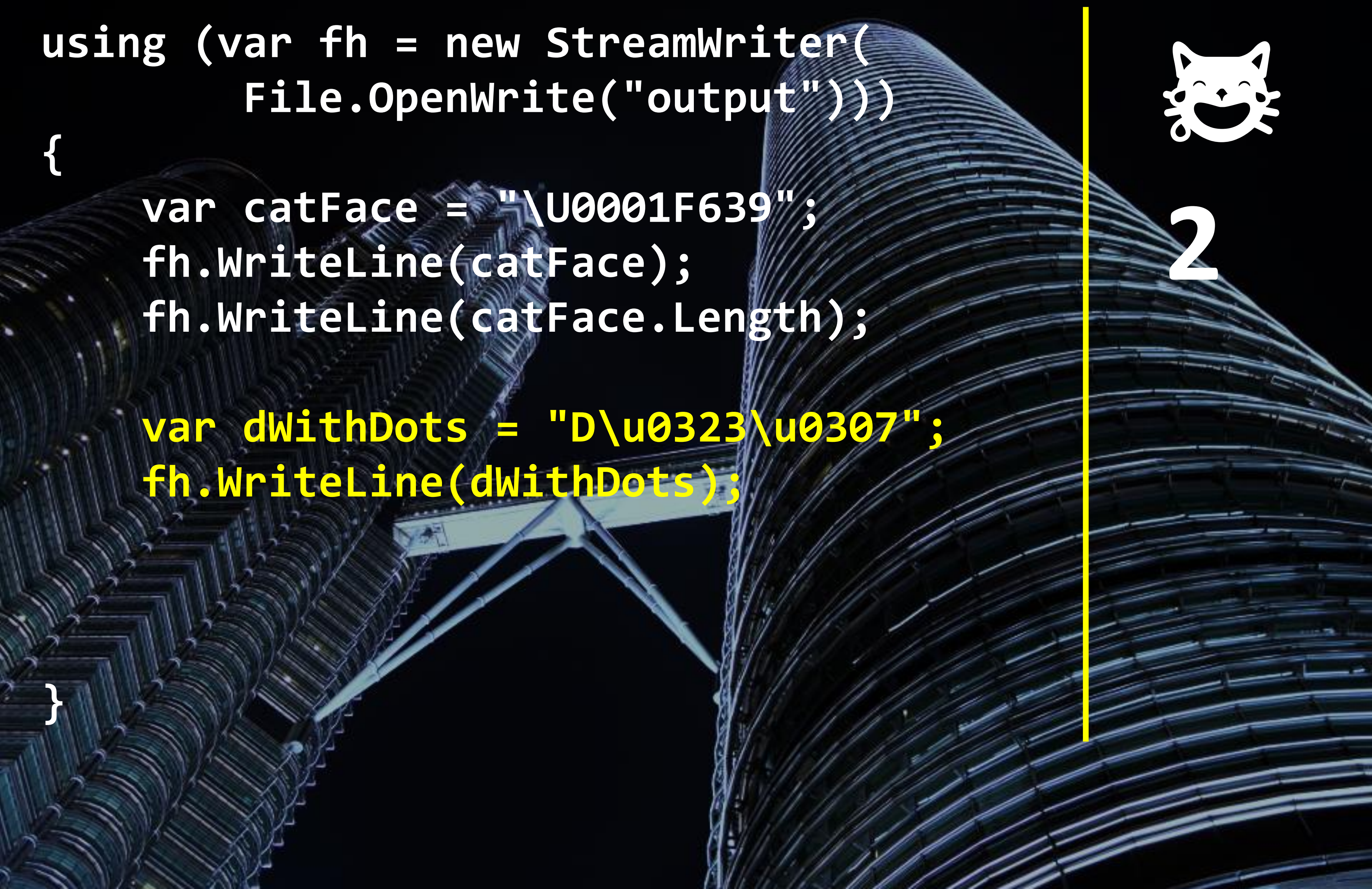
```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);



}
```

😹

2



```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);

    var dWithDots = "D\u0323\u0307";
    fh.WriteLine(dWithDots);


}
```

😹

2

```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);

    var dWithDots = "D\u0323\u0307";
    fh.WriteLine(dWithDots);


}
```

```
😹
2
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```

```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);

    var dWithDots = "D\u0323\u0307";
    fh.WriteLine(dWithDots);
    fh.WriteLine(dWithDots.Length);


}
```

😹

2

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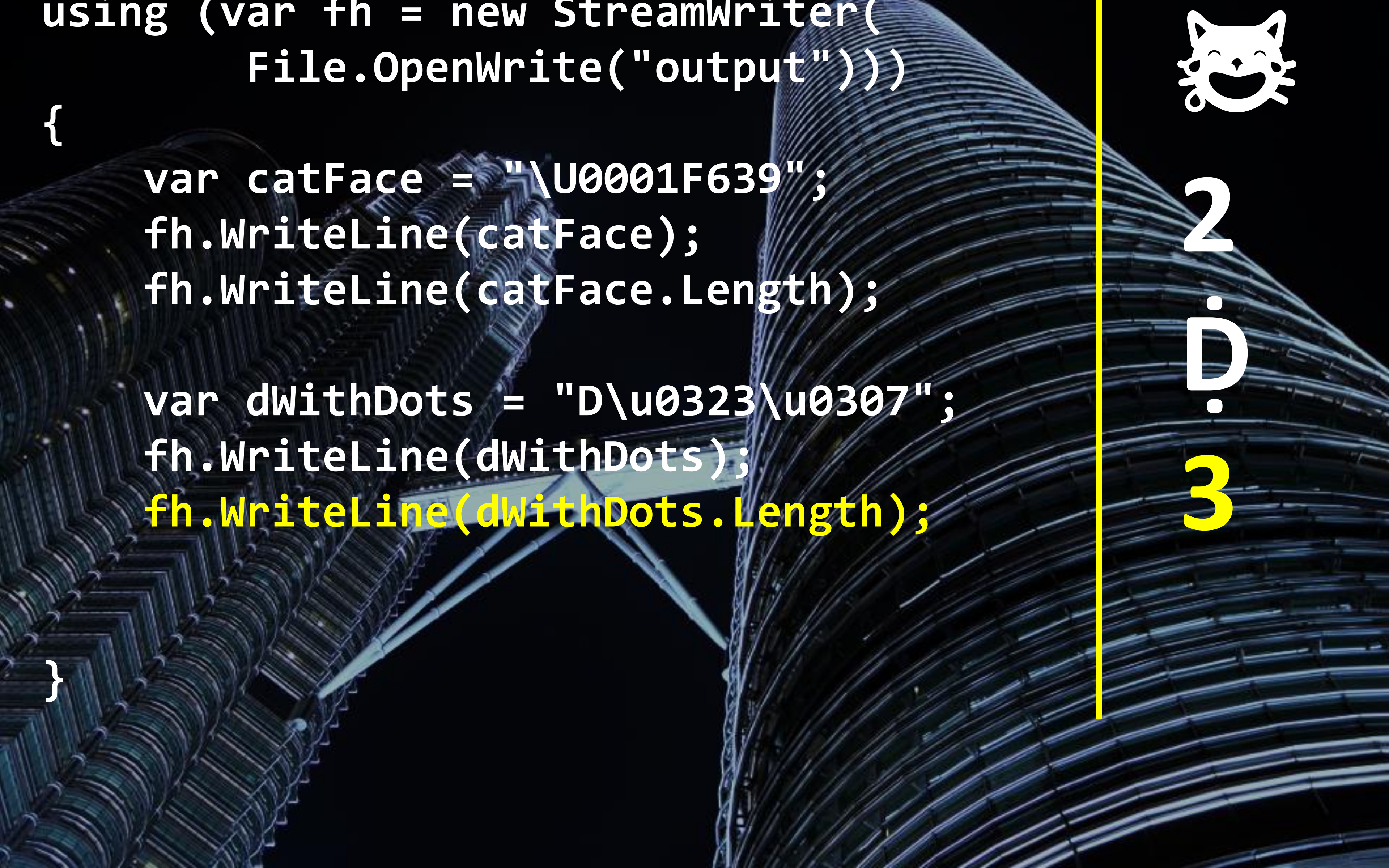

```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);

    var dWithDots = "D\u0323\u0307";
    fh.WriteLine(dWithDots);
    fh.WriteLine(dWithDots.Length);


}
```

😹
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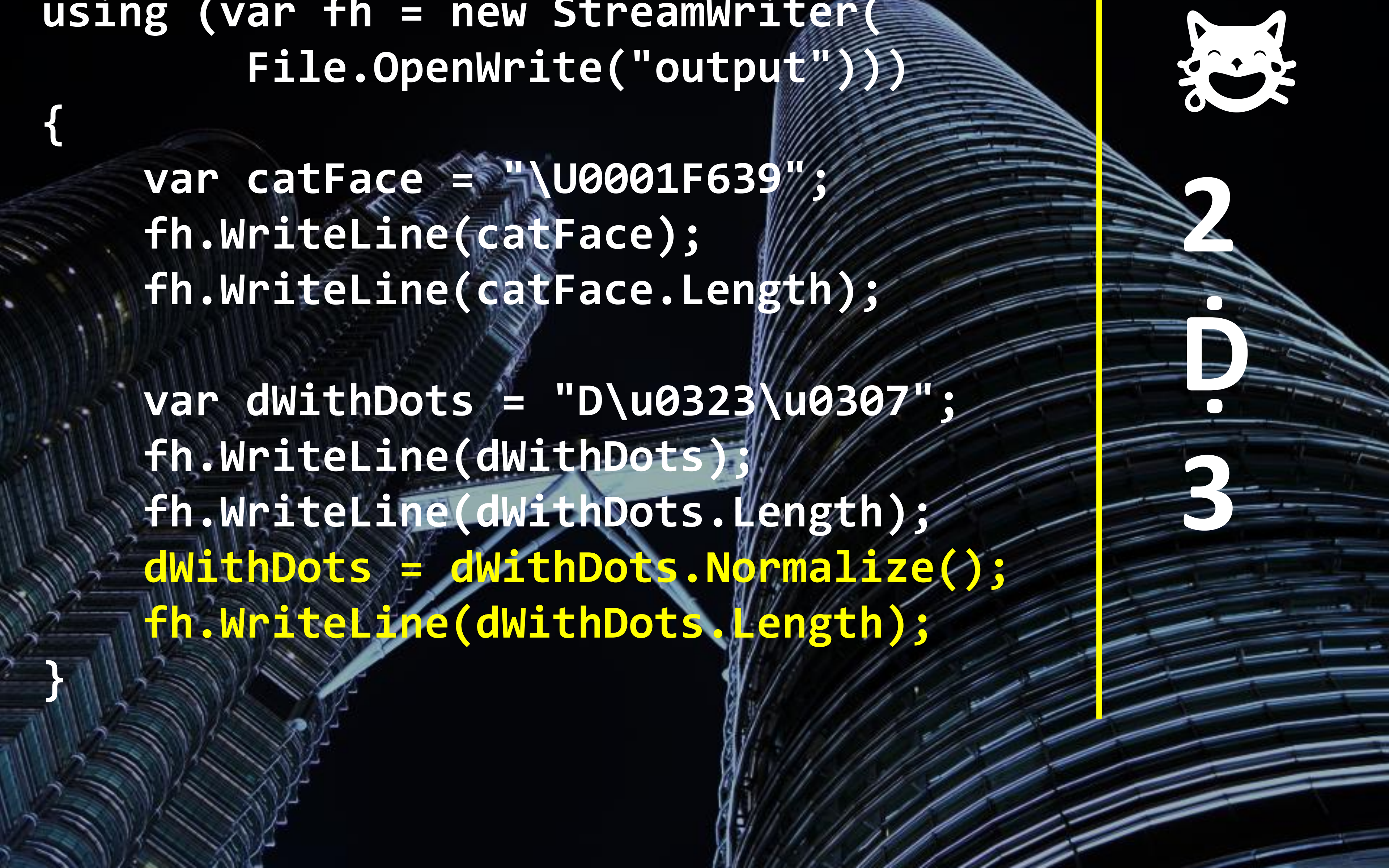

```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);

    var dWithDots = "D\u0323\u0307";
    fh.WriteLine(dWithDots);
    fh.WriteLine(dWithDots.Length);
    dWithDots = dWithDots.Normalize();
    fh.WriteLine(dWithDots.Length);
}
```

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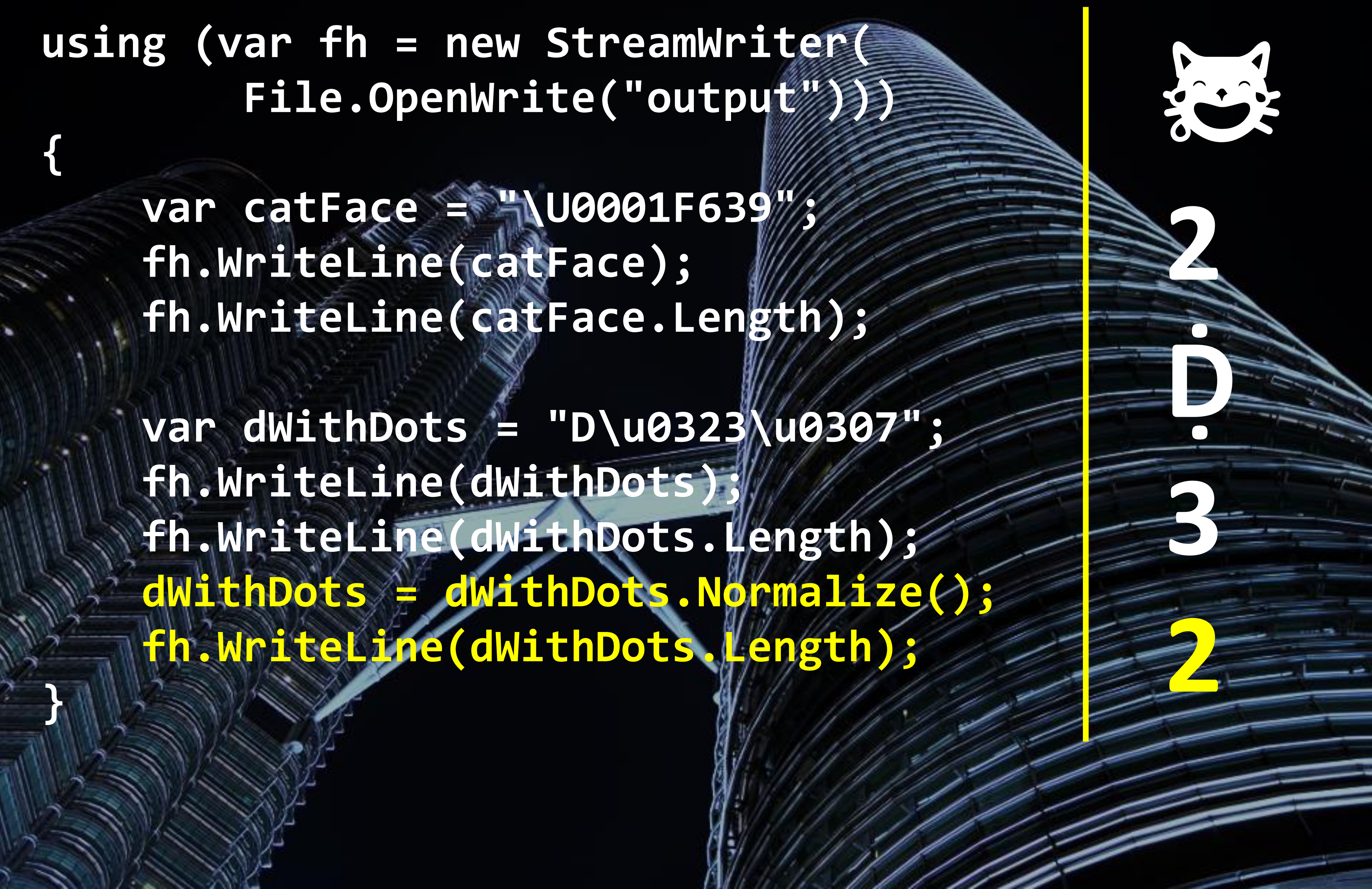

```
using (var fh = new StreamWriter(
        File.OpenWrite("output")))
{
    var catFace = "\U0001F639";
    fh.WriteLine(catFace);
    fh.WriteLine(catFace.Length);

    var dWithDots = "D\u0323\u0307";
    fh.WriteLine(dWithDots);
    fh.WriteLine(dWithDots.Length);
    dWithDots = dWithDots.Normalize();
    fh.WriteLine(dWithDots.Length);
}
```

😹

2

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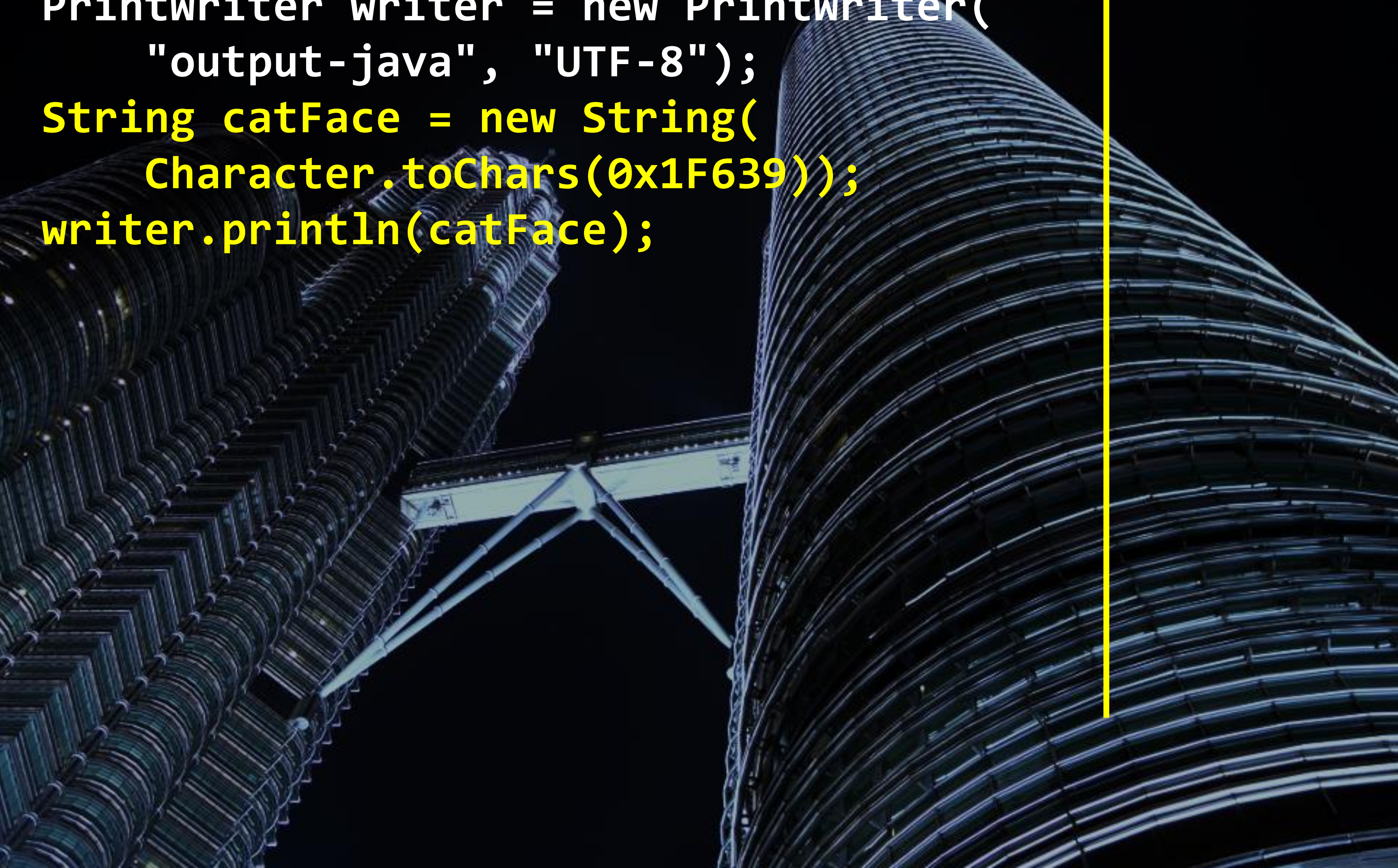
2

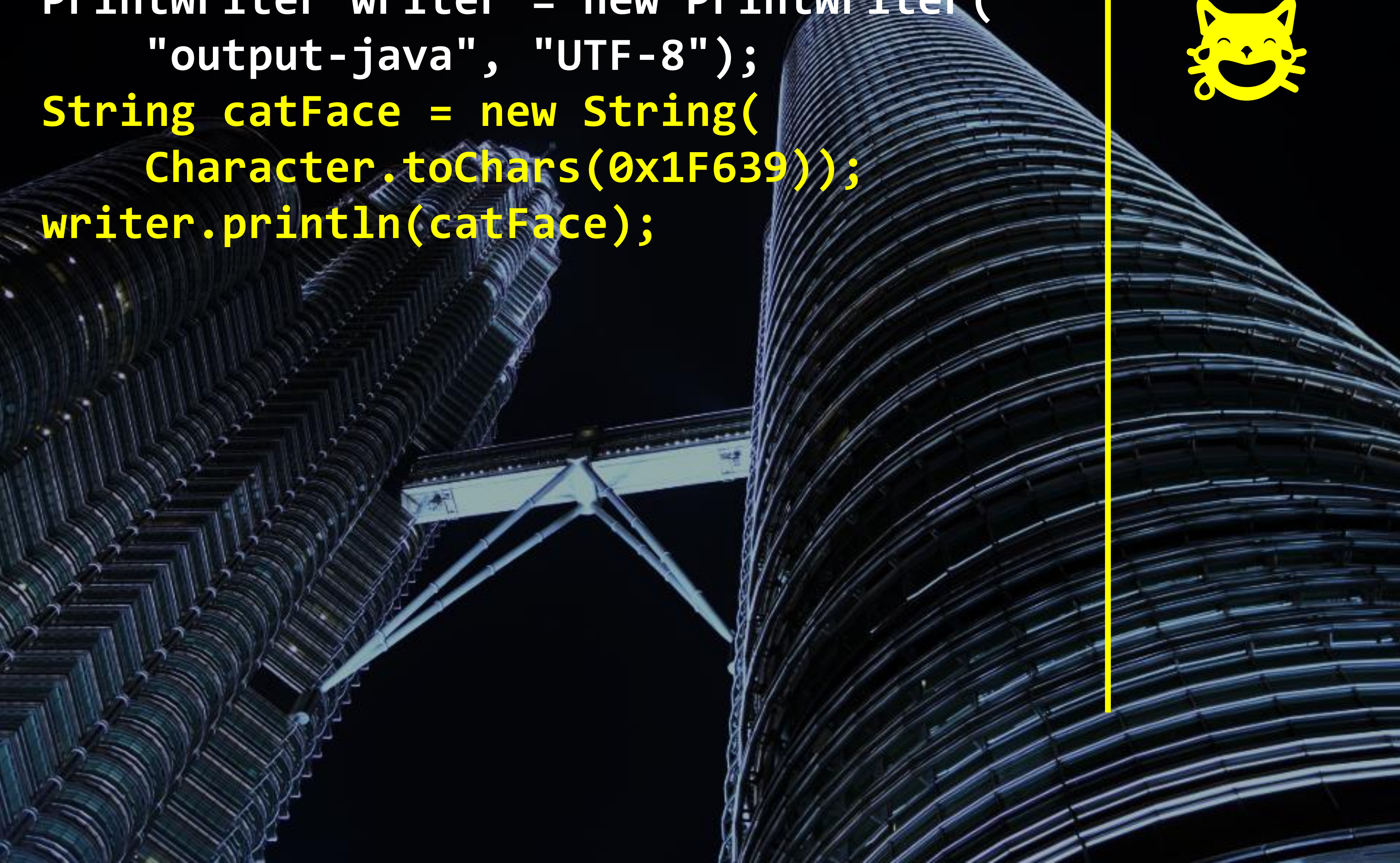
Java

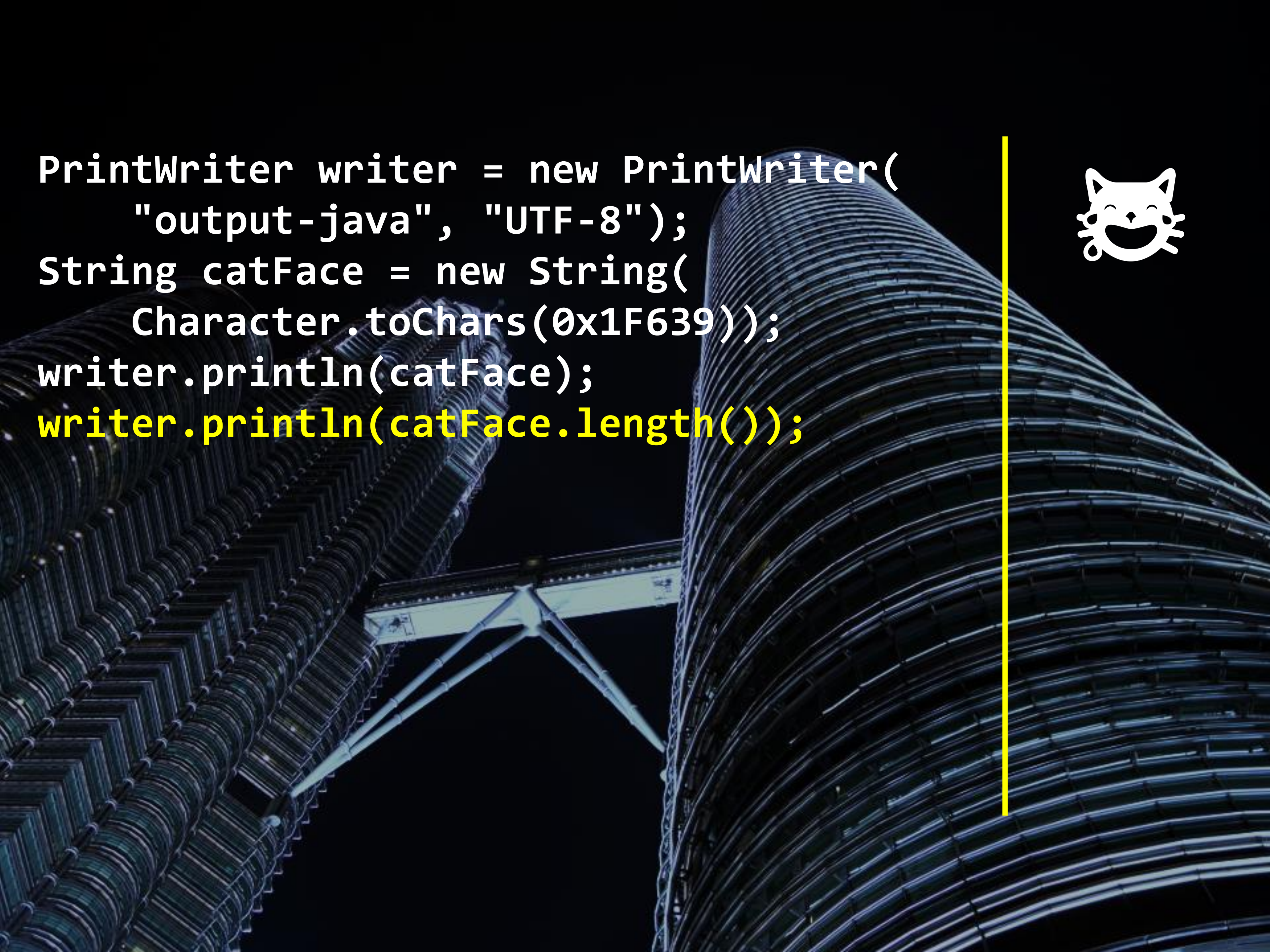


```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
```

```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
```

😹





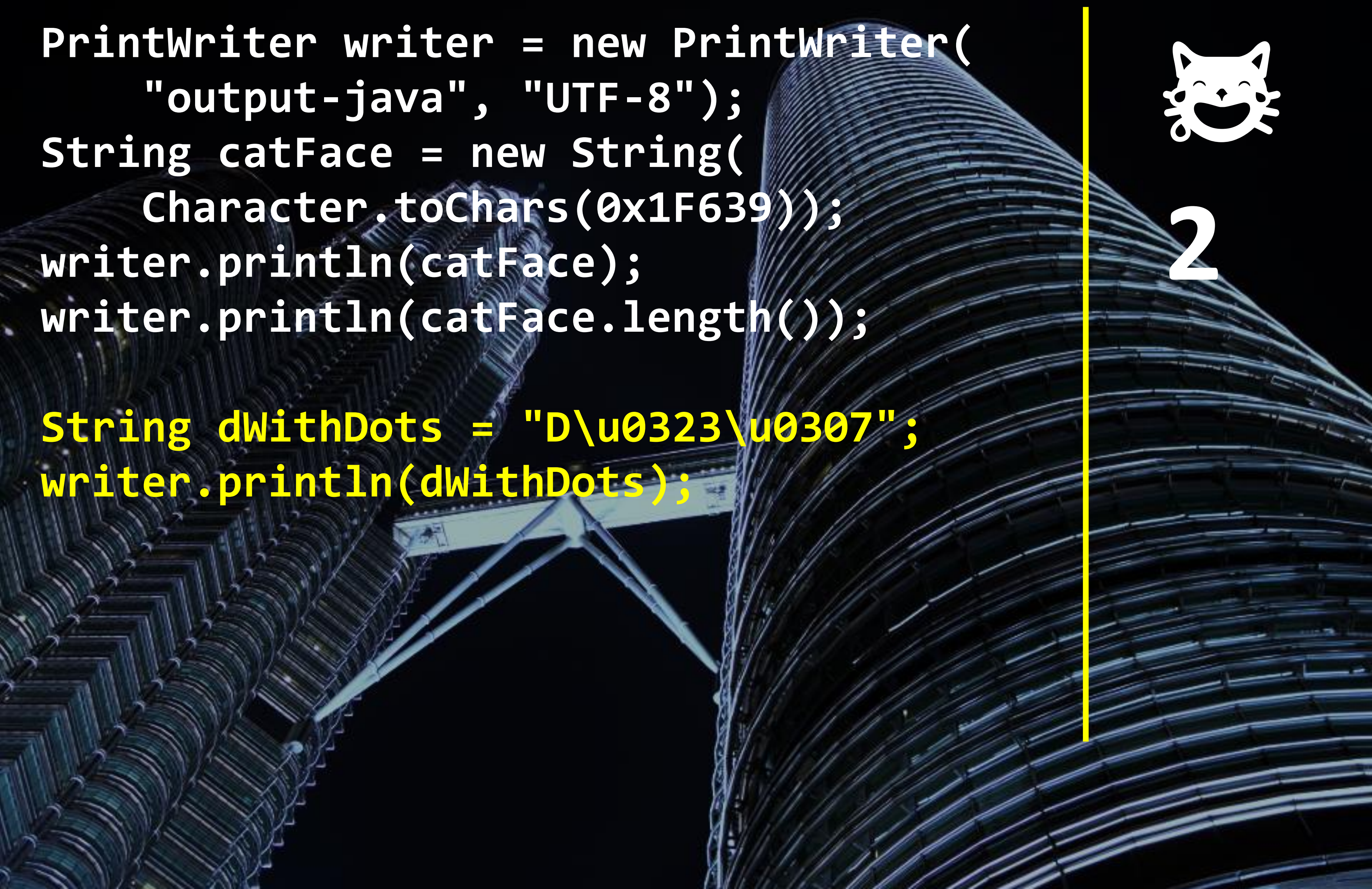
```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());
```

😹

```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());
```

😹

2



```java
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());

String dWithDots = "D\u0323\u0307";
writer.println(dWithDots);
```

```
😹
2
```

```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());

String dWithDots = "D\u0323\u0307";
writer.println(dWithDots);
```

```
😹
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```

```java
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());

String dWithDots = "D\u0323\u0307";
writer.println(dWithDots);
writer.println(dWithDots.length());
```

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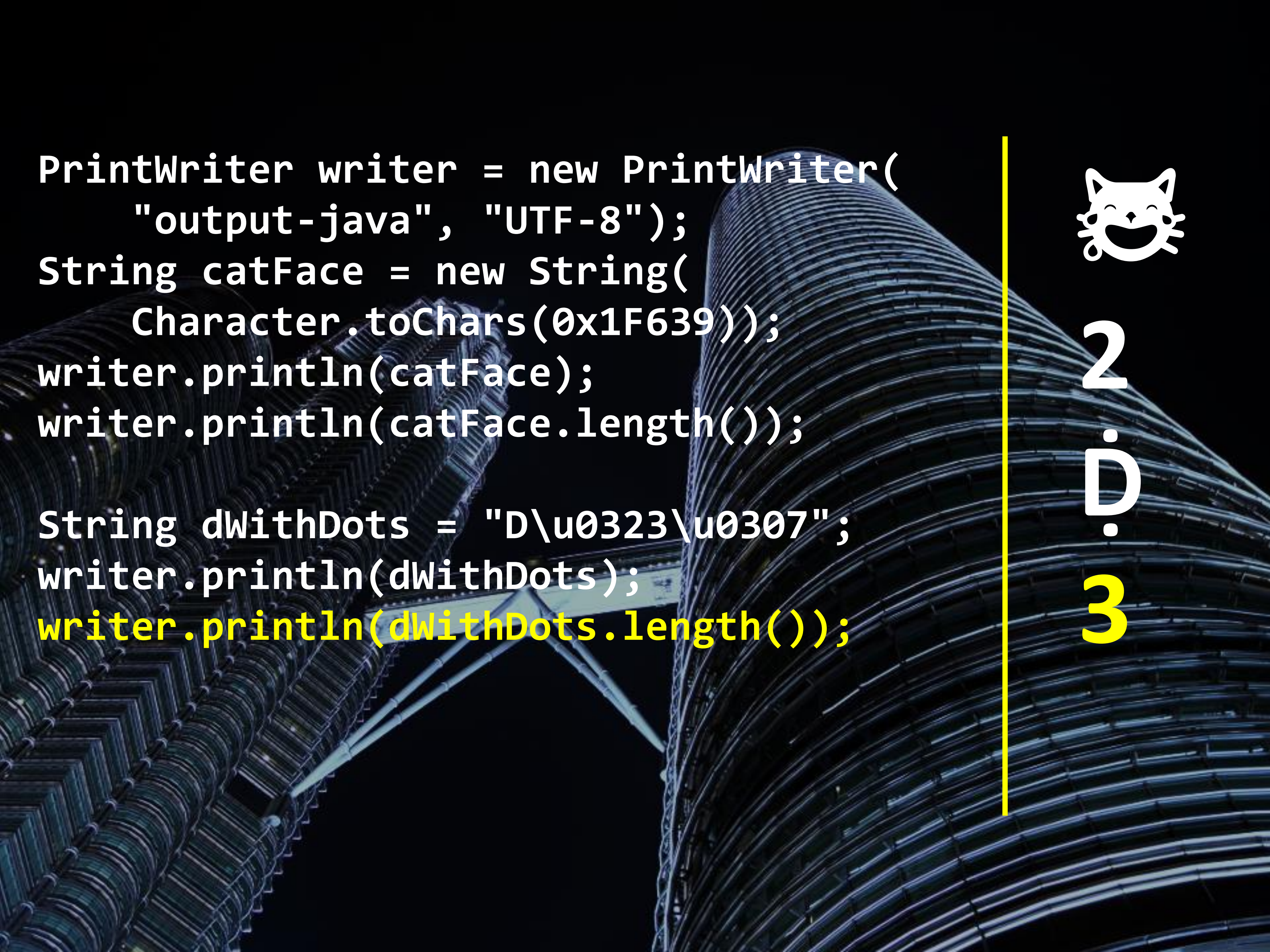

```java
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());

String dWithDots = "D\u0323\u0307";
writer.println(dWithDots);
writer.println(dWithDots.length());
```

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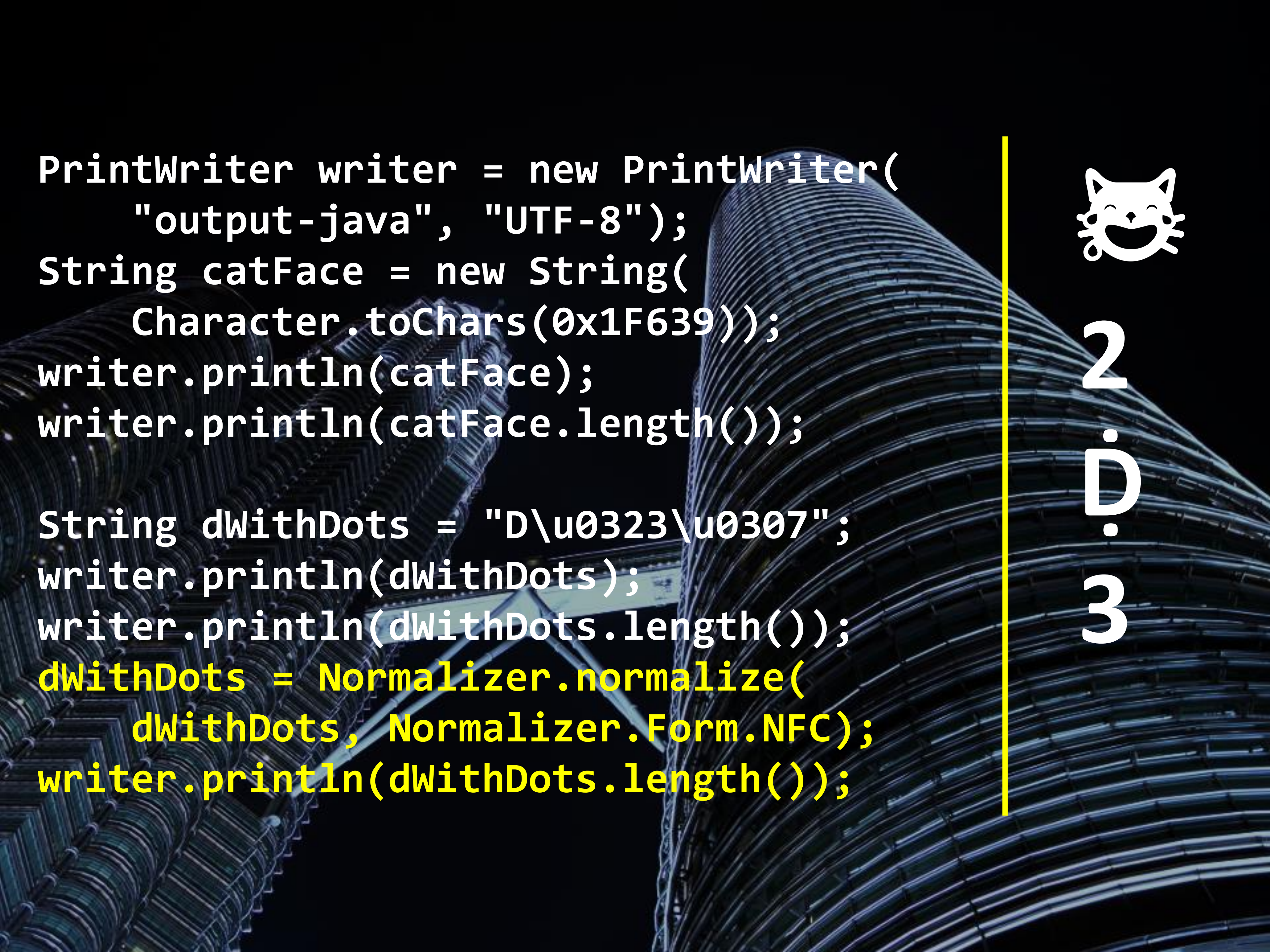

```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());

String dWithDots = "D\u0323\u0307";
writer.println(dWithDots);
writer.println(dWithDots.length());
dWithDots = Normalizer.normalize(
    dWithDots, Normalizer.Form.NFC);
writer.println(dWithDots.length());
```

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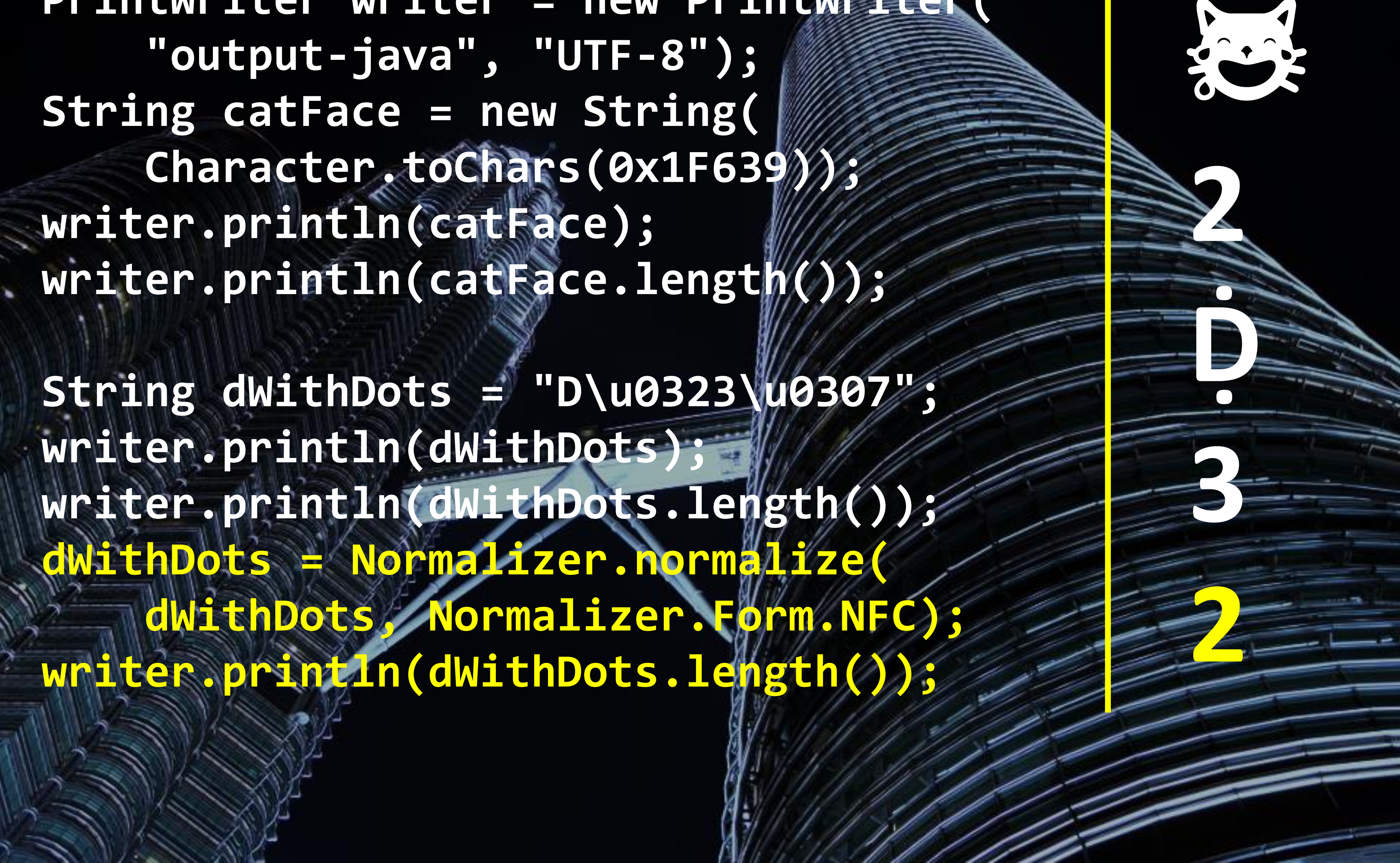

```
PrintWriter writer = new PrintWriter(
    "output-java", "UTF-8");
String catFace = new String(
    Character.toChars(0x1F639));
writer.println(catFace);
writer.println(catFace.length());

String dWithDots = "D\u0323\u0307";
writer.println(dWithDots);
writer.println(dWithDots.length());
dWithDots = Normalizer.normalize(
    dWithDots, Normalizer.Form.NFC);
writer.println(dWithDots.length());
```

😹
2
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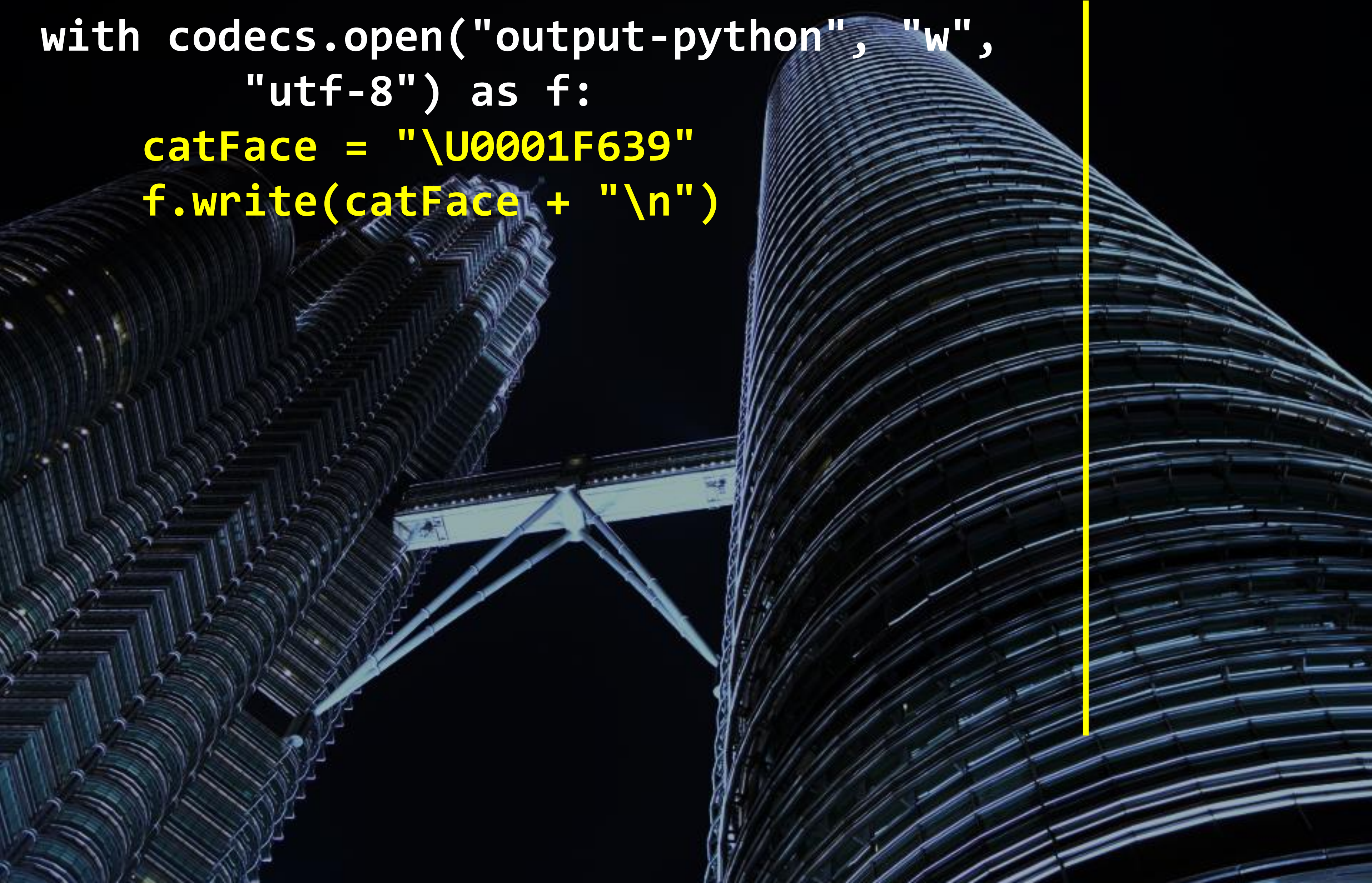
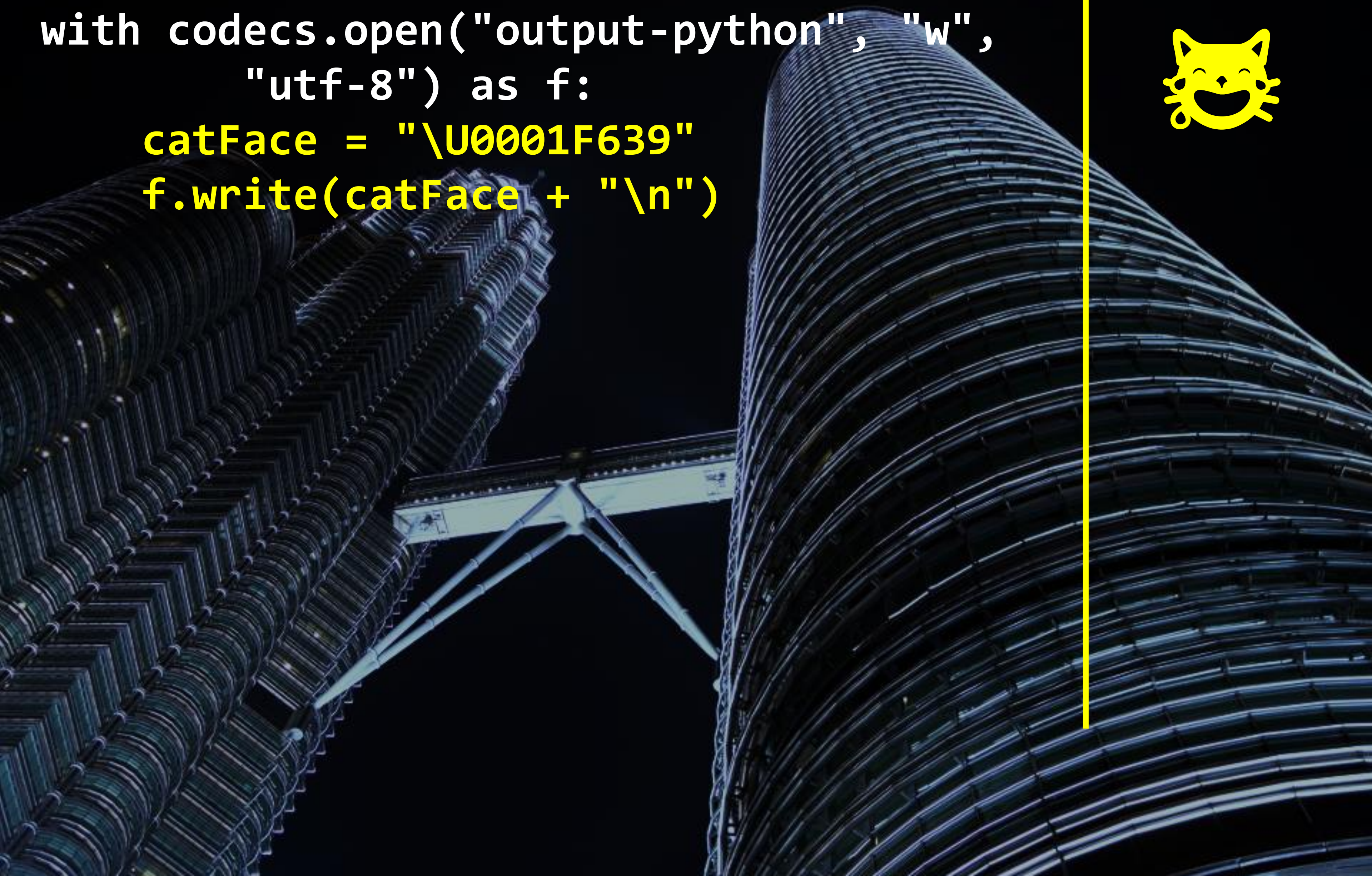
2

Python

(3, with gooder Unicode)

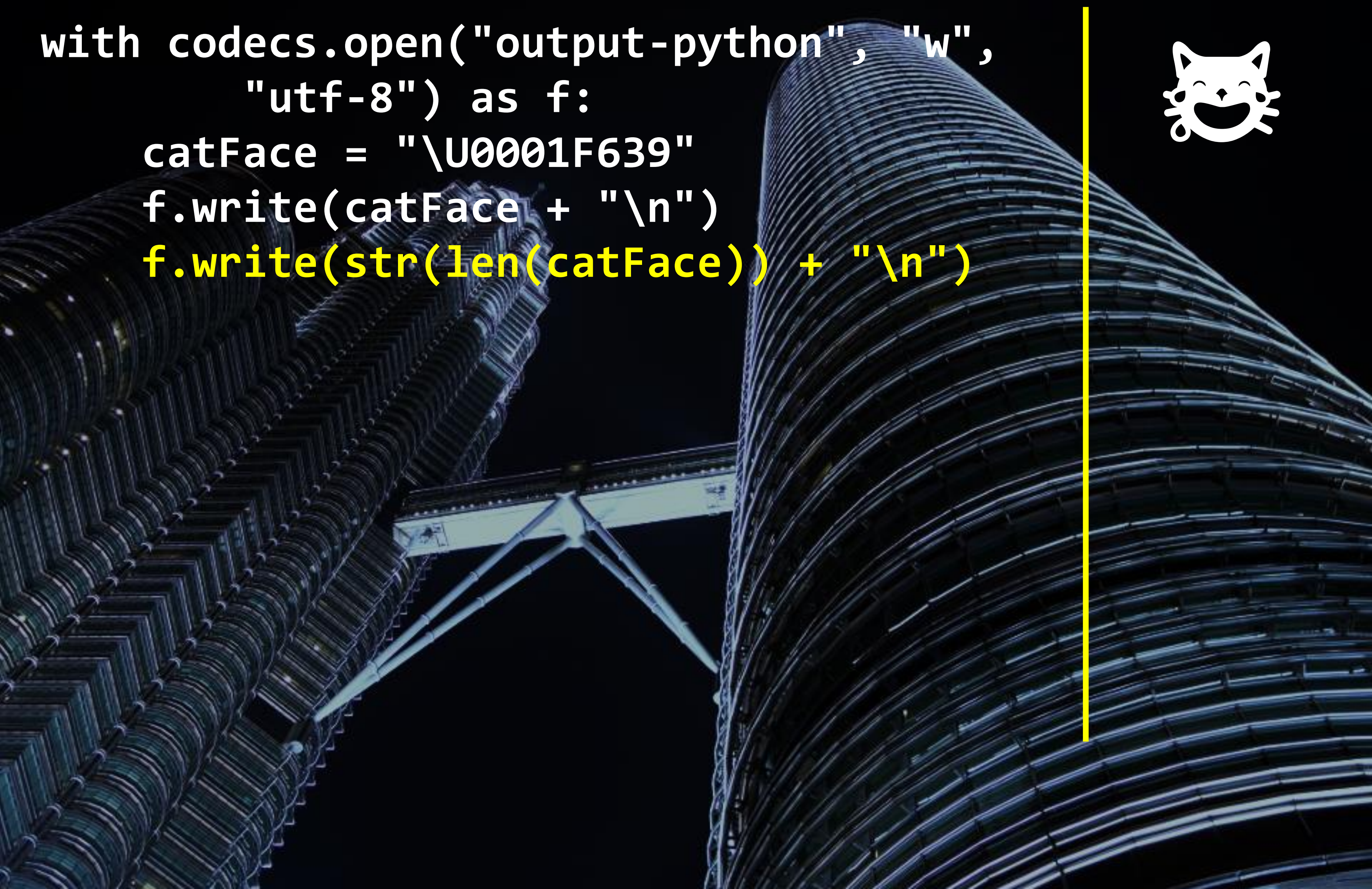


```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
```



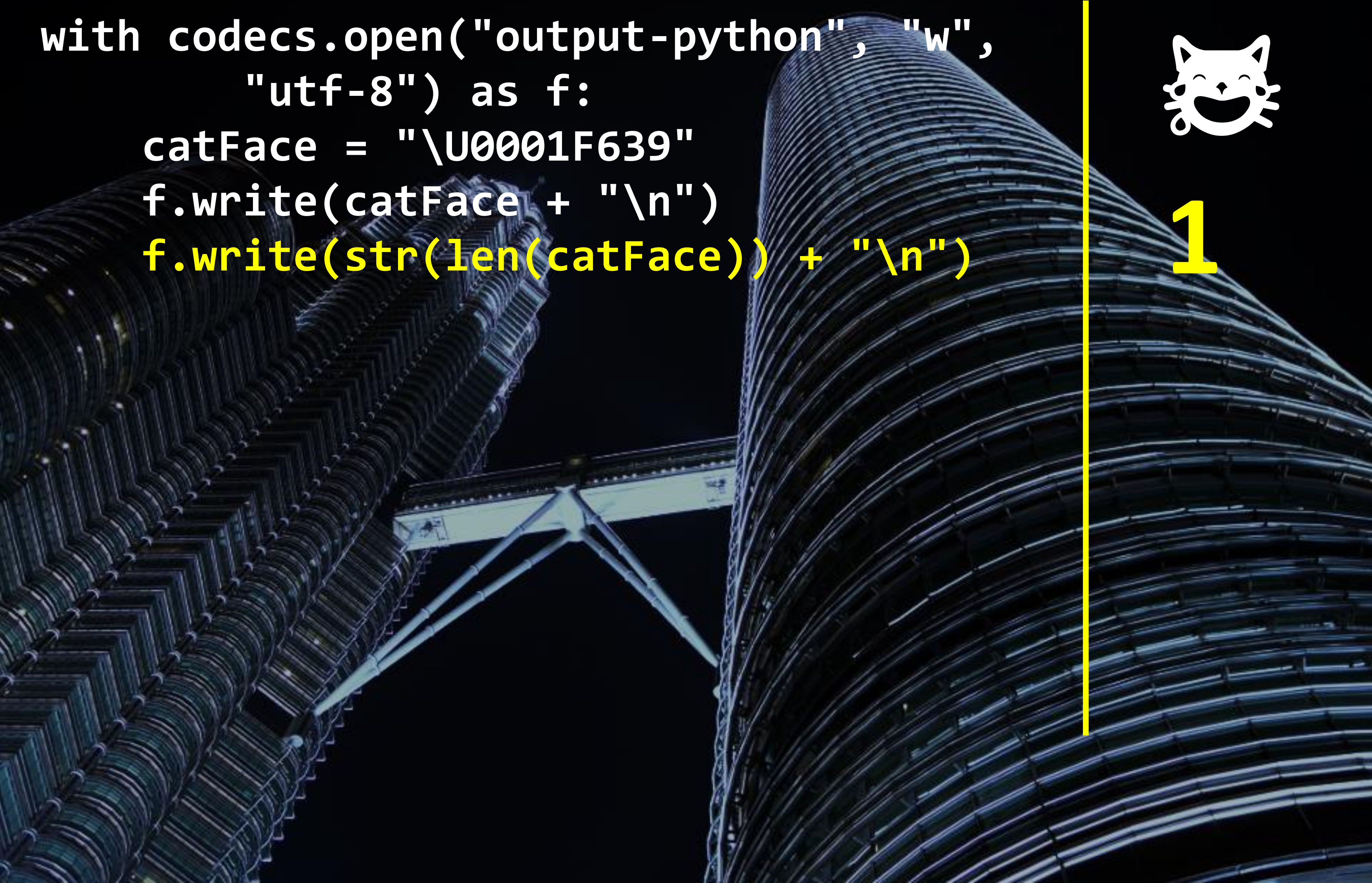
```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
```

😹



```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")
```

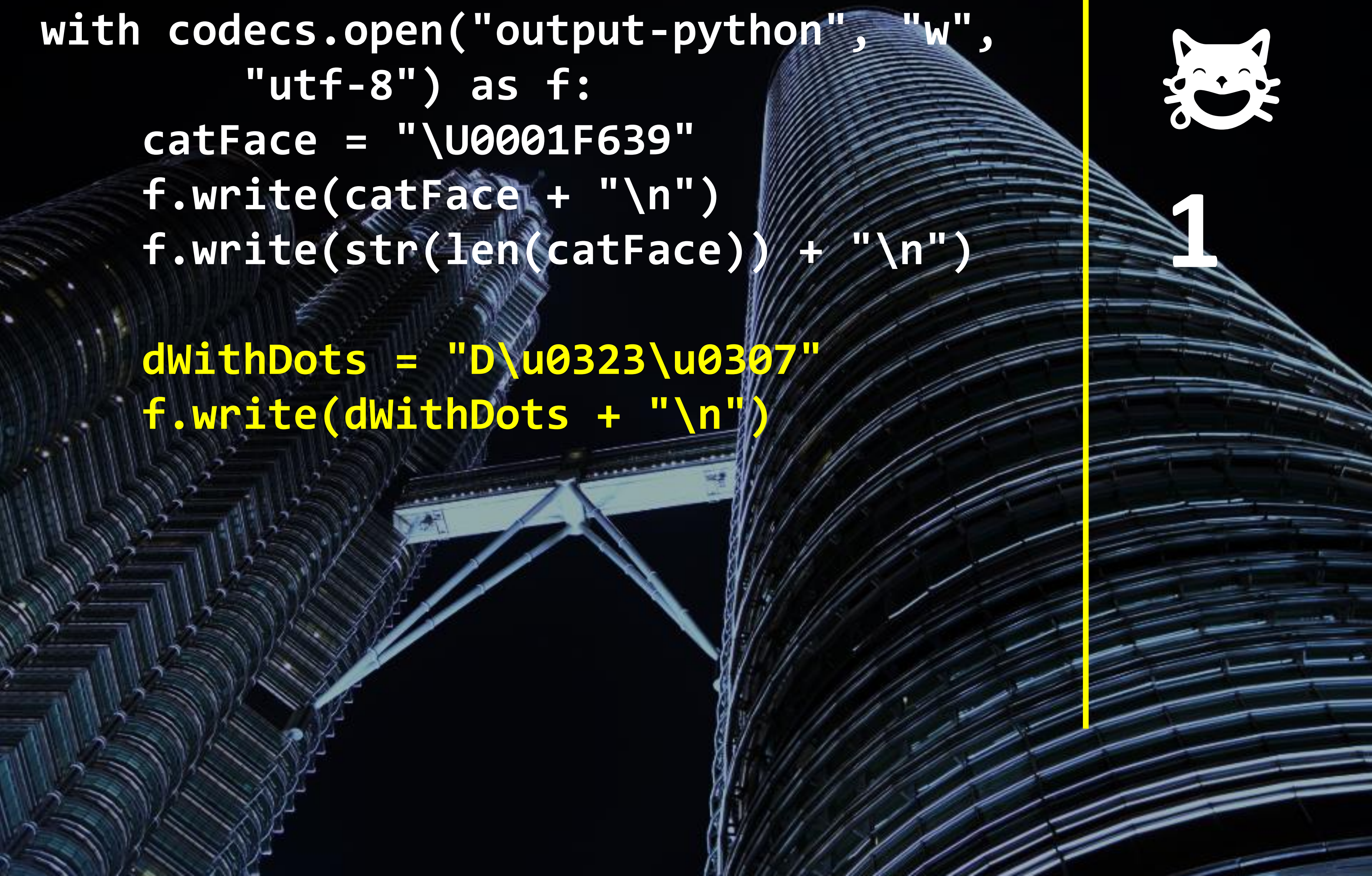
😹



```
with codecs.open("output-python", "w",
          "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")
```

😹

1

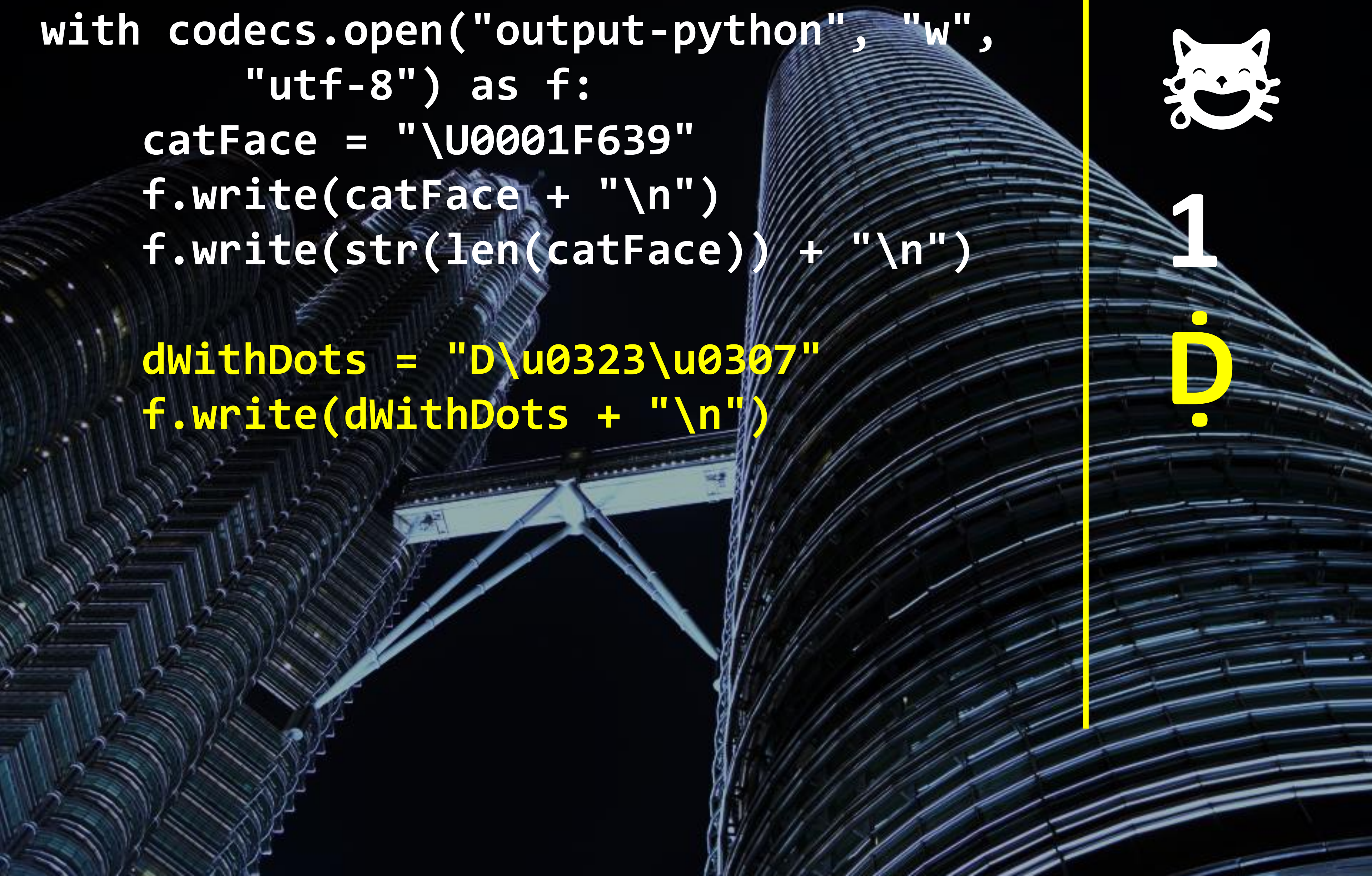


```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")

    dWithDots = "D\u0323\u0307"
    f.write(dWithDots + "\n")
```

😹

1



```python
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")

    dWithDots = "D\u0323\u0307"
    f.write(dWithDots + "\n")
```

😹

1

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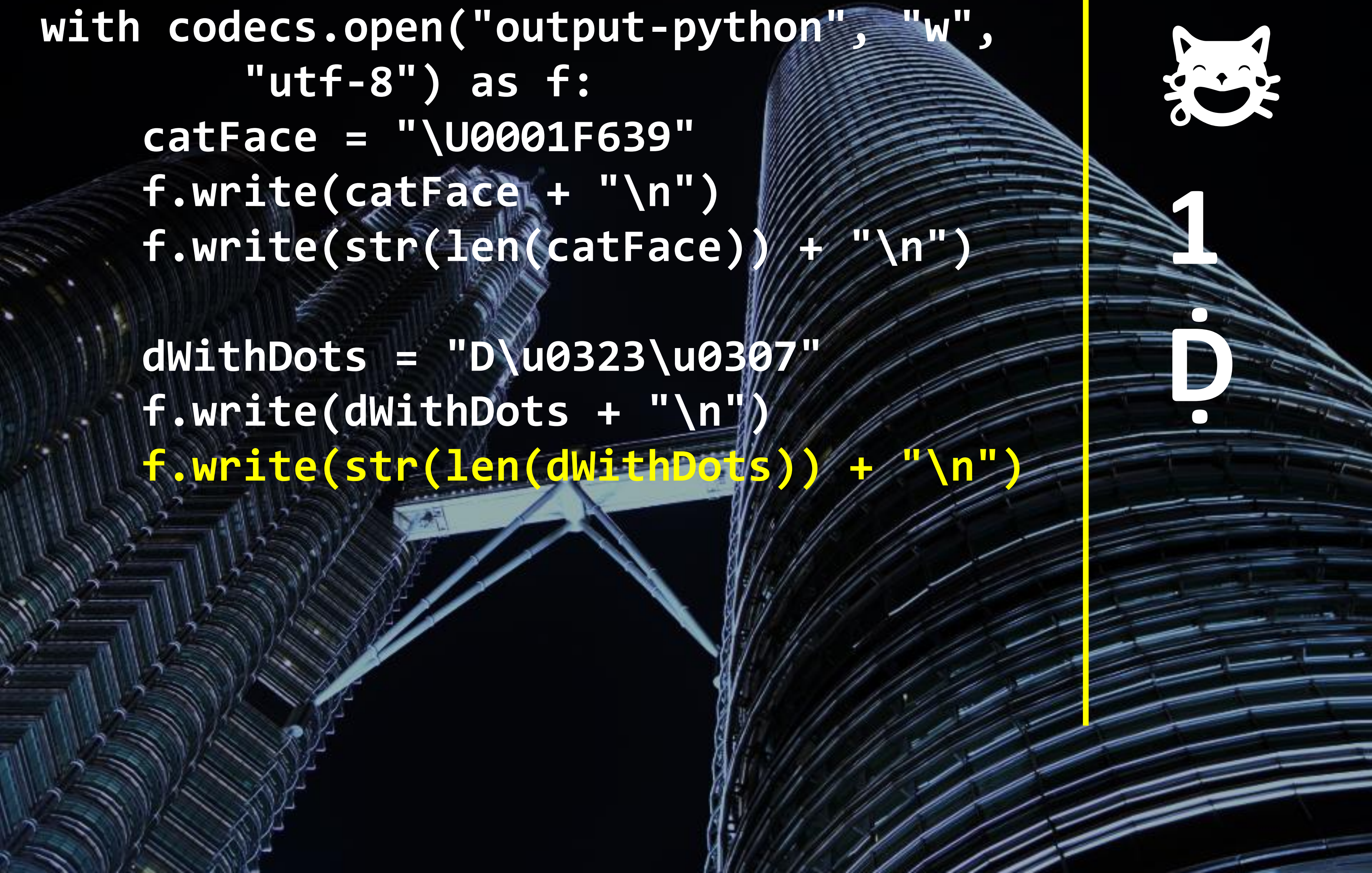

```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")

    dWithDots = "D\u0323\u0307"
    f.write(dWithDots + "\n")
    f.write(str(len(dWithDots)) + "\n")
```

```
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```

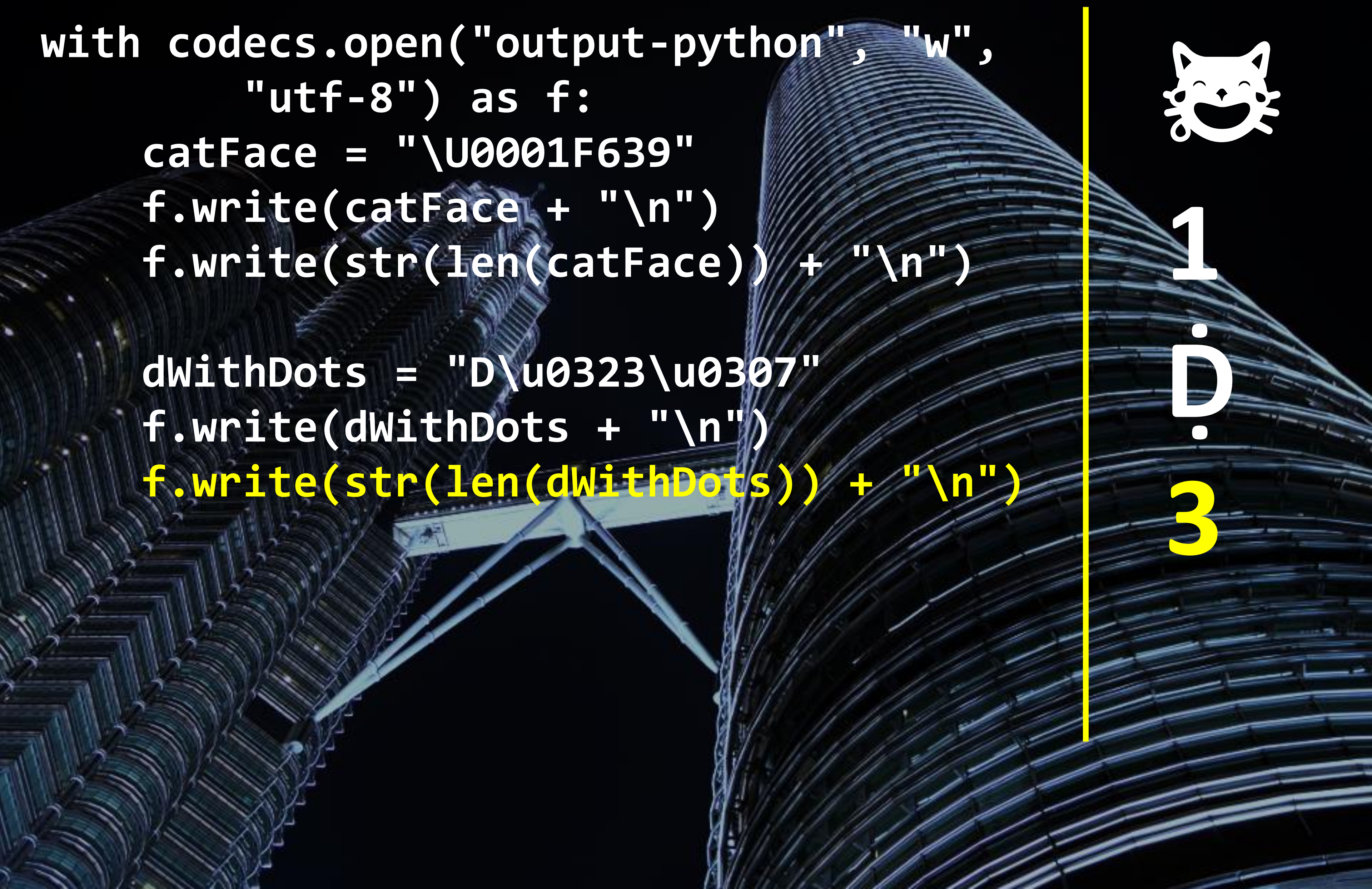

```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")

    dWithDots = "D\u0323\u0307"
    f.write(dWithDots + "\n")
    f.write(str(len(dWithDots)) + "\n")
```

```
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```

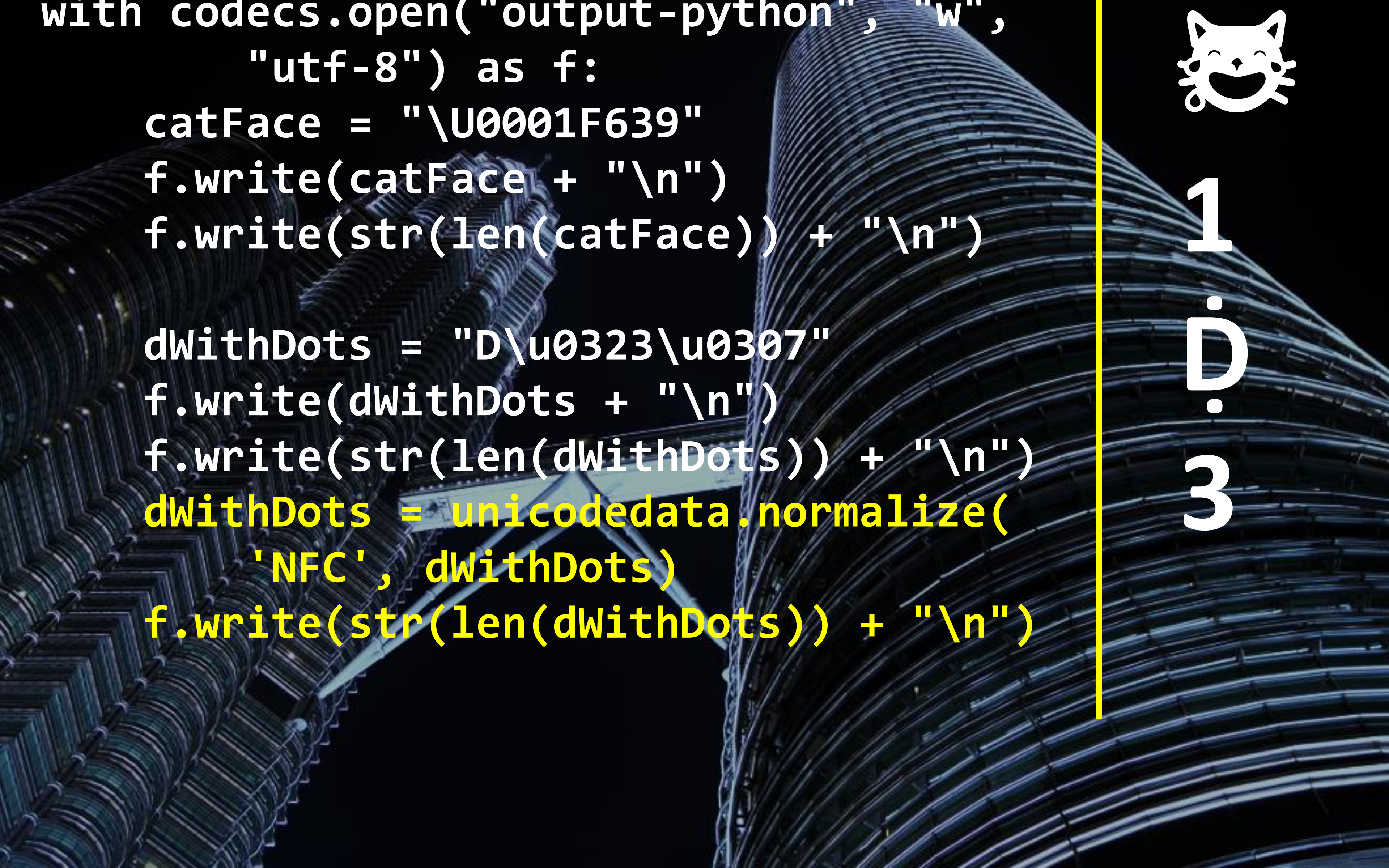

```python
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")

    dWithDots = "D\u0323\u0307"
    f.write(dWithDots + "\n")
    f.write(str(len(dWithDots)) + "\n")
    dWithDots = unicodedata.normalize(
        'NFC', dWithDots)
    f.write(str(len(dWithDots)) + "\n")
```

```
😹
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```
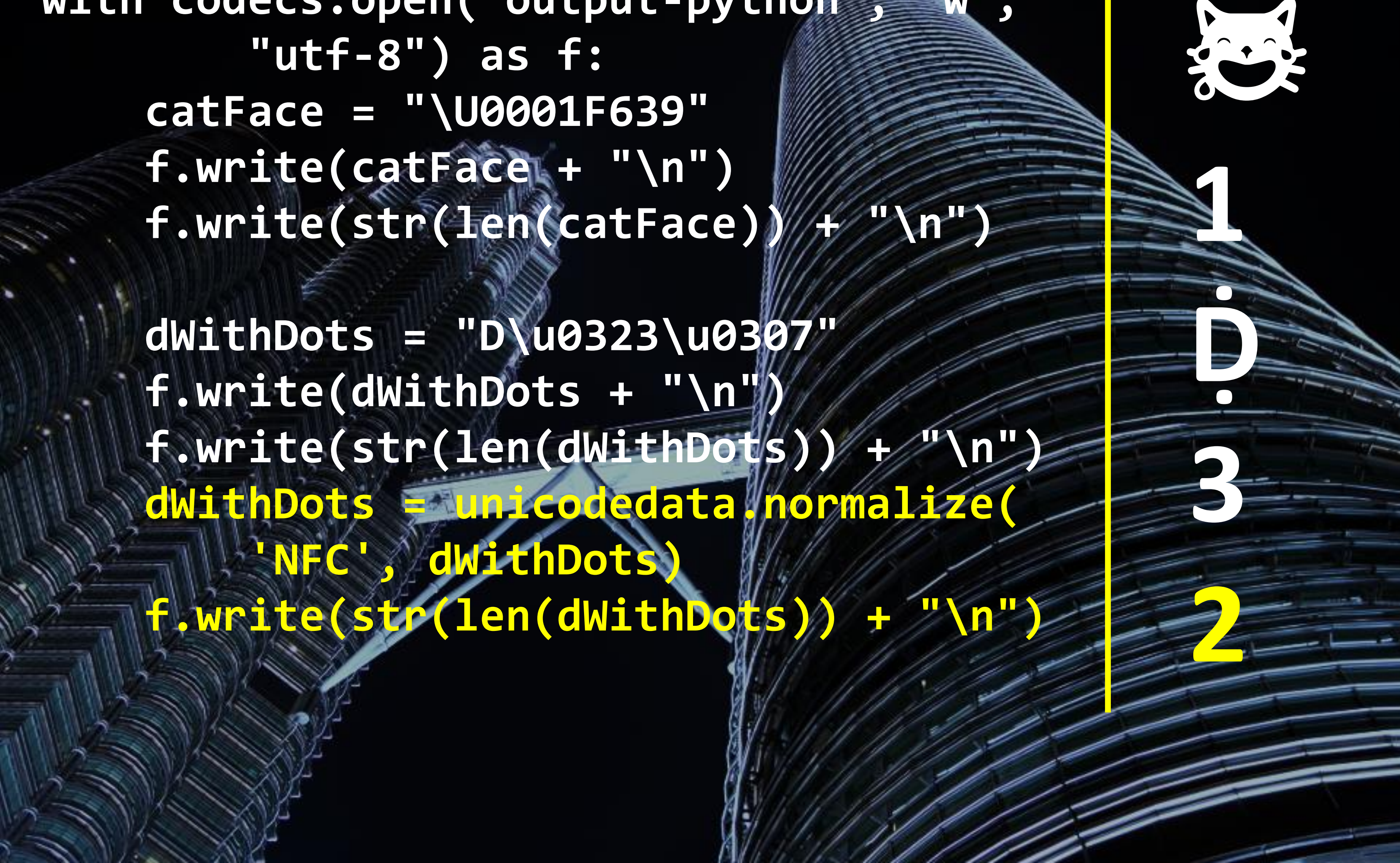
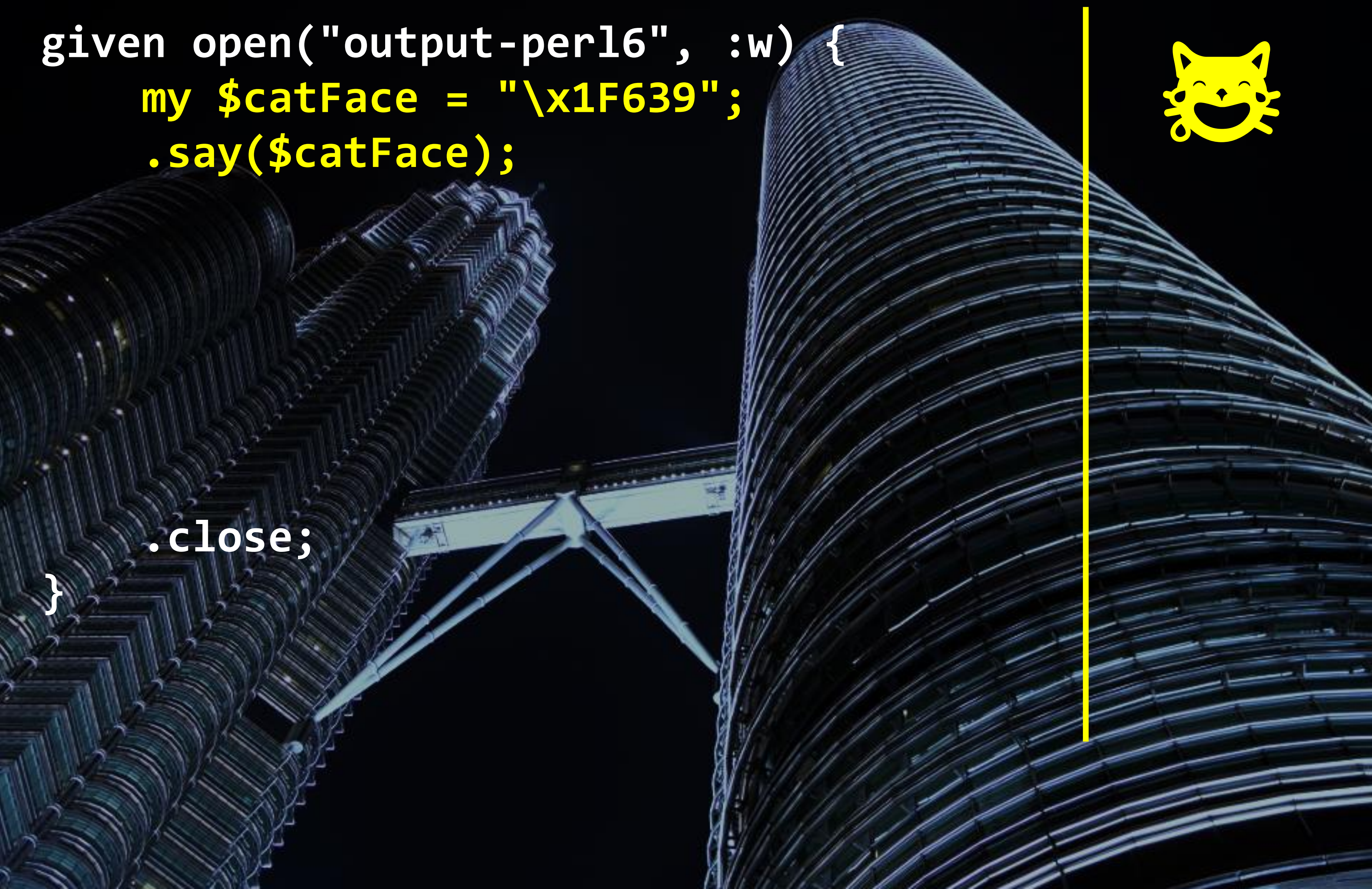



```
with codecs.open("output-python", "w",
        "utf-8") as f:
    catFace = "\U0001F639"
    f.write(catFace + "\n")
    f.write(str(len(catFace)) + "\n")

    dWithDots = "D\u0323\u0307"
    f.write(dWithDots + "\n")
    f.write(str(len(dWithDots)) + "\n")
    dWithDots = unicodedata.normalize(
        'NFC', dWithDots)
    f.write(str(len(dWithDots)) + "\n")
```

```
😹
1
Ḍ̇
3
2
```

Perl 6

```
given open("output-perl6", :w) {
    my $catFace = "\x1F639";
    .say($catFace);




    .close;
}
```



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    my $catFace = "\x1F639";
    .say($catFace);




    .close;
}
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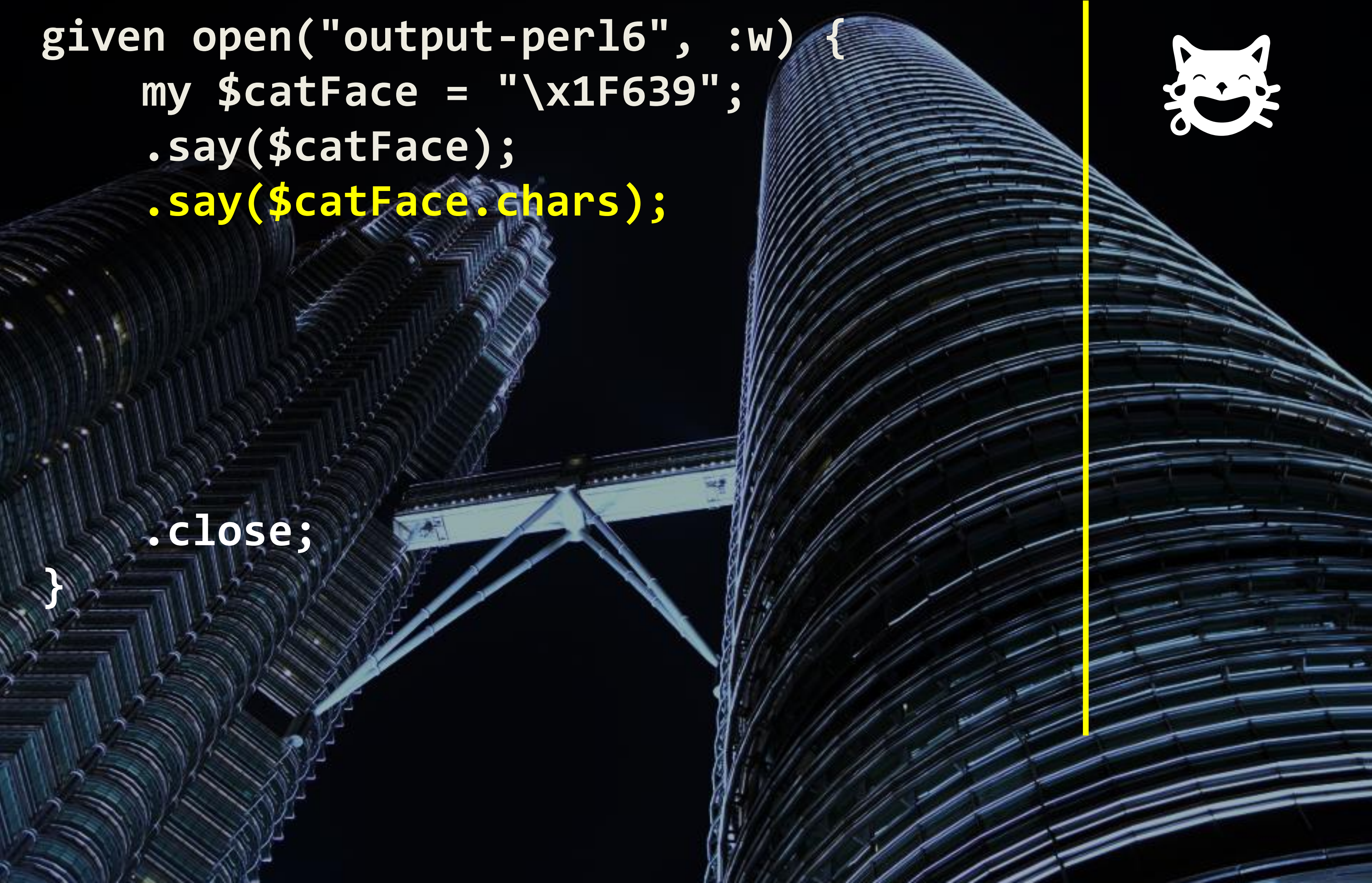
😹

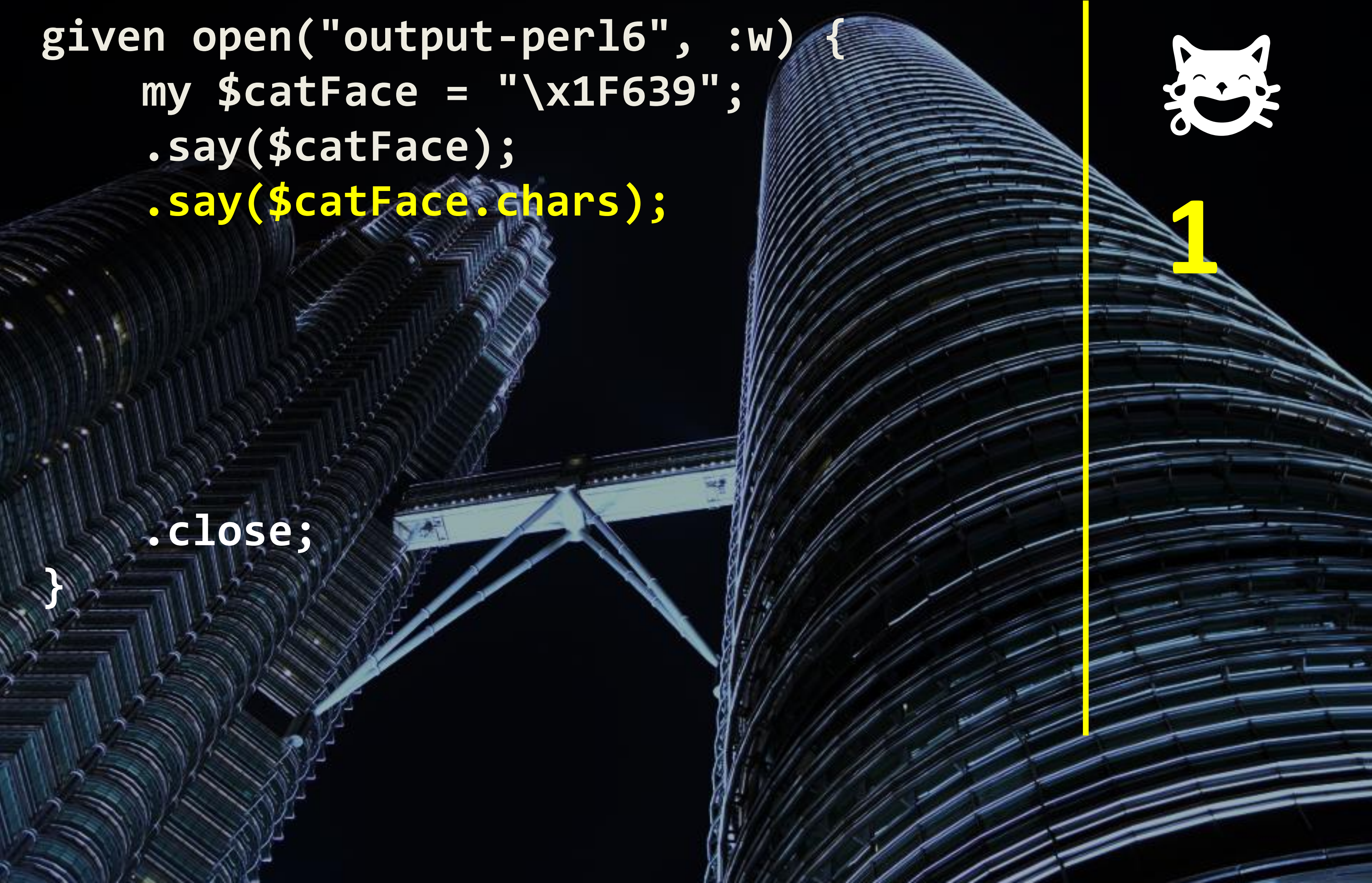


```
given open("output-perl6", :w) {
    my $catFace = "\x1F639";
    .say($catFace);
    .say($catFace.chars);




    .close;
}
```

😹



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    my $catFace = "\x1F639";
    .say($catFace);
    .say($catFace.chars);



    .close;
}
```

😹

1

```
given open("output-perl6", :w) {
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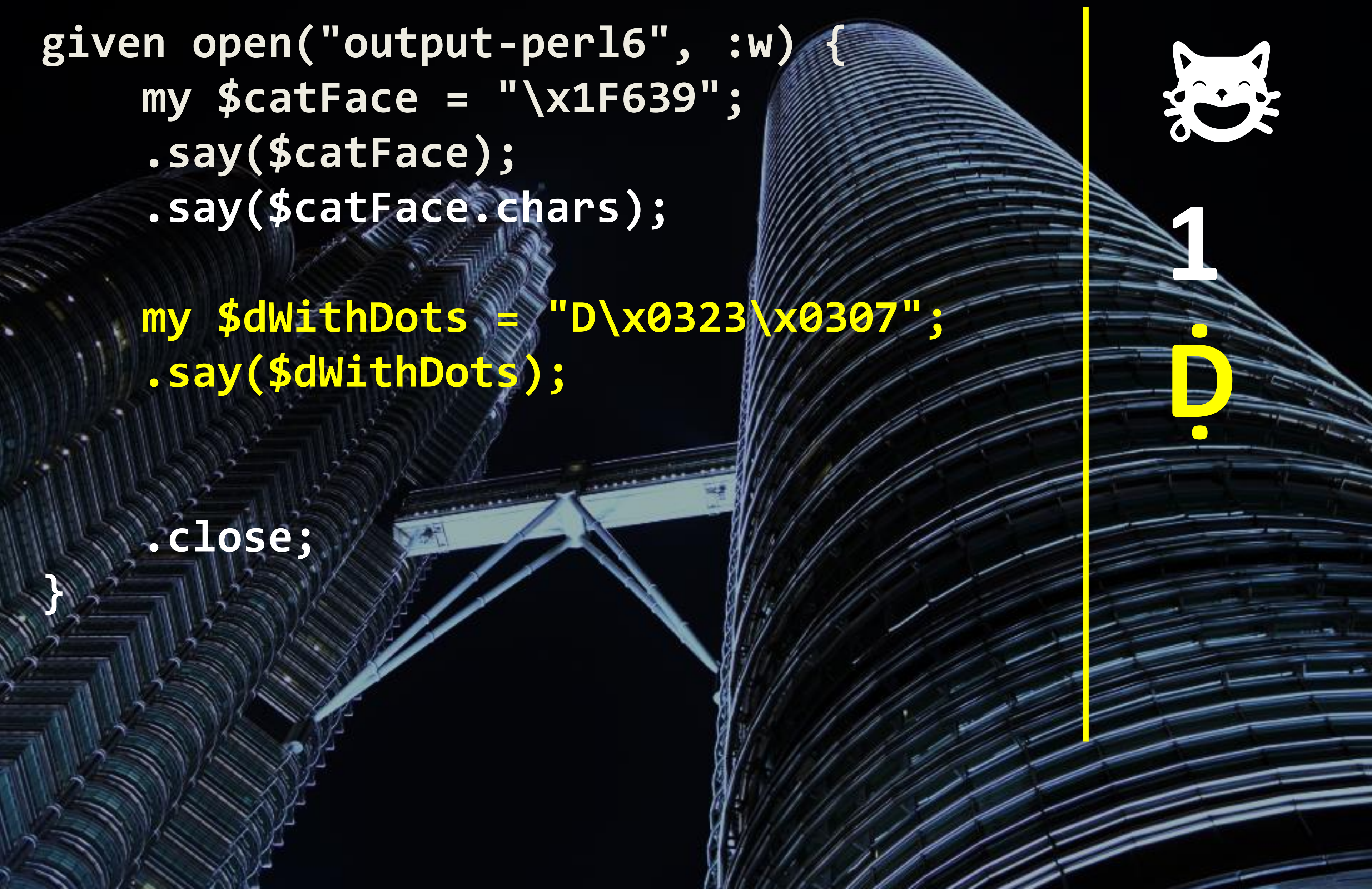
    .say($catFace);
    .say($catFace.chars);

    my $dWithDots = "D\x0323\x0307";
    .say($dWithDots);


    .close;
}
```

😹

1



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```
😹
1
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```

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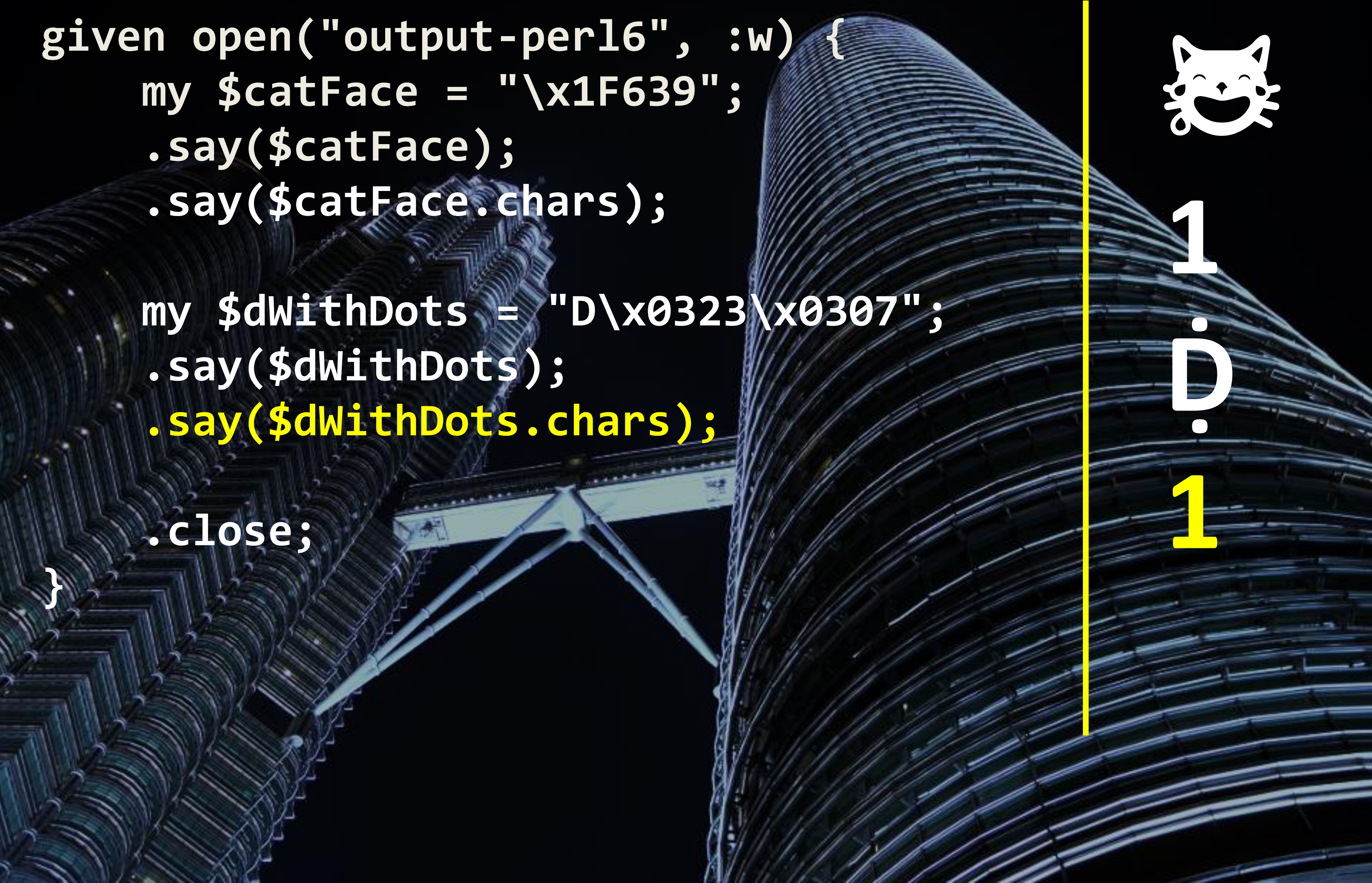

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    .say($dWithDots);
    .say($dWithDots.chars);

    .close;
}
```

```
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1
```
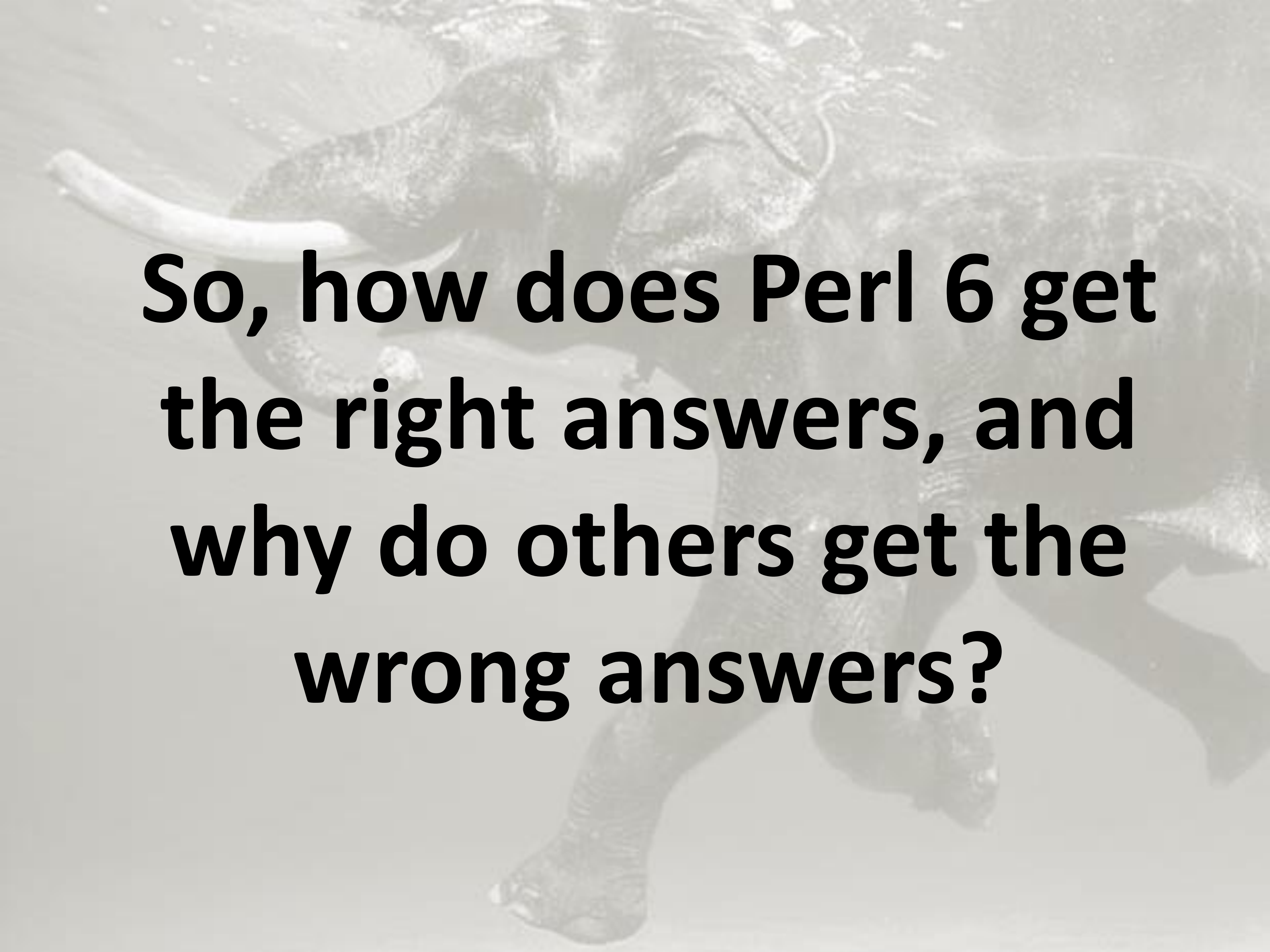

U+270C

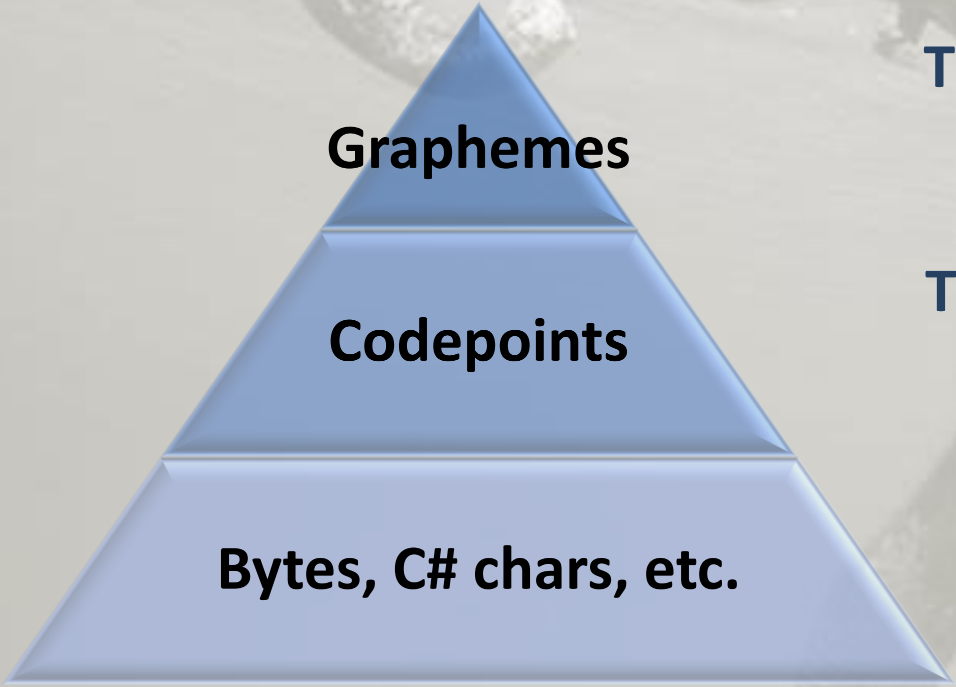
✌

VICTORY HAND



So, how does Perl 6 get the right answers, and why do others get the wrong answers?

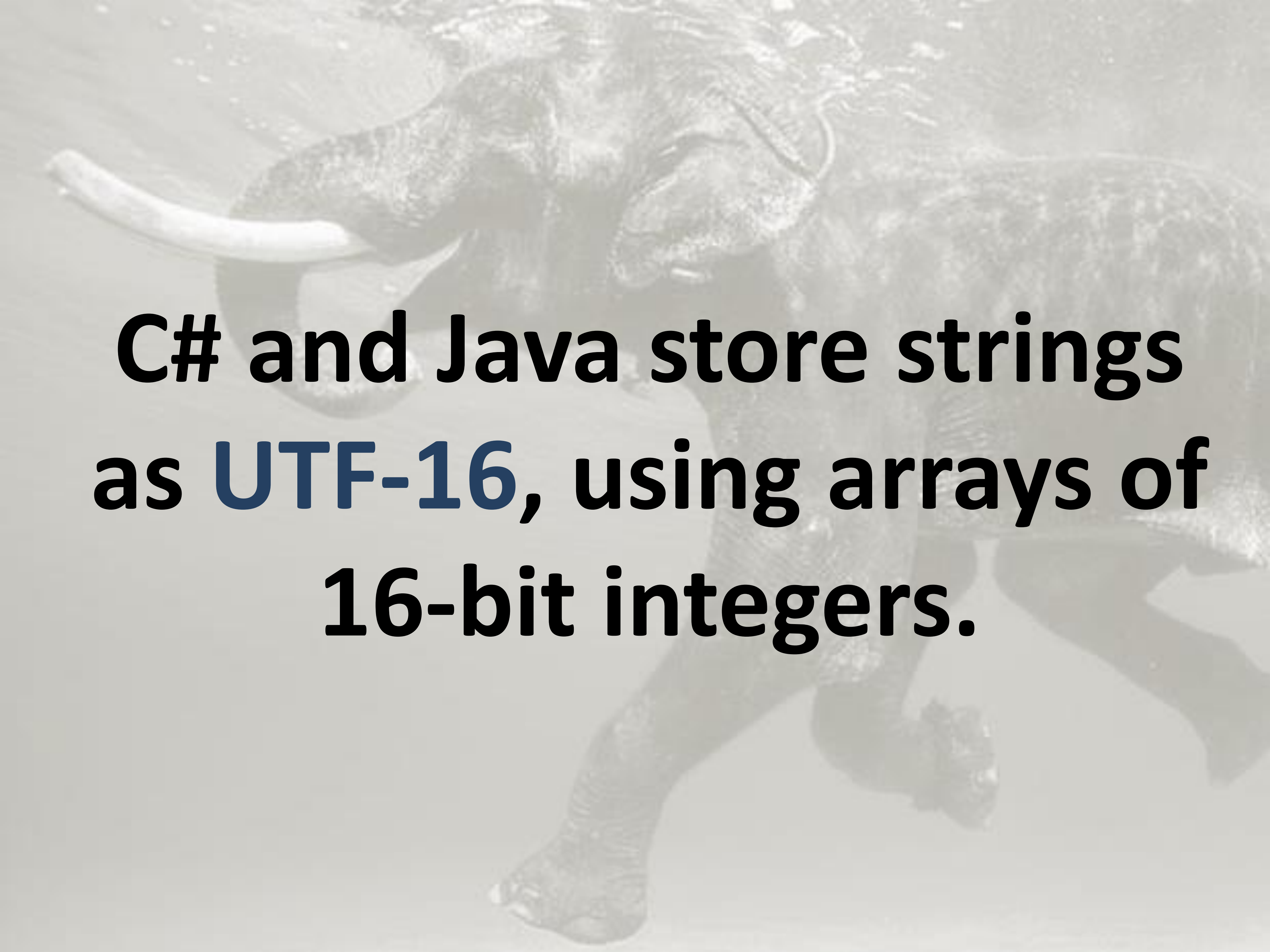
The 3 levels of Unicode



Things a human would consider a character

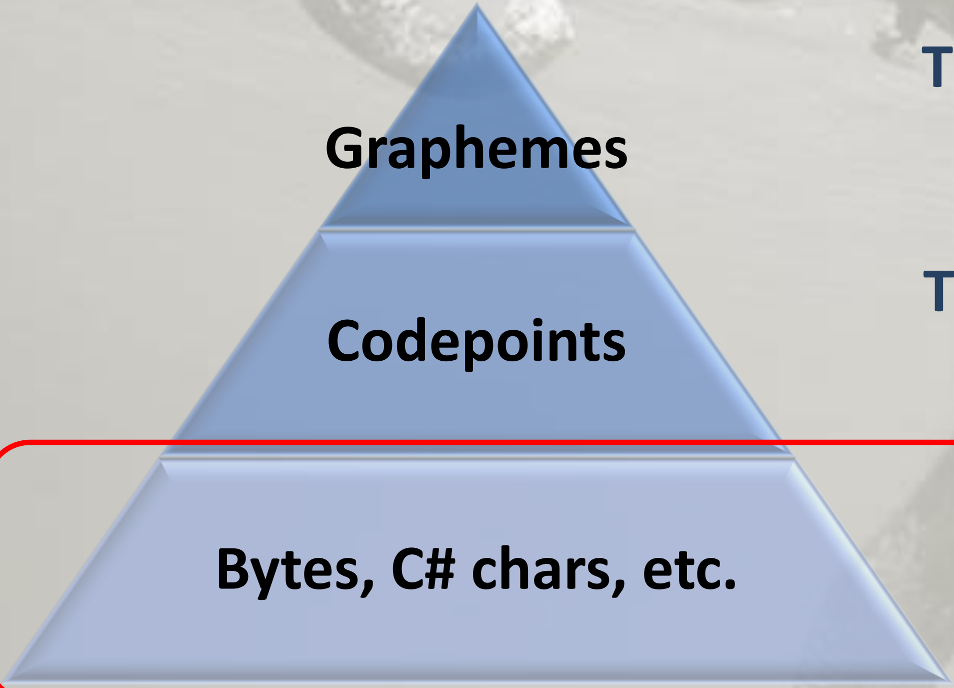
Things the Unicode spec gives a number to

How things look on disk or in memory



C# and Java store strings as **UTF-16**, using arrays of 16-bit integers.

They work down here!



Things a human would consider a character

Things the Unicode spec gives a number to

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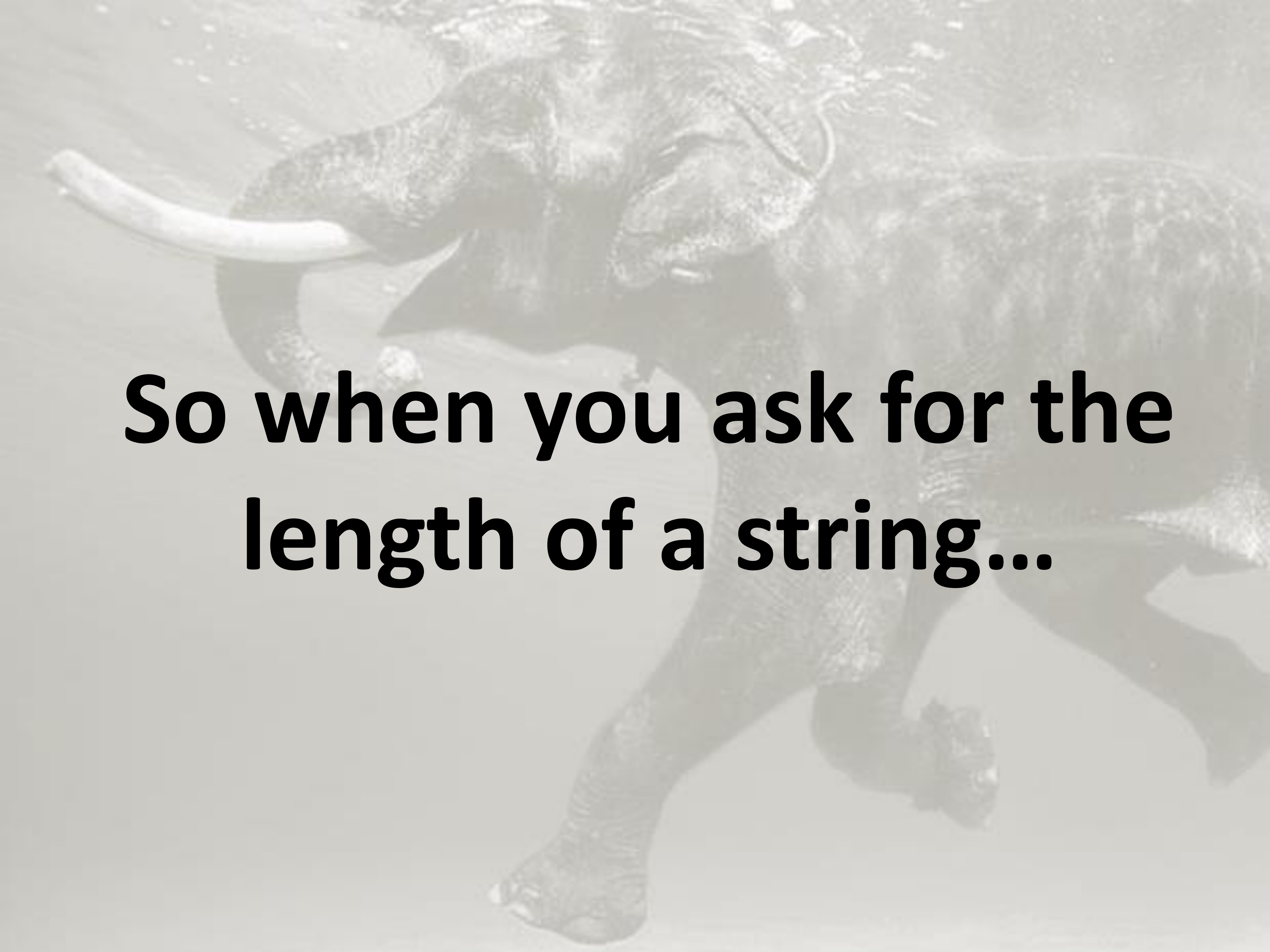
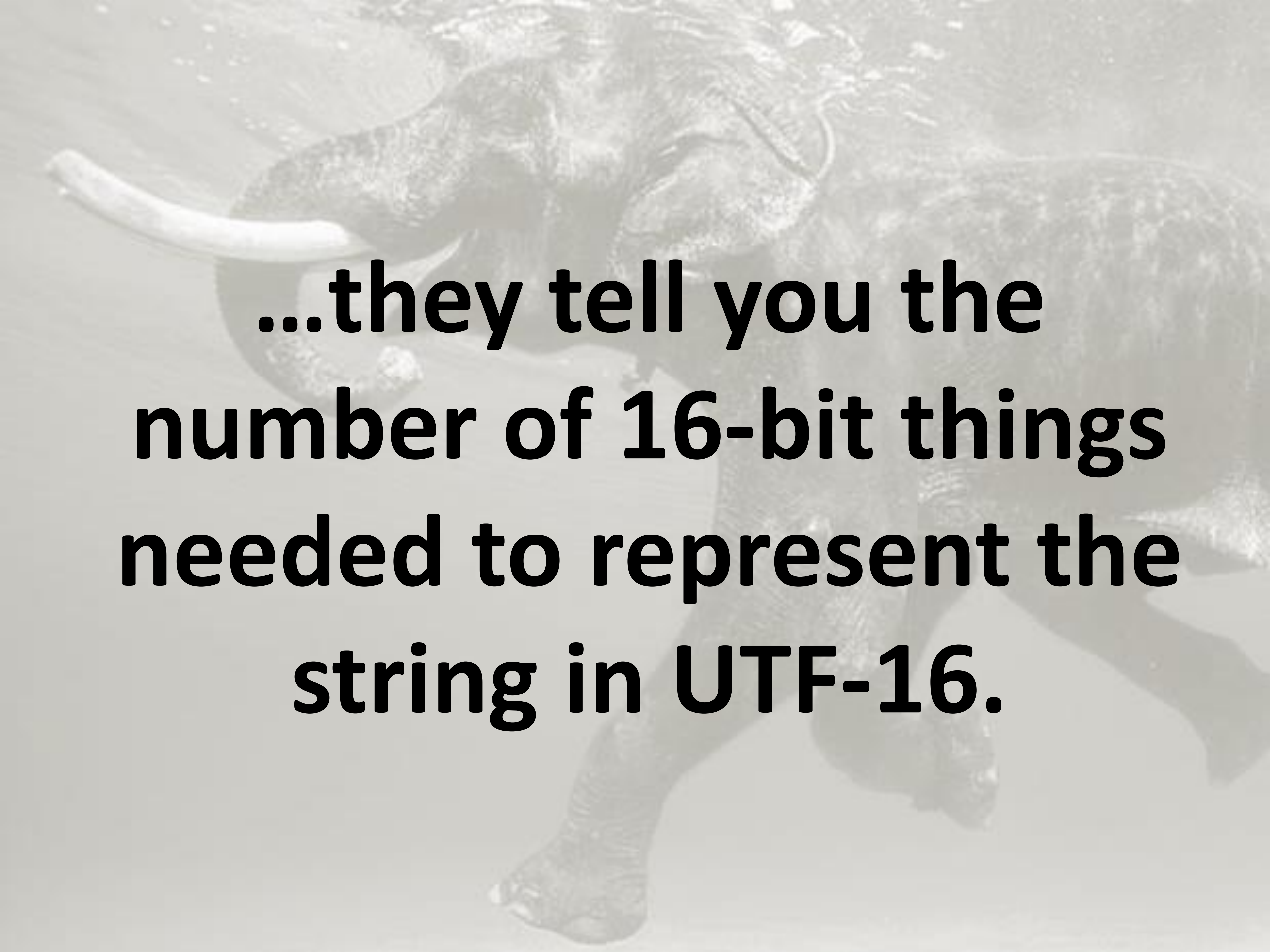


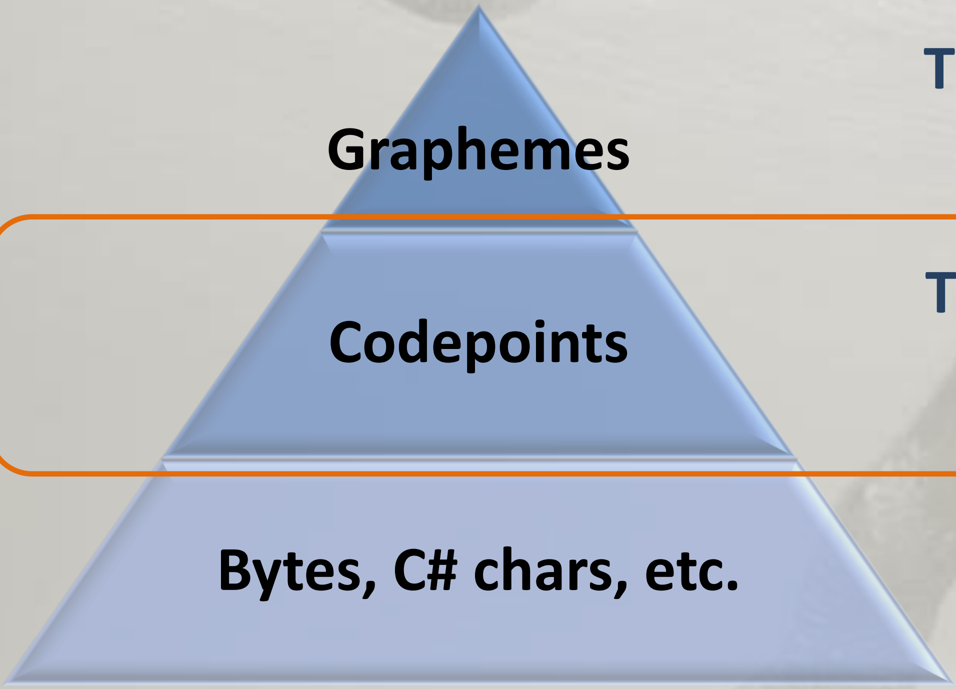
So when you ask for the length of a string…



…they tell you the number of 16-bit things needed to represent the string in UTF-16.

It's…enterprise.

Some languages have codepoint-level strings



Things a human would consider a character

Things the Unicode spec gives a number to

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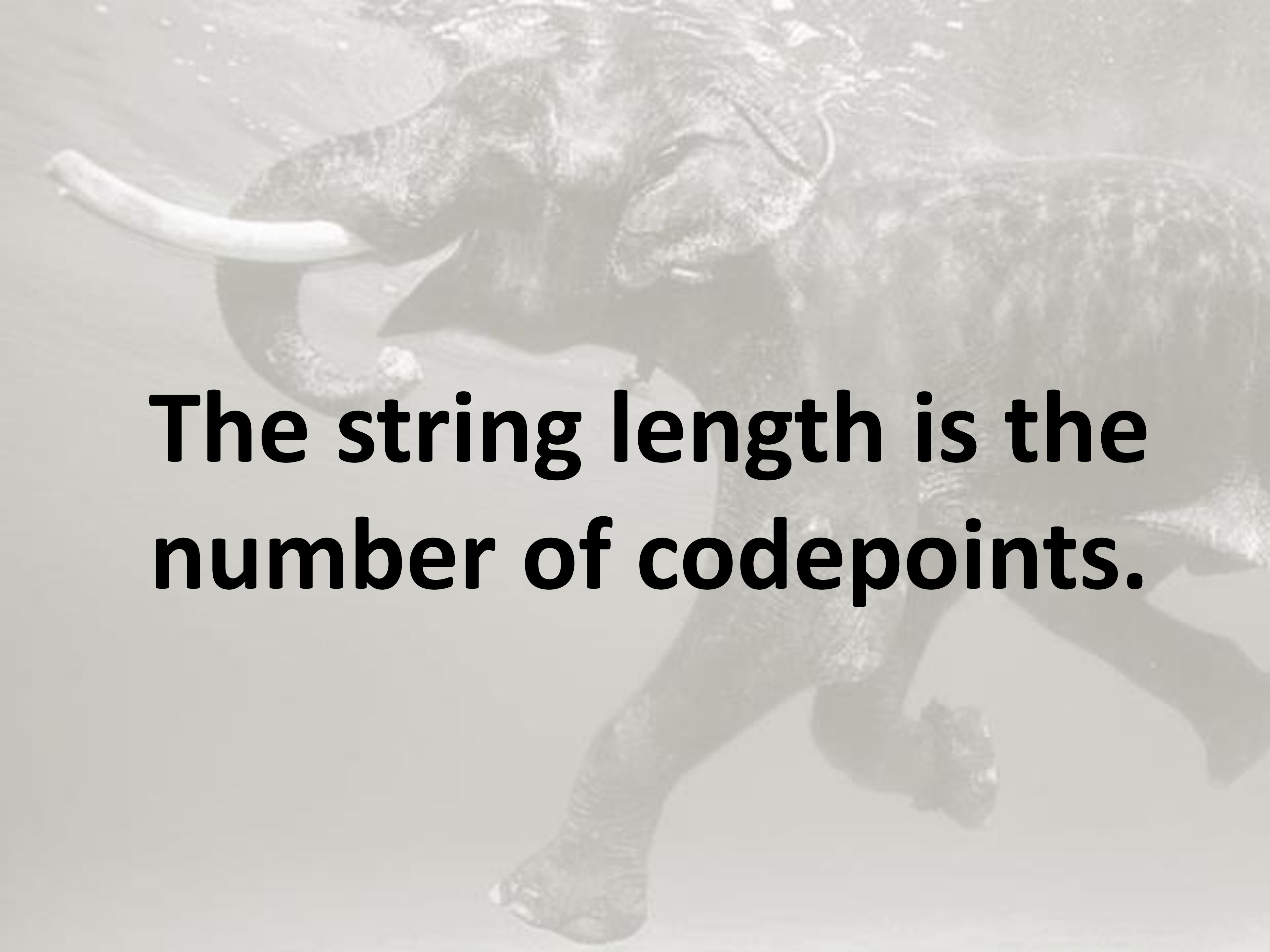
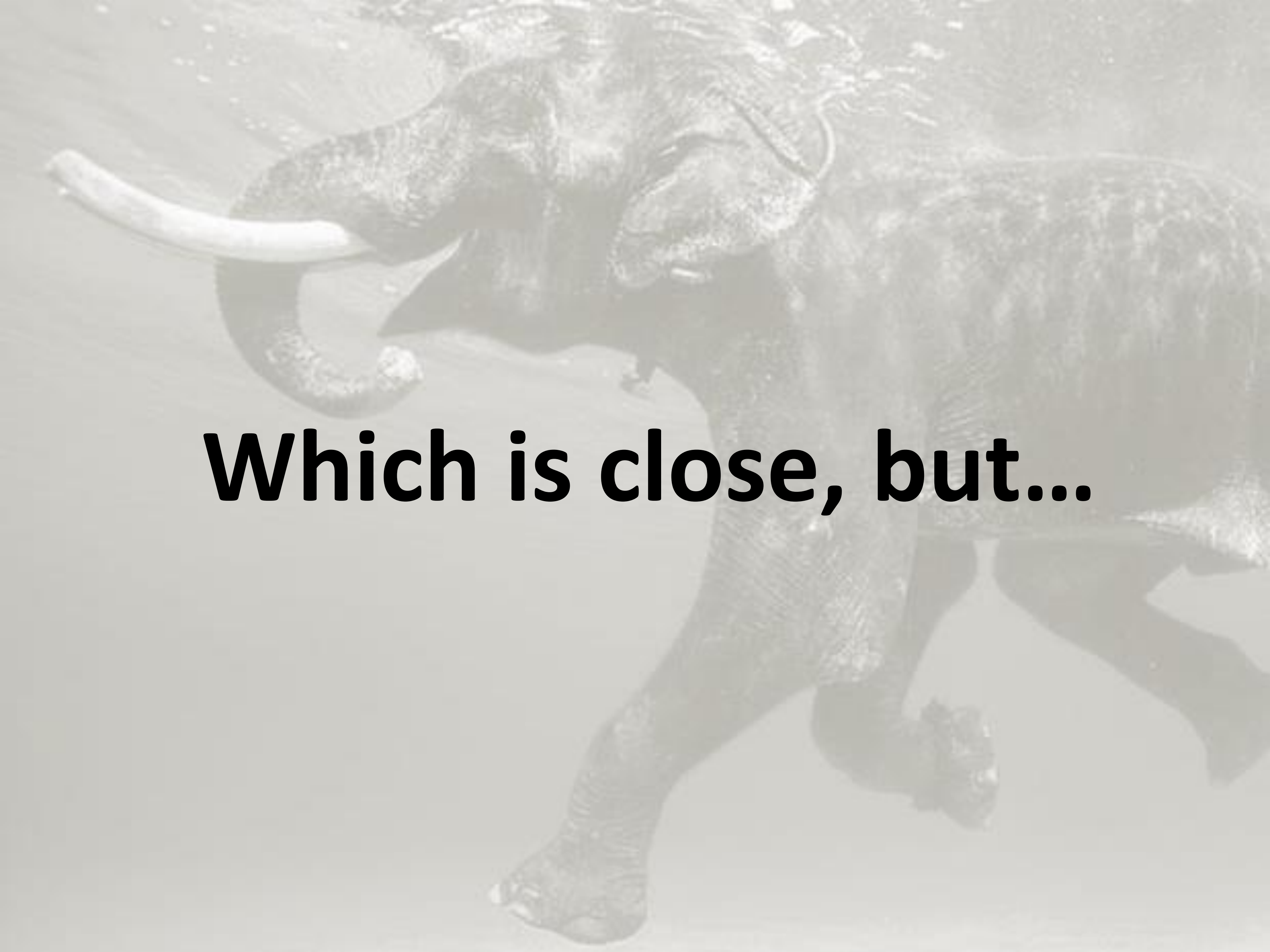
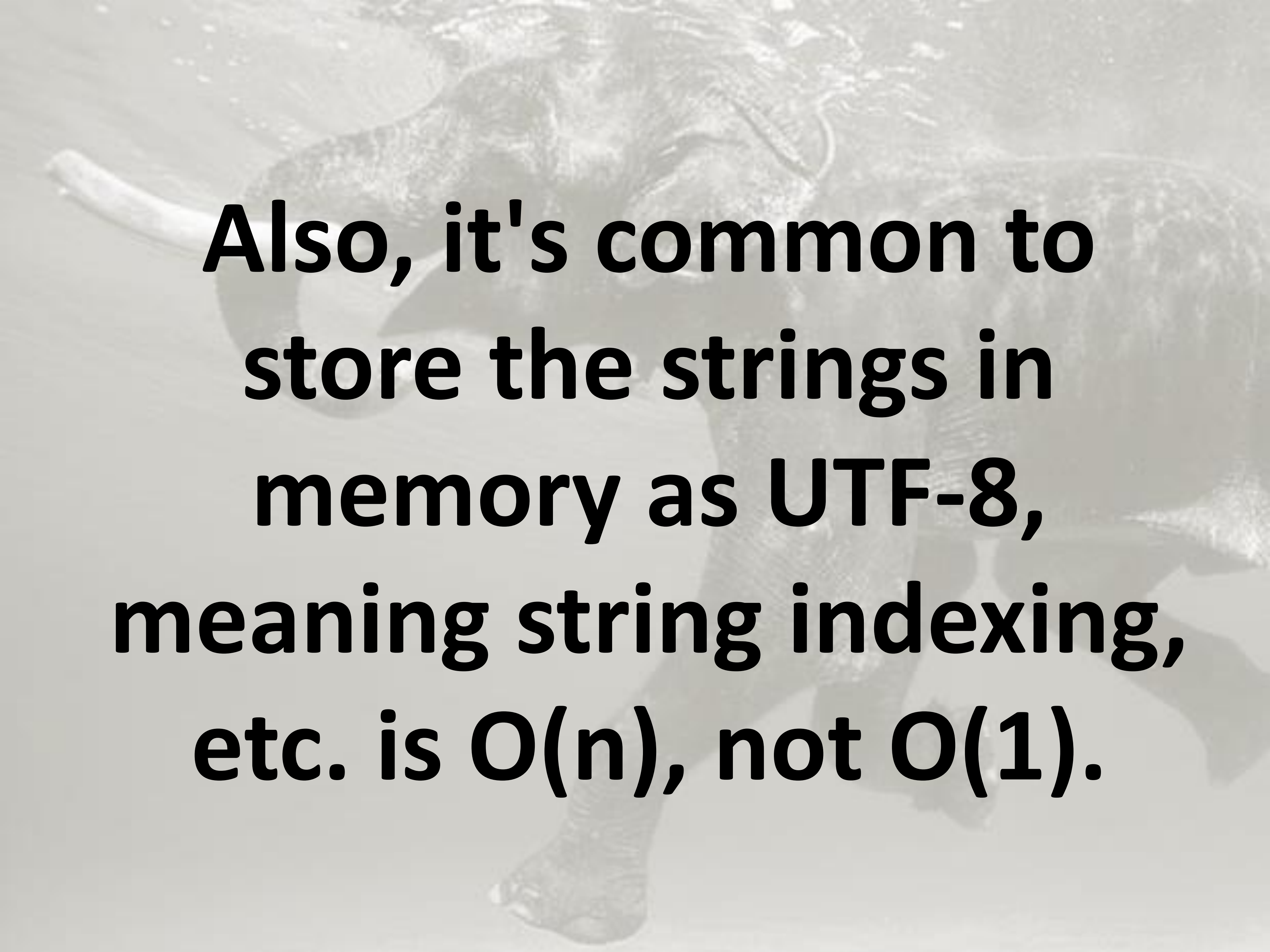


The string length is the number of codepoints.

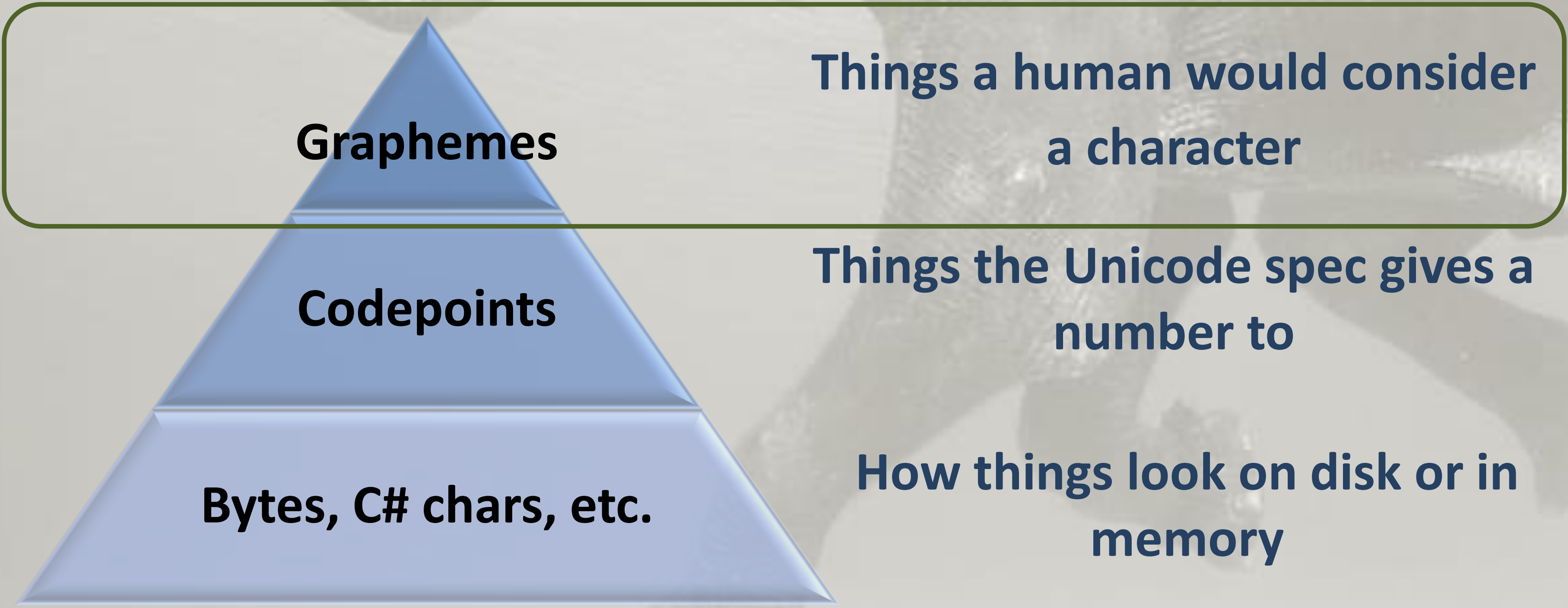


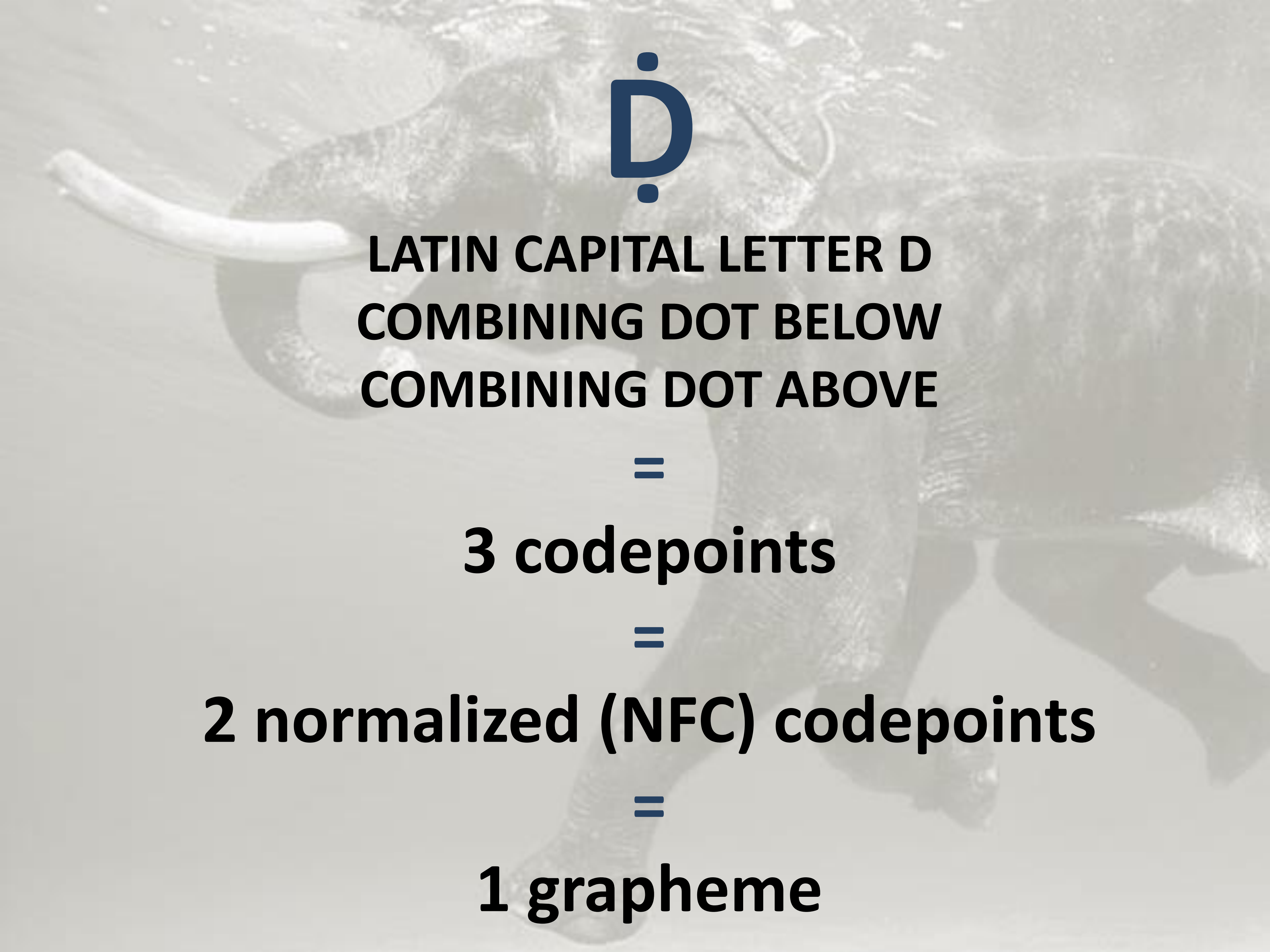
Which is close, but…



Also, it's common to store the strings in memory as UTF-8, meaning string indexing, etc. is O(n), not O(1).

Perl 6 strings work at the grapheme level


Graphemes
Codepoints
Bytes, C# chars, etc.
Things a human would consider a character
Things the Unicode spec gives a number to
How things look on disk or in memory



Ḍ̇

LATIN CAPITAL LETTER D
COMBINING DOT BELOW
COMBINING DOT ABOVE

=

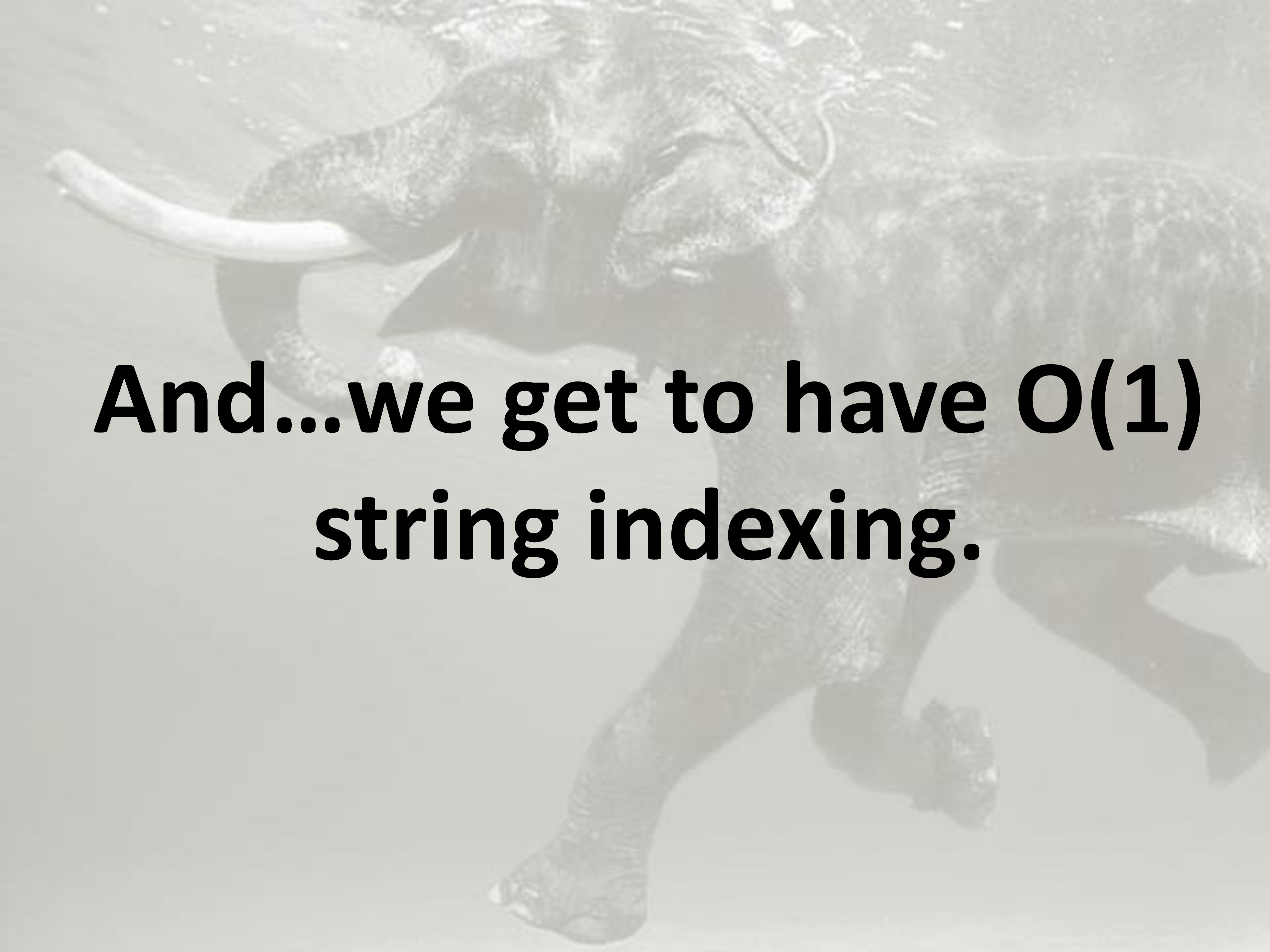
3 codepoints

=

2 normalized (NFC) codepoints

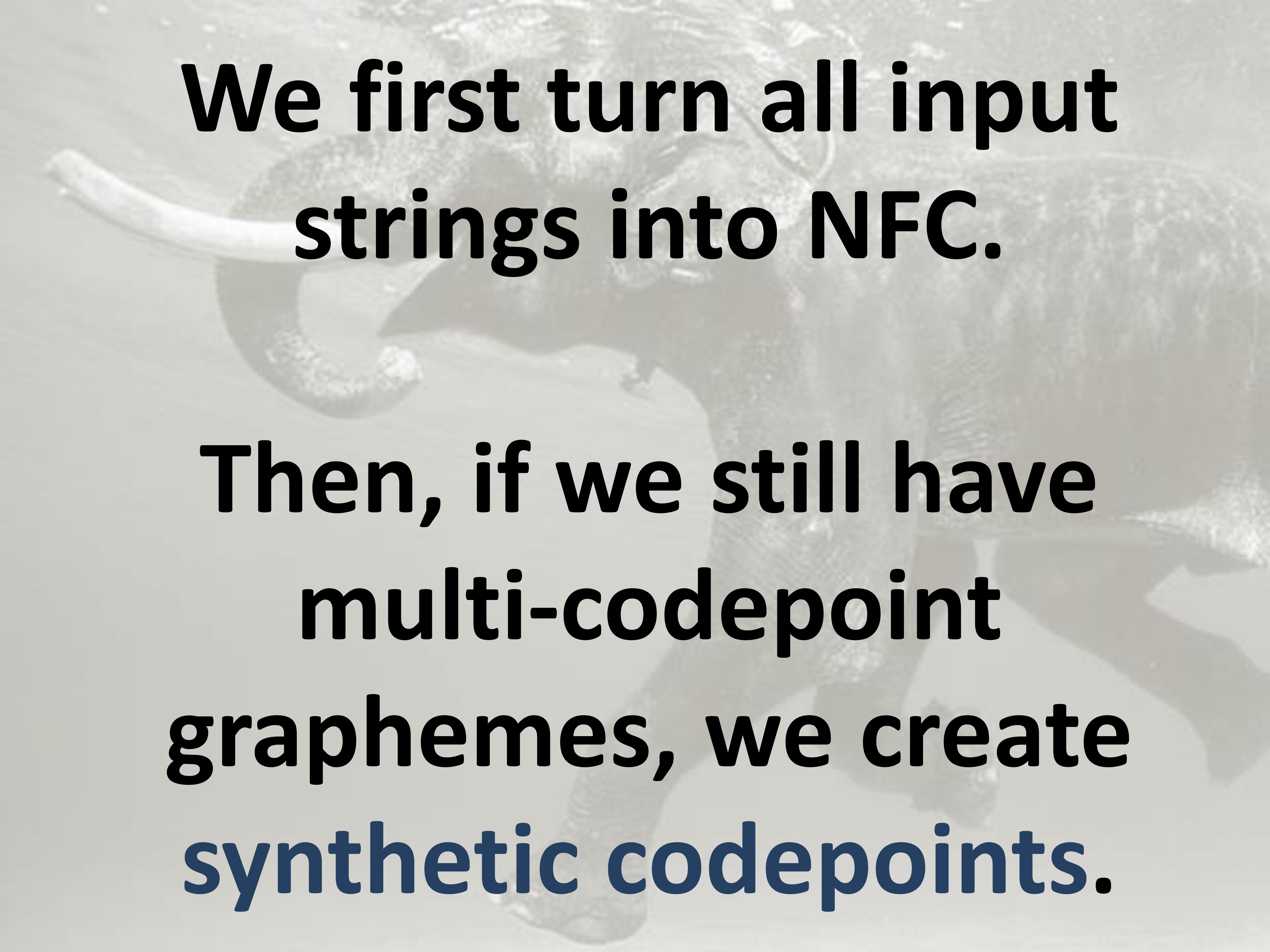
=

1 grapheme



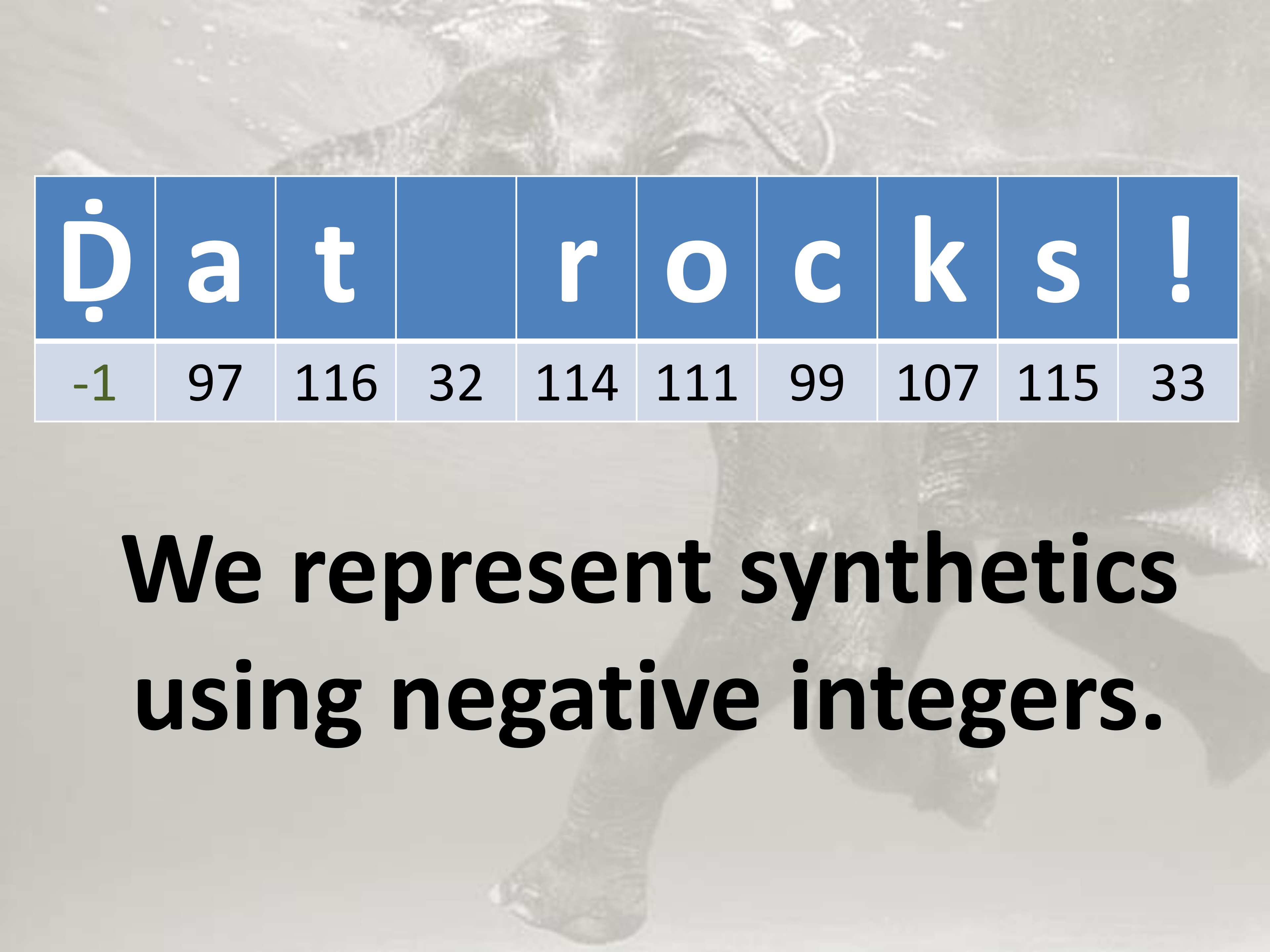
And…we get to have O(1) string indexing.

How do we do it?



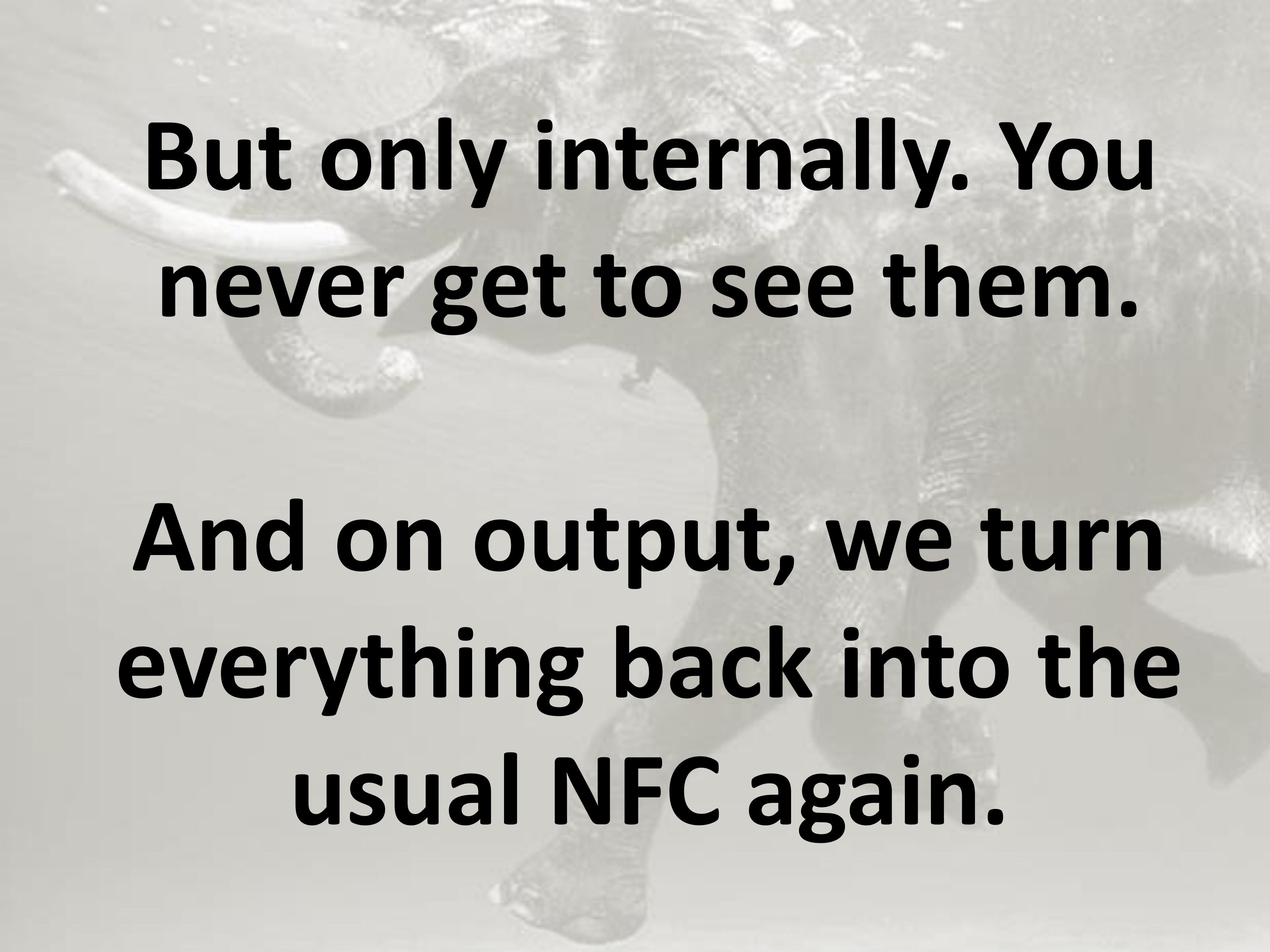
We first turn all input strings into NFC.

Then, if we still have multi-codepoint graphemes, we create **synthetic codepoints**.



Ḍ̇	a	t		r	o	c	k	s	!
-1	97	116	32	114	111	99	107	115	33

We represent synthetics using negative integers.



But only internally. You never get to see them.

And on output, we turn everything back into the usual NFC again.

Awesome!

Questions?